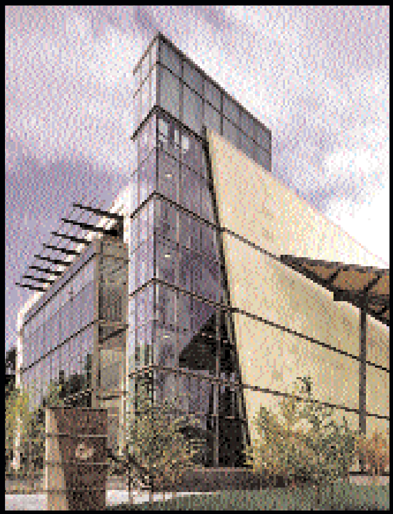
Solar Technology Reference Guide

January 2012

Aaron Binkley



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Aaron G. Binkley is Director, Sustainability Programs for Prologis. Binkley is an expert throughout the Prologis organization on matters associated with sustainable design and construction such as LEED™ Certification, renewable energy, energy conservation, carbon emissions and environmental sustainability. His responsibilities include working closely with operations and development teams globally to further Prologis' sustainability initiatives, including carbon strategy, customer and investor education programs, energy efficiency and retrofit initiatives and renewable energy projects.

Binkley was previously Director, Sustainability Programs for AMB Property Corporation. Binkley led the AMB renewable energy program which was responsible for the development of 4 megawatts of rooftop solar projects and planning and due diligence for 60 megawatts. Binkley was also responsible for customer advisory on renewable energy for new construction projects and existing buildings. Other responsibilities included energy conservation programs, sustainable building advisory, carbon footprint benchmarking, sustainability reporting and customer education on sustainability topics.

Binkley is a member of the Real Estate Roundtable Sustainability Policy Advisory Committee and was a past appointee to the NAIOP Sustainable Development Committee. As a member of the USGBC (U.S. Green Building Council) Warehouse and Distribution Center Adaptation Working Group, Binkley co-authored revisions to the renewable energy credit (EAc6), now available in the LEED pilot credit library. Binkley has published articles and white papers on renewable energy and energy conservation.

Binkley previously worked as an architect, specializing in sustainable design and renovation projects. Binkley is a Registered Architect and a LEED™ Accredited Professional. He has a master of science degree from MIT in Real Estate Development and an architecture degree from Carnegie Mellon University.

Acknowledgements

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Executive Summary

The *Solar Technology Reference Guide* provides real estate decision-makers with the information needed to evaluate a range of solar technologies and their impact on the buildings supporting them. **Solar technologies can be defined in four categories based on their interaction with the host building. These categories generally group products according to weight, installation process and method of attachment to buildings.**

This makes it possible to make side-by-side comparisons and evaluate the pros and cons of solar products. Selecting and installing the most appropriate solar technologies for a given building helps ensure that projects are completed quickly, profitably and without undesired structural or operational impacts.

This guide provides recommendations such as best practices for building design to:

- Identify suitable building sites
- Design a building that maximizes the space available to support solar modules
- Manage project costs
- Minimize construction risks
- Prevent roof damage
- Identify solutions suited to local climate conditions.
- Know what to look at in solar product warranties

This enables real estate industry professionals to make informed decisions that reduce project costs and minimize operational risks.

Categorizing Solar Products

The key to choosing appropriate products for a specific project is understanding the similarities and differences between available solar photovoltaic (PV) technologies. This makes it possible to recognize relevant risk factors and make better choices of technology. **Current solar products on the market can be grouped into four broad categories based on their interaction with the host building:**

- Rack Mounted Glass PV Module Systems
- Composite Frame Glass PV Module Systems
- Adhered Building-Integrated PV Module Systems (Adhered BIPV)
- Structural Building-Integrated PV Module Systems (Structural BIPV)

Rack Mounted Glass PV Module Systems are the most common type of solar solution. They tend to be the heaviest solutions, but they enable optimum energy production and they can be customized for almost any roof condition. Racking systems are designed to accommodate nearly all standard solar module sizes. These systems represent more than 90 percent of the solar market and are supported by an experienced base of installers.

Composite Frame Glass PV Module Systems offer modular and pre-assembled solar module designs that support fast installation and lower total system weight. There are a limited number of manufacturers of composite frame systems. These types of products are becoming more popular on commercial roofs where there is a need to both minimize weight and expedite the installation process.

Adhered Building-Integrated PV Module Systems address weight-constrained rooftops and metal roofs that are difficult to accommodate with traditional solar module systems. These technologies are the lightest solar products on the market today. They are adhered to the roof without racking or ballast. Energy production tends to be lower because they are installed flat to the roof, not angled to maximize the energy they capture from the sun. Modules can be installed close together because they do not cast shadows on one another.

Structural Building-Integrated PV Module Systems offer solutions that are integrated into building components such as curtain wall facades, carports and overhead canopies. These systems are highly engineered for custom applications and they tend to be the most expensive type of solar project. The aesthetics of these projects can be carefully controlled.

How Solar Products Affect Cost

The physical characteristics of each category interact with economic considerations to determine whether the technology is appropriate for a given building, including:

- Cost of solar module technologies
- Electrical production of solar array
- Costs to install, including labor and balance-of-system costs
- Building preparation, including structural upgrades and roof coatings/replacements

- Roof protection and warranty maintenance
- Types of climates conditions that can be accommodated (i.e., High wind zones)
- Net area suitable for coverage of solar modules
- The angle at which modules can be positioned

The best economics on a solar project result from more than simply selecting the most energy-productive solar modules or the least expensive products. **While all solar modules perform best when perpendicular to the sun, higher module efficiency ratings do not always mean greater electricity output.** Each technology produces electricity in different amounts depending on sunlight and project conditions. Less efficient modules may achieve similar energy output -- when compared to higher efficiency modules -- by producing electricity for more hours throughout the day or in cloudy conditions.

Planning and Constructing Projects

The type of solar technology selected has an impact on the construction process. Rack mounted module systems often require large amounts of space onsite for staging and prep areas. Composite systems and adhered BIPV systems are pre-assembled and can be loaded directly onto a rooftop, minimizing construction disruptions. Structural BIPV systems are integrated into the existing construction process for other building elements, plus the additional work to connect the solar array.

Only a portion of a roof's total area can be covered with solar modules. Panels should not be placed in areas shaded by tall HVAC equipment, adjacent buildings, penthouses or trees. Modules should also be spaced adequately so they do not cast shadows on each other. The perimeter of the roof should also be kept clear to facilitate worker safety, roof inspections and the placement of nonsolar equipment on the roof.

The location of existing rooftop equipment such as HVAC units, skylights and shaded areas can affect the layout of a solar array. On a small or cluttered roof, as little as 50 percent of the roof may be available for solar modules. On a large open roof the suitable area may approach 90 percent. **An array that is efficiently laid out is easier to maintain, will fit more solar panels and therefore generate more electricity. It can also reduce solar project costs by simplifying design and speeding installation.**

Solar modules typically weigh between 25 and 70 pounds and are designed to be carried by two workers on the job site. Module products can be larger, but those are designed primarily for ground-based applications where they can be craned into place.

Solar array weight can become a driving factor in the choice of which solar product is the most suitable. Few existing buildings were designed with solar in mind, so there is often little excess structural capacity to support solar equipment on rooftops. Array weight can vary from less than one pound per square foot to nine pounds per square foot. This range exists due to the technology selected, local wind conditions that may necessitate more ballast to resist wind forces, system design and method of attachment to the building.

Before installing any solar products on a building's roof, it is essential that you determine whether the roof is suitable for the project. The roof should be in good condition and have sufficient longevity that it will not need replacing during the operational life of the solar project. Pay special attention to areas of poor drainage. Standing water can damage solar equipment as well as over-stress the roof. For roofs that are nearly new, the addition of a white roof coating can extend the roof's life, help resist wear from construction traffic and reduce performance-robbing high roof temperatures.

During the contruction process, care is needed to avoid unnecessary roof wear or damage. **Performing a pre-construction roof inspection and a post-installation inspection provide a way to proactively identify and resolve potential problems. Care should be taken during construction to ensure that adequate roof protection is in place to avoid jeopardizing roof warranties or causing preventable damage.**

The construction process for each type of solar technology can affect the suitability of that product for a particular building. Where staging areas are limited, it may be advantageous to specify a solar product that can be delivered directly to the site ready-to-install. For sites where there is no large open expanse of roof, a rack mounted system may provide more customization. On buildings with a much greater facade area than roof area, structural BIPV facade products may be advantageous.

There are two types of warranties that concern the real estate professional. These are materials and workmanship warranties and energy output warranties. A materials and workmanship warranty will vary based on the type of equipment. **Modules, inverters and racking are typically warranted for 10 years, while racking is often warranted for five years. The energy output warranty typically covers 25 years and provides solar project investors protection against the loss of revenue due to underperformance of the solar modules.** For newer module technologies, manufacturers may provide insurance policies to protect investors until there is sufficient track record of adequate performance.

Connecting to the utility grid is a factor that can affect the economic viability of a solar project. Solar project owners often need to undertake interconnection reviews in order to get approval from the local utility. At times the utility may require upgrades to the local grid system to accommodate the solar facility's new capacity. Depending on the scope of these costs it may affect the economics of the solar project.

Conclusion

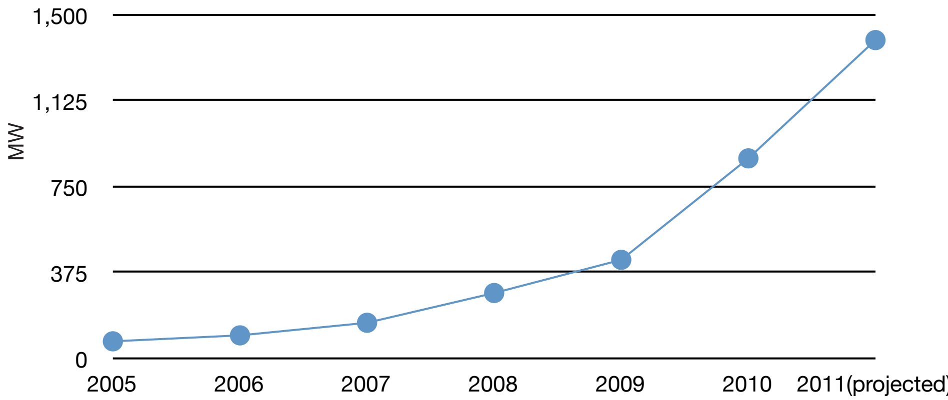
The solar industry in the U.S. is poised to continue its upward trajectory of growth in the years that come as more states adopt solar programs. Combined with global growth in the scale of solar module manufacturing, costs for solar modules and equipment can be expected to continue to decline over time.

It is widely acknowledged that not every solar technology will achieve commercial success. There will be success stories and failures along the way but it will ultimately lead to better products that meet the needs of commercial property owners and drive even wider adoption.

Solar Market Overview

The global solar industry is supported by growth in the United States and has grown rapidly in the past decade, recording 27-fold growth between 2000 and 2010.[1] In the United States there is currently enough solar capacity installed to power more than 600,000 homes.[2] The United States is currently the third largest solar market in the world, behind the European Union and Japan.

Figure 1: Megawatts (MW) of Solar Capacity Installed Each Year in the United States[6]



To put the United States market in context, Germany has installed solar capacity more than ten times greater than the United States; Germany alone accounts for 56 percent of European demand.[3] It is projected, however, that the U.S. could become the world's largest solar market as soon as 2013 if growth in the United States continues while the German market slows.[4] That is, of course, if China does not overtake both countries as it seeks to ramp up its domestic solar projects.

A growing number of states have issued regulations and funded incentive programs that support solar projects on commercial buildings. This has contributed to significant growth in the solar industry in recent years (Figure 1).

Within the United States, California has the largest solar market, accounting for 45 percent of national demand.[5] Other southwestern states such as Arizona and Nevada have also begun to develop substantial solar portfolios. Solar is not constrained to sun-drenched locations. States not traditionally known for their sunshine such as New Jersey, Pennsylvania and Massachusetts have created programs that support solar projects on commercial buildings. As support for solar projects on commercial buildings grows, property owners will see more opportunities for solar projects throughout the United States.

The real estate industry is increasingly eyeing rooftop solar projects as a way to generate additional revenue and improve sustainability. However, many property owners are wary of pursuing solar until they become familiar with solar products on the market.

Solar manufacturers and installers can inadvertently contribute to this wariness. Vendors may have expertise with a limited number of solar products so their proposals often tailor these solutions to most projects. As such, the impact on the building can only be minimized to the extent it is feasible with the limits of that technology. Without knowing the range of product solutions available, property professionals may accept a solution that's not appropriate for their building site. They may also reject solar altogether as a viable solution when a suitable solution may exist with a different solar technology.

Real estate professionals considering solar have valuable knowledge about their buildings' condition and suitability for solar. When they can evaluate which solar technologies align best with these conditions, the projects are more likely to be successful.

Solar Basics

Electricity is created by solar panels and delivered to the building or utility grid in the following steps:

1. Sunlight hits a *solar module* (also referred to as a *solar panel*). Semi-conducting materials in the module convert the sun's energy into electricity.

2. Electricity from each panel is combined with many other solar modules. An assembly of interconnected solar panels is referred to as a *solar array*.

3. Specialized electrical devices such as charge controllers, inverters and transformers take the raw electricity from the solar array and condition it to become usable electricity.

4. This electricity is then delivered to the building to offset electric loads, or is returned to the local electric utility.

Solar arrays on buildings can be almost any size, from a few kilowatts -- to power signage and other incidental electricity use -- to multi-megawatt systems capable of powering the host building and its neighbors.

The rules that determine the feasibility of solar projects vary from one utility to another, as well as from one state to another. As a result, the economic value of a given solar project will vary based on the project's location. In some markets, it may make sense to produce electricity for use in the host building. In other markets, it may be more cost-effective to sell energy to the utility.

Solar companies and local utilities can help identify suitable markets where a commercial property portfolio overlaps with solar-friendly regulations.

Classifying Solar Technologies

Solar technology literature typically groups solar panels based on the composition of the electricity-producing materials in solar cells. Accordingly, there are four predominant solar cell compositions in commercial production:

- Crystalline silicon (C-Si)
- Amorphous silicon (A-Si)
- Cadmium telluride (CdTe)
- Copper Indium Gallium Selenide (CIGS)

This type of classification is used by the solar industry because manufacturing requirements, cost, installation methods, financing potential and performance varies with each technology. There are also sub-classifications within these groups (such as mono-crystalline and polycrystalline within the C-Si group).

Other classifications for solar technologies exist for specialized applications, such as those used to power satellites. These technologies tend to be many times more expensive and are not a fit for commercial building projects. In addition, innovative research in academia and start-up companies are developing new solar technologies for the future.

Classification based on solar cell composition is not the most useful way for real estate professionals to categorize technologies. This is because one type of solar cell can be assembled to create modules that have very different shapes, weights, or dimensions depending on its manufacture. Conversely, nearly all solar cell compositions are being used in rectangular glass modules even though their performance varies widely.
For example, amorphous silicon is a solar cell composition used by several solar panel manufacturers, and the form of solar panel they produce has very different physical characteristics. Some modules are thin and flexible, while others are sandwiched between rigid glass panels.

A more useful way to classify solar technologies for commercial property owners is to group them by the way they interact with the host buildings. This classification depends on their physical attributes such as form factor, weight, installation process and method of attachment to the building.

This way when a project encounters older buildings with limited load-bearing capacity, lightweight solar products can be selected. A building with a metal roof would use a different solution than one with a gravel-ballasted built-up roof, and so on.

Categorizing modules this way is not scientific; it is practical. This makes it possible to sort solar technologies based on their impacts on buildings rather than their inner workings.

There are four main categories:
- *Rack Mounted Glass PV Module Systems* (Page 6)
- *Composite Frame Glass PV Module Systems* (Page 7)
- *Adhered Building-Integrated PV Module Systems* (Adhered BIPV) (Page 8)
- *Structural Building-Integrated PV Module Systems* (Structural BIPV) (Page 9)

Both rack-mounted and composite solar products use similar rectangular glass modules. These systems also generally use ballast, typically masonry blocks or gravel used for its weight to hold the array on the roof and resist wind forces.

The key difference for the real estate owner is that rack-mounted solar arrays are assembled from many components in the field. They generally require more ballast and are heavier than the other technologies, but they tend to produce more electricity because modules of high efficiency can be specified and they can be positioned optimally to absorb the sun's energy.

Both rack mounted and composite frame module categories can be anchored to the building to resist wind and seismic forces. This can reduce system weight by reducing the need for ballast. These are typically discrete connections that can be disassembled without affecting the integrity of the roof or the building structure.

In contrast, adhered BIPV systems are physically attached to building roof or facade components such as the existing roof membrane. These products can not readily be removed without removing the entire roof or facade. Patching and repairs are typically required.

Structural BIPV systems are similar to adhered BIPV systems in that they are attached to the building. The key difference is that BIPV systems are integrated into the building in a way that makes them integral to the function of the building.

For example, curtain wall glazing can be replaced by solar modules. Without the modules, the curtain wall system would not be able to keep out the weather unless the modules were subsequently replaced with window glass.

Table 1: Solar Cell Composition by Product Category

	Rack Mounted Module Systems	Composite Frame Module Systems	Adhered Building-Integrated Modules	Structural Building-Integrated Modules
Crystalline Silicon	✓	✓	✓	✓
Amorphous Silicon	✓	✓	✓	✓
Cadmium Telluride	✓			
Copper Indium Gallium Selenide	✓		✓	

Rack-Mounted PV Module Systems

Rack-mounted glass modules are used in the most common types of rooftop solar arrays. Rows of solar panels are held at an angle atop the roof on a metal frame composed of rails, braces and trays for ballast. Rack-mounted systems can be highly customized to accommodate varying roof conditions and can be adjusted to hold the solar panels at almost any angle to optimize energy production.

These racks can accommodate nearly all rectangular glass solar panel makes and models. They can be anchored to the roof structure with standard pipe fittings and flashing boots used throughout the roofing industry. These racks are metal so they require grounding, an added step in the construction process.

Figure 2: Racking System Detail

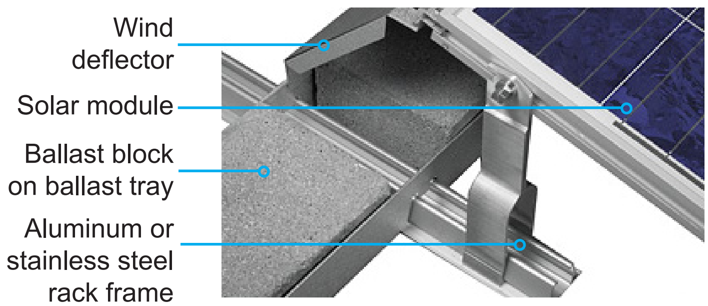


Image: ZEP Solar

Figure 3: Example Rectangular Solar Modules

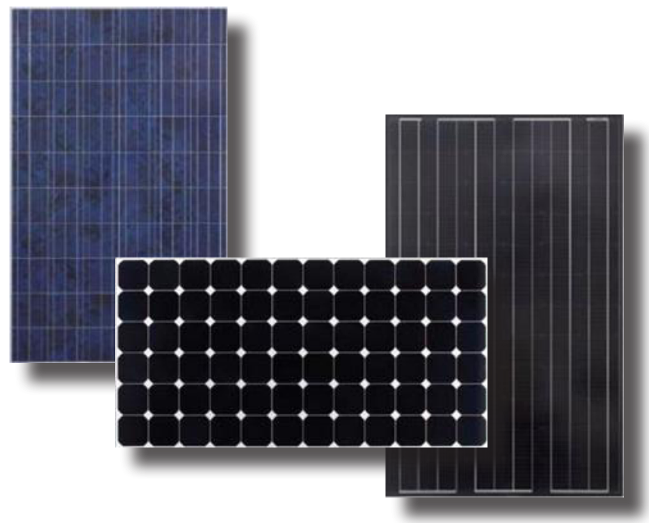


Figure 4: Example Rack-Mounted Solar Installations

Solar racking permanently attached to roof structure. Note post with bolted connection. Image: Aaron Binkley

Field-assembled racking system under construction on an asphalt built-up roof. Image: Aaron Binkley

Rack-mounted array with masonry ballast blocks on an asphalt built-up roof. Note aluminum wind deflector at right. Image: Aaron Binkley

Rack-mounted array with masonry ballast blocks on a gravel ballasted roof. Image: Aaron Binkley

Composite Frame PV Module Systems

Composite frame glass module systems are designed to meet the needs of low-slope commercial roofs. Composite frame products use similar solar modules as rack-mounted arrays. The key differences are:

- They are installed in a reinforced composite fiberglass or plastic frame, usually at the factory before being shipped to the job site;
- The frames snap together without tools;
- The module and frame are installed at the same time;
- The installation process is expedited;
- The impact of construction activity on the roof is reduced.

Image: SunPower

Composite frames are designed to hold the solar modules either parallel to the roof or at a shallow angle up to about 10 degrees. This is a compromise between a low profile that minimizes wind forces and reduces ballast needs, and a higher angle that increases electricity production but requires more ballast to resist wind forces.

Figure 5: Composite Frame Module Detail

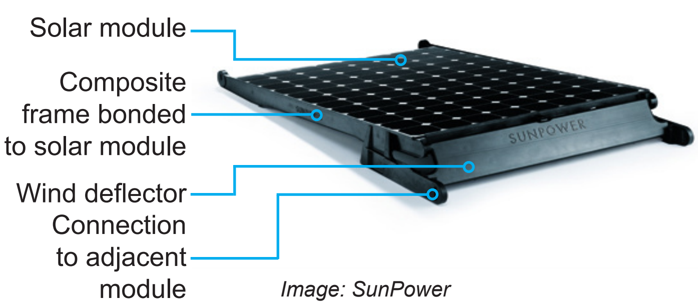


Image: SunPower

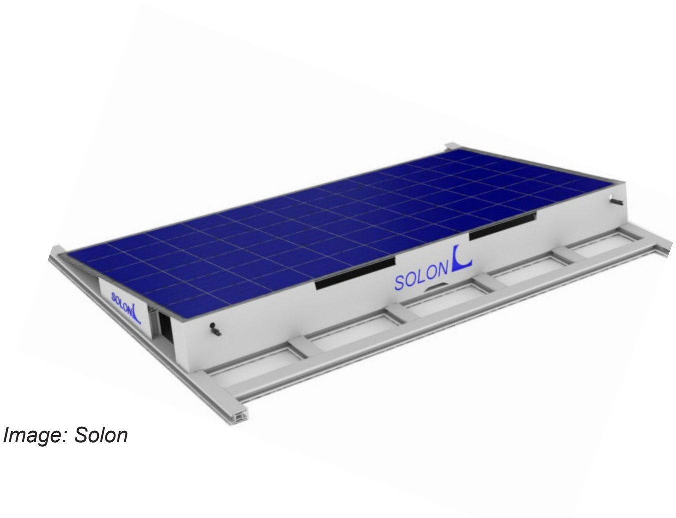


Image: Solon

Each project will vary based on local conditions and design requirements, but in general, rack mounted systems are heavier than composite frame systems. This is due in part to the higher angle of the solar panels, which increases wind forces that must be counteracted with ballast. Alternatively, the racking may be anchored to the roof, but this introduces roof penetrations to the project that may or may not be desirable from the property owner's standpoint.

Composite systems may also require ballast, but their shallower angle reduces wind forces. In contrast, neither adhered BIPV nor structural BIPV systems require ballast because they are integrated into existing building elements. This makes them lighter when compared to glass module systems. The table below compares the relative added weight of the four solar technology categories.

Image: Solon

Table 2: Added Weight and Method of Attachment

	Rack Mounted Module Systems	Composite Frame Module Systems	Adhered Building-Integrated Modules	Structural Building-Integrated Modules
Weight (typical range)	4 to 9 PSF	2 to 6 PSF	1 to 1.5 PSF	n/a
Method of Attachment	Ballasted; affixed	Ballasted	Affixed	Integrated into building component

Note: PSF = Pounds per square foot

Adhered Building-Integrated PV Module Systems

Adhered building-integrated photovoltaic modules (adhered BIPV) are products that are attached directly to existing building elements, most commonly the roof. These products do not need a racking system for support. This class of products is adhered directly to the roof surface and does not need ballast to hold them in place.

Adhered BIPV products can be used on a wide range of roof types, from standing seam metal roofs to membrane roofing. These products are only suitable on gravel-ballasted roofs if the gravel is removed and the roof is thoroughly cleaned. This is necessary for adequate bonding of the solar module product to the roof surface.

Image: SoloPower

Although not recommended, adhered BIPV modules can be walked on (with care), so they do not create obstructions on the roof. While they can be removed, they are bonded in place with adhesives. This may require patching the roof where the panel has been removed.

Adhered BIPV modules lie parallel to the roof and are not angled to face the sun. This can reduce energy production. Conversely, more density of modules can often be installed because the modules will not cast shadows on one other.

Figure 6: Adhered BIPV Installation Details

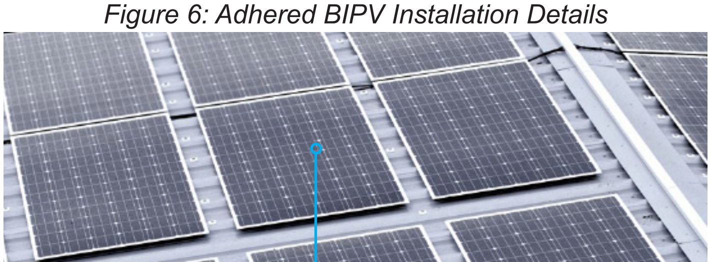


Image: Solon

BIPV modules bonded to ridges of metal roof

Existing roof membrane prepped for solar modules

BIPV modules bonded to secondary roof membrane

Image: Uni-Solar

Adhered BIPV Arrays on Membrane Roofs

Image: Uni-Solar

Image: Lumeta

Adhered BIPV Solar Arrays on Metal Roofs

Image: Uni-Solar

Image: Solon

Structural Building-Integrated PV Module Systems

Structural building-integrated photovoltaic modules (structural BIPV) are integrated into a building's facade, roof or other building element. **These products differ from adhered BIPV in that they completely replace building components, such as curtain wall or atrium glazing.** BIPV products become integral to the function of the building system, and the modules rely on the existing facade elements (such as the curtain wall frame) to provide structural support. Below is a list of common structural BIPV applications, although others can be engineered:

- Curtain walls
- Windows
- Awnings
- Sunshades
- Carports
- Atrium glazing
- Panelized metal wall systems

Structural BIPV products are specialized solutions engineered to be integral with the building facade. Their aesthetics can be carefully controlled. They can be more challenging to service because they are built into the building.

Figure 7: Structural BIPV System Detail

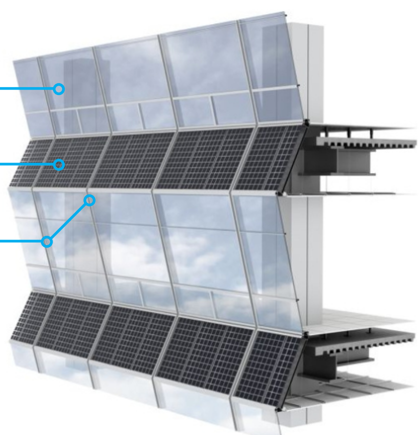


Image: Aaron Binkley

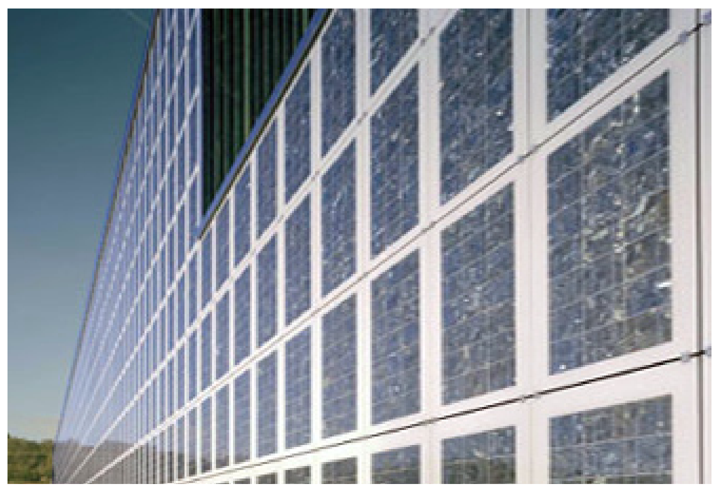


Image: Aaron Binkley

Solar Carports

Carports are a structural BIPV solution that is becoming more common, particularly in warm climates where shaded parking is a building amenity. Modules are attached to a supporting steel structure and form the roof of the carport. This application can be considered structural BIPV because the solar modules make up the roof of the carport itself.

Image: Yingli Americas and Borrego Solar

Image: Suntech

Product Characteristics

The product characteristics (Table 3) listed below provide a side-by-side comparison on the four product categories. Characteristics are defined by their physical features, shape, composition, manufacturer adoption and racking requirements.

The table provides a list of pros and cons for each product. This list identifies major considerations and common factors that can be used to help determine which product category is better-suited to a particular application. The pros and cons focus on product availability and substitutes, as well as building impacts related to the installation of the solar array. The installation process can accelerate roof wear and lead to damage if not planned for and monitored carefully throughout the construction process.

The structural impacts of each category are also considered based on a typical range of installed system weights. The most common applications for each category are provided to further assist in targeting the right product to the right application on commercial buildings. These characteristics are general for each category, and do not represent an exhaustive feature-set for every product on the market.

Table 3: Product Characteristics

	Rack Mounted Module Systems	Composite Frame Module Systems	Adhered Building-Integrated Modules	Structural Building-Integrated Modules
Characteristics	• Rectangular glass sandwich panels • Supported by a metal rack • Rack is assembled in the field • Wide variety of shapes • Many module manufacturers	• Rectangular glass sandwich panels • Supported by a composite reinforced plastic rack • Modular shape • Few manufacturers • Frame designed to fit specific module type and size	• Flexible panels encapsulated in a wear-resistant polymer • Lays flat on roof • Few products • Few manufacturers • Adhered to roof • No racking required	• Solar cells encapsulated in glass or insulated glazing unit • Integrated into building system such as curtain wall or atrium glazing • Specialized product • Few manufacturers
Pros	• Many modules to choose from • Compatible with most racking systems • Mature technology • Large number of suppliers • Experienced installers • High efficiency modules	• Designed for low-slope commercial roofs • Light weight • Modular • Requires few or no tools for installation • Reduces amount of ballast required compared to rack mounted system	• Designed for low-slope commercial roofs • Light weight • Requires few or no tools for installation • No ballast required • Does not restrict roof travel • Not affected by wind • Little impact on building structure	• Designed to be built into building components • Similar weight to traditional glazing system • Requires specialized installation • Not affected by wind • Little impact on building structure • Color options
Cons	• Requires separate racking system and ballast • Highest weight • Difficult to remove • Extensive roof traffic for installation • Snow removal in cold climates	• Few manufacturers • Single profile - not adjustable or customizable • Snow removal in cold climates	• Few manufacturers • Limited installer experience • Difficult to remove • Not suitable for use in conditions of standing water	• Proprietary technology • Limited installer experience • Difficult to remove • Aesthetics vary
Common Applications	• Commercial rooftops • Carports • Awnings • Ground-based systems • Residential rooftops	• Commercial rooftops	• Commercial rooftops	• Curtain wall • Windows • Awnings • Sunshades • Carports • Atrium glazing • Panelized metal wall systems

Module Composition

Rectangular glass panels are the predominant solar module type. There are hundreds of solar module manufacturers producing panels in a variety of sizes and efficiencies suitable for commercial building projects.

The top layer of a rectangular glass module is a sheet of tempered glass. Beneath that is a grid of solar cells. A back sheet of glass, steel or flexible polymer laminate provides support and seals the module together. Electrical contacts and wiring are then installed on the back of the solar module.

Structural BIPV modules are constructed in a similar manner, often with clear space between solar cells to let light pass through. Structural BIPV panels typically use glass as both the front and back sheet.

Adhered BIPV solar modules are designed to be flexible because they attach to building surfaces that are seldom perfectly flat. A typical adhered BIPV module front sheet is a rugged, clear polymer. The solar cells lie behind this layer. The back sheet may be polymer coated stainless steel or a fiberglass reinforced plastic that offers structural support while remaining flexible.

Electrical contacts and wiring are installed on the front of the solar module when the back of the module is adhered to the host building. This also makes inspection and maintenance easier, although the components are exposed to weather and possible foot traffic.

Figure 8: Cutaway of Glass Solar Module

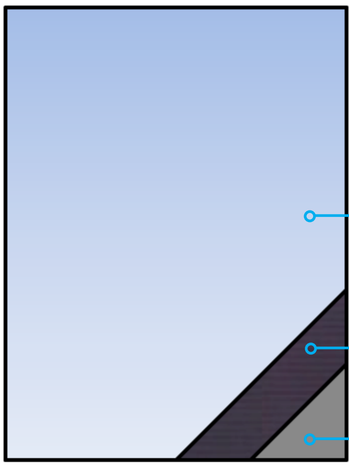
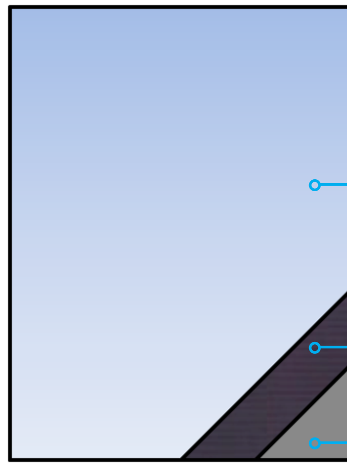


Figure 9: Cutaway of Flexible BIPV Solar Module



Manufacturers, Market Share and Distribution

The solar industry is highly globalized, with many companies manufacturing in several countries and selling products in many more. There are hundreds of solar module manufacturers producing panels in a variety of sizes and efficiencies suitable for commercial building projects. The vast majority of the solar industry's production is rectangular glass panels. The majority of these are crystalline silicon solar cells.

Table 4: Manufacturers, Market Share and Distribution

	Rack Mounted Module Systems	Composite Frame Module Systems	Adhered Building-Integrated Modules	Structural Building-Integrated Modules
Manufacturers	Hundreds; examples include: • SunPower • Yingli • Suntech • Sanyo • BP Solar • Trina • First Solar • QCells	• SunPower • Solon • Renusol (composite frame only) • Solyndra (see page 21 for additional information)	Thin film: • Uni-Solar • SoloPower • Global Solar • Ascent Solar Crystalline: • Solon • Lumeta	• Canadian Solar • BP Solar • Suntech • Pythagorus Solar • Zytech Solar • Voltarlux
Market Share	+/-90 percent of commercial solar market	+/-8 percent of commercial solar market	+/-2 percent of commercial solar market	Niche; <<1 pct. of commercial solar market
Distribution	Global	Global	Global	Global

Physical Characteristics

Physical characteristics help to define each solar category. Table 5 provides indicative ranges for the product's dimensions, component weight and total installed system weight. **The data in the table provides a typical range for products you can expect to encounter as a general comparative guide; it does not represent all products on the market.**

While there is variation within each category, many manufacturers products have been somewhat standardized to facilitate easier handling, installation, and integration with common racking systems. Consult manufacturer's data for detailed specifications for the modules that are being considered.

Table 5: Physical Characteristics[7]

	Rack Mounted Module Systems	Composite Frame Module Systems	Adhered Building-Integrated Modules	Structural Building-Integrated Modules
Width	24 to 48 inches typical; up to 86 inches	43 to 54 inches	Thin film: 14 to 25 inches Crystalline: 48 inches	Varies according to frame of supporting building system
Length	48 to 75 inches tyical; up to 102 inches	78 to 90 inches	Thin film: 188 to 216 inches Crystalline: 93 inches	Varies according to frame of supporting building system
Aspect Ratio	Varies; 1:1 to 2:1 by manufacturer	2:1	Thin film: 14:1 Crystalline: 2:1	Varies; similar to curtain wall glazing
Thickness	0.25 to 2 inches with frame	10 to 12 inches including integrated frame	Thin film: 0.25 inches Crystalline: 0.5 inches	0.25 inches to 1 inch
Module Weight	Varies; 3 to 5 PSF typical	2.5 to 3.0 PSF	Thin film: 0.5 to 1 PSF Crystalline: 2.1 PSF	Varies according to frame of supporting building system
Racking and Ballast Weight	Varies; 1 to 4 PSF typical	0.5 to 2.0 PSF	none required	none required
Total System Weight	Varies; 4 to 9 PSF typical	3.0 to 5.0 PSF	Thin film: 0.5 to 1 PSF Crystalline: 2.1 PSF	Varies according to frame of supporting building system

Note: PSF = Pounds per square foot

The size of solar modules can vary considerably depending on the type of panel and its intended use. Solar modules intended for rooftop applications are designed to be handled by two workers at a time, and weigh in at 25 to 70 pounds per module.[8]

Solar modules can be larger for applications where they can be craned into place – such as curtain wall glazing or carport canopy roofs. The largest module for these applications weighs more than 200 pounds and is intended primarily for ground-based applications.[9]

Flexible thin film modules like the one shown at the far right, are longer and narrower than typical solar modules. This form factor allows them to be used on metal roofs and on applications where glass panels are too wide. Their flexible steel base sheet allows them to be applied to curved surfaces.

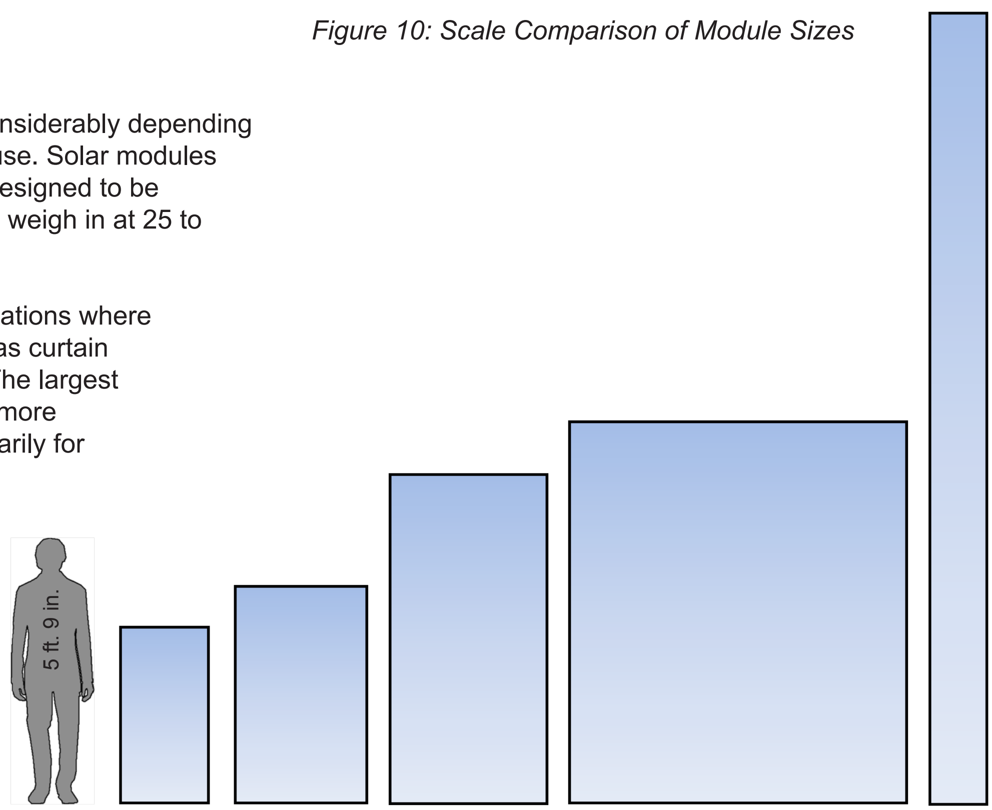


Figure 10: Scale Comparison of Module Sizes

Building Impacts, O&M and Climate Considerations

The impact that the solar array has on the building host is often a determining factor that makes one solar product more suitable than another for commercial building applications.

An important consideration is the weight of the solar equipment (solar modules plus racking and ballast). A structural engineer should inspect the building and calculate the allowable weight of the solar array. Exceeding this safe limit could result in roof ponding, difficulty accommodating other rooftop equipment in the future due to weight constraints, or in a worst case scenario contribute to roof damage. This is a particular concern in climates subject to heavy rain or snowfall that may be difficult to remove from the roof.

The ease of roof maintenance with solar installed is another consideration. BIPV products have little impact on roof or facade access for maintenance purposes. Rack-mounted and composite module systems need to be worked around or temporarily removed to gain access to roof or building areas. Pathways must be included in the design to service rooftop equipment as well as the solar array itself (see pages 15 to 17).

Roof repairs underneath all solar product types may require temporary removal or repositioning of solar panels, racking and ballast in order to access the roof. Rack-mounted systems may have 'tilt-up' features that allow limited access to the roof underneath. Even with this feature, roof repairs that extend underneath several solar panels may require temporary removal of the array for convenience and safety.

Operations and maintenance (O&M) is minimal for most solar products. All panels lose performance due to dust and dirt accumulation, in the range of 1.5 percent to 6 percent under normal conditions.[10] Periodic rain is usually sufficient to clean the modules and restore output. Semi-annual inspections should identify and repair damaged equipment. Inspections should also be conducted immediately after extreme weather events.

Solar panels are designed to withstand a broad range of climates and temperatures. Products installed in high-wind zones may require additional ballast to resist wind forces. With proper engineering, BIPV systems can be used in hurricane zones. Special care must be taken when selecting products in corrosive coastal and marine environments to prevent premature module deterioration, racking system corrosion, and even damage from birds.

Table 6: Building Impacts, O&M and Climate Considerations

	Rack Mounted Module Systems	Composite Frame Module Systems	Adhered Building-Integrated Modules	Structural Building-Integrated Modules
Building Impacts	• Weight can have significant effect on building structure • Increases wind loads on building structure • Increases seismic load on building structure • Difficult to remove once installed • Suitable for low slope roofs and pitched roofs with suitable racking system	• Weight can have moderate effect on building structure • No increase in wind loads on building structure • Increases seismic load on building structure • Easy to remove once installed • Suitable for low slope roof types	• Weight has little effect on building structure • Difficult to remove once installed • Suitable for all low slope roof types • Requires little setback from roof edge or obstructions • Can be walked on • Does not obstruct maintenance paths	• Weight has little effect on building structure • Difficult to remove once installed • Suitable for building systems when properly engineered • Solar cells visible in the installed product can have aesthetic impacts
O&M	• Inspections 2X per year • Cleaning 1X-2X per year	• Inspections 2X per year • Cleaning 1X-2X per year	• Inspections 2X per year • Cleaning 1X-2X per year	• Inspections 2X per year • Cleaning 1X-2X per year
Climate Considerations	• Suitable for all climate regions • Use in high-wind zones requires additional ballast or fastening to roof Best performance in direct sunlight	• Suitable for all climate regions • Suitable for use in high-wind zones with additional ballast • Best performance in direct sunlight	• Suitable for all climate regions • Suitable for use in high-wind zones (some are Miami-Dade approved) • Suitable for direct and indirect sunlight	• Suitable for all climate regions • Suitable for use in high-wind zones • (can be engineered to meet Miami-Dade regulations) • Best performance in direct sunlight

Performance, Cost and Design Characteristics

Solar module performance varies widely among products. Practical efficiency -- the real world conversion of sunlight into electricity -- varies from 5 percent to more than 17 percent. However, efficiency is not the only factor. Less efficient products may produce as much energy as high efficiency models by operating more efficiently in different lighting conditions, or by generating energy for more hours throughout the day.

Solar module prices have declined by more than 50 percent since 2008 (Figure 11), and continue to drop as global production rises to meet growing demand. Project costs, expressed in $ per watt, can vary widely based on design parameters. Project costs (modules, balance-of-system plus installation) can be in the $3 to $5/watt range on large projects.[11]

Figure 11: Retail Module Price Index (2001-2011)[12]

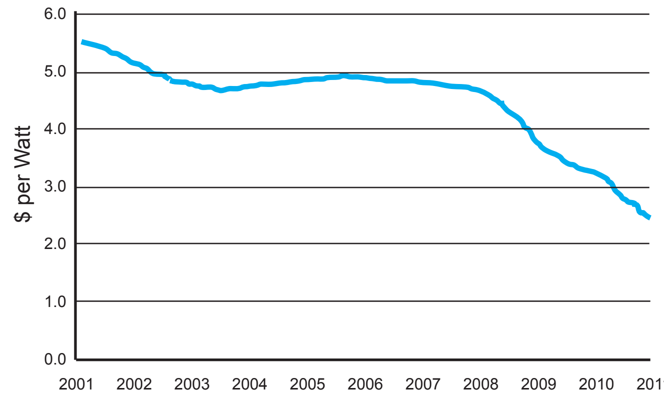


Table 7: Performance and Design Characteristics[13]

	Rack Mounted Module Systems	Composite Frame Module Systems	Adhered Building-Integrated Modules	Structural Building-Integrated Modules
Cost per kWh (relative)	$	$	Thin film: $ to $$ Crystalline: $ to $$	$$$$
Power Density	8 to 16 watts/SF	8 to 16 watts/SF	Thin Film: 6 to 10 w/SF Crystalline: 13 w/SF	6 to 13 watts/SF
Practical Efficiency	8% to 17.5%	8% to 17.5%	Thin Film: 5% to 7% Crystalline: 10% to 12%	5% to 12%
Net-to-Gross Layout[14]	50% to 80%	50% to 80%	Thin Film: 70% to 90% Crystalline: 60% to 90%	20% to 40%

Solar Module Efficiency

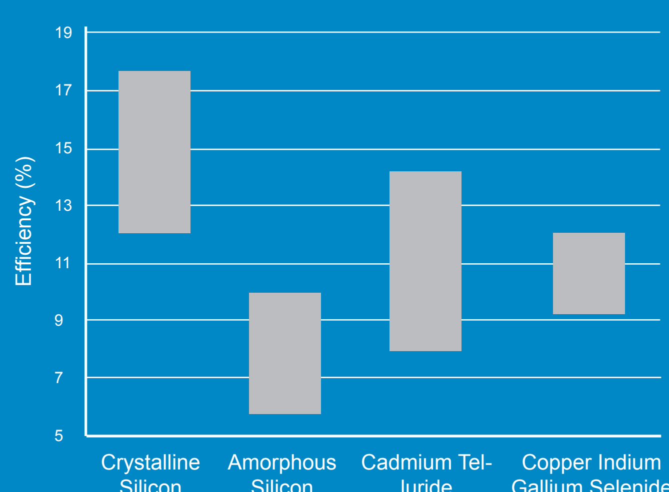
Solar technologies have a wide range of efficiencies - the percentage of sunlight striking the module that is converted into electricity. On the low end of the spectrum you will find efficiencies in the single digits; at the high end, efficiencies are in the high-teens in percentage.

Higher module efficiency does not always mean greater electricity output. Each technology produces electricity in different amounts depending on sunlight and project conditions. Some modules produce best in bright, direct sunlight but output falls off quickly in cloudy conditions. Less efficient modules may achieve similar energy output by producing electricity earlier in the morning and later in the evening when the sun is less intense, a trade-off that offsets lower module efficiency.

Solar modules perform best when perpendicular to the sun. This delivers the greatest amount of sunlight to the module. For some modules, shallower angles quickly reduce energy output because the sun's energy is not absorbed as efficiently. For other technologies, performance is not impacted as greatly. These modules may have an advantage at sites where it is not feasible to install solar modules at the angle that would allow modules to produce at optimum efficiency.

Because of these factors, it is essential to look at more than just the efficiency of the solar modules when comparing different solar technologies. Solar project designers can provide expected annual kilowatt-hour production projections based on the performance characteristics of the technology they propose. This will allow you to see how different technologies compare in terms of energy output, not just energy conversion efficiency.

Figure 12: Typical Solar Module Efficiency Range



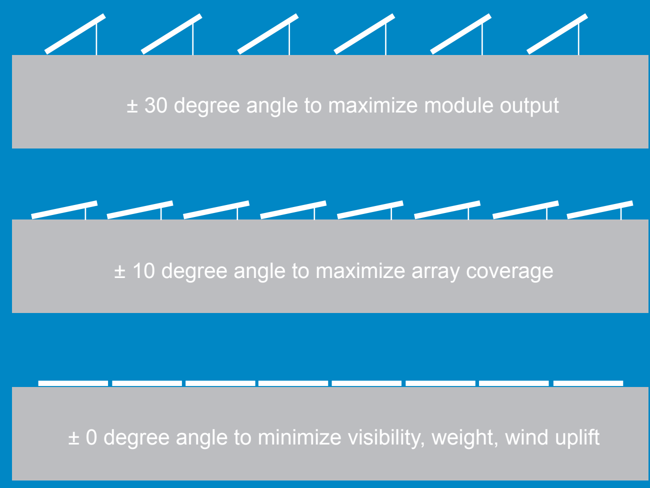
The Angle of Racking

Solar modules produce the greatest amount of energy when they are positioned perpendicular to the sun. This is why, in large ground-based systems, modules are installed on motorized frames that track the sun throughout the day to maximize energy production.

It is rarely feasible to install solar tracking systems on buildings due to cost and installation constraints. Instead, racking systems hold the solar modules at a fixed angle that balances energy production with cost, aesthetic and structural considerations.

Where modules can be positioned at a near-optimal angle, traditional high-efficiency solar modules often make sense. If this is not possible due to height, wind uplift or aesthetic considerations, solar technologies that produce more energy given the practical constraints of that site may be a preferable solution.

Figure 13: Racking Angle Comparison



Space must be maintained between rows of solar modules to avoid casting performance-degrading shadows on adjacent modules. The steeper the angle of the solar modules, the greater the distance required between rows of modules.

Space-constrained sites face a trade-off between:
1) optimum output from fewer modules, or
2) installing a greater number of modules in total, but accepting that the output of each module will not achieve its peak level of performance.

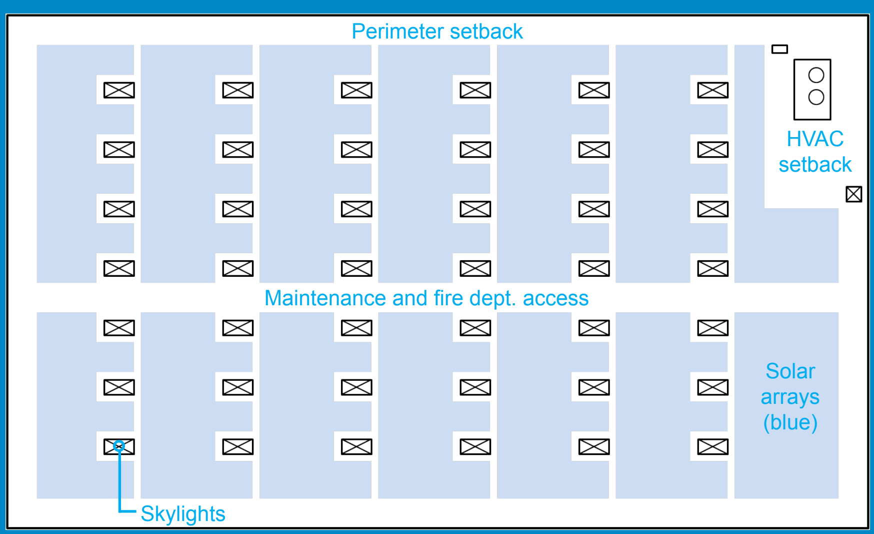
Determining what solution is best for your project requires analysis by the solar project designer as they experiment with module spacing angle, module type, cost and weight of the project. **With the number of variables at play, there is no one-size-fits-all solution for maximizing power output and economics of a solar system design.**

Net-to-Gross Layout

Only a portion of a roof's total area can be covered with solar modules. Panels should not be placed in areas shaded by tall HVAC equipment, adjacent buildings, penthouses or trees. Modules should also be spaced adequately so they do not cast shadows on each other. The perimeter of the roof should also be kept clear. This ensures there is sufficient distance from the roof edge to support worker safety. It also allows access to the perimeter of the building to facilitate roof inspections, load equipment onto the roof, and provides a place to store panels if portions of the solar array need to be moved temporarily.

Walkways are needed for maintenance, inspection and fire department access. Keep a clear area around rooftop equipment such as skylights, HVAC equipment, roof hatches and exhaust fans. Consider reserving a portion of the roof for HVAC equipment that future building tenants may require.

Figure 14: Example Roof Layout Indicating Setbacks



Once these space requirements are factored into the design, you can determine the net-to-gross solar layout. This is the roof area covered by solar panels compared to the gross roof area. A number of 70 percent means that 70 percent of the roof can be used by the solar array (inclusive of walkways for solar equipment access).

The net-to-gross ratio can be very low on small cluttered roofs or it can be very high on large unobstructed roofs. The percentages listed in Table 7 represent a typical range for projects. Actual ratios are likely to vary for any given site.

Solar Array Weight

The weight of a solar array is a significant consideration for commercial buildings. **Few existing buildings were designed with solar in mind, so there is often little excess structural capacity to support solar equipment on rooftops. This limitation can become a driving factor in the choice of which solar product is the most suitable.** In some cases, only the most lightweight products may work. A structural engineer can determine the allowable additional load criteria for a given building.

The weight of a solar array is a combination of the solar panels, racking and any ballast required to resist wind uplift. Racking and ballast for rectangular glass panels often weigh more than the panels themselves. Large flat panels are subject to significant forces as wind blows across them.

More ballast is required to resist wind forces in higher wind zones. This weight can become a limiting factor in the design of rooftop solar projects, especially on buildings with little excess structural capacity. Extra weight also affects the building's structure by adding weight that can be shaken in an earthquake.

Adhered BIPV products lie flat on the building's roof. When properly installed, these products act as part of the roof membrane to resist wind forces without the need for ballast.

Structural BIPV products are integrated into the building's facade. The facade element that the solar modules are anchored to is already designed to resist wind and seismic forces.

Solar array weights will vary based on local requirements, choice of solar technology and design parameters. The table below lists typical ranges of solar array weights for both moderate and high-wind zones.

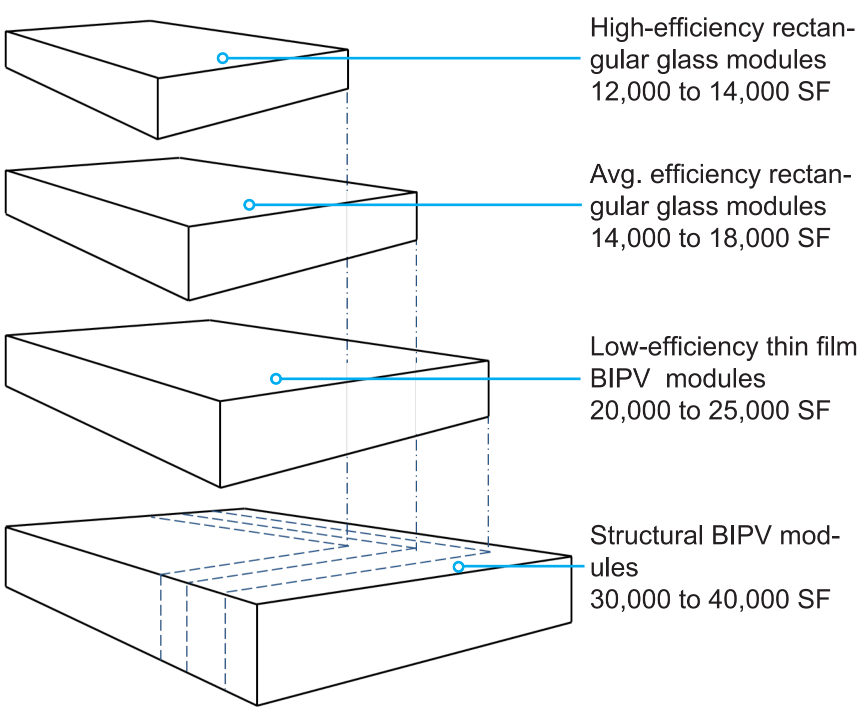
Table 8: Solar Array Weights in Various Wind Zones

	Rack Mounted Module Systems	Composite Frame Module Systems	Adhered Building-Integrated Modules	Structural Building-Integrated Modules
90 mph wind zone	4 to 7 PSF	2 to 4 PSF	1 to 1.5 PSF	n/a
120 mph wind zone	5 to 9 PSF	3 to 6 PSF	1 to 1.5 PSF	n/a

Roof Area Requirements

The area required on a roof to host a solar array varies depending upon the technology selected. **High-efficiency solar modules take up the least amount of space, while low efficiency adhered BIPV and structural BIPV modules require a much greater area - as much as double that of high-efficiency modules to achieve the same installed capacity.**

Figure 15: Roof Area Requirements for 100 kW Array



Where space is limited and energy production per square foot needs to be high, a high efficiency product may suit. But it is not always as simple as choosing the highest efficiency module. Weight constraints on the project may dictate a much smaller array when using highly efficient, but heavier rectangular glass modules. A lighter weight solar array may help alleviate weight limits and allow a larger system with greater output to be installed.

Module cost can also affect the choice of one technology over another. A high-efficiency module may be relatively more expensive, making a larger, but less efficient solar array a more cost-effective solution.

In other cases, it may be advisable to use a particular type of solar product whether or not it is the most efficient, in order to comply with zoning restrictions or aesthetic requirements at the building. An adhered BIPV product may be needed on a building with no parapet if the solar array needs to be hidden from view.

Designing an Efficient Roof Layout

When planning a building that will have solar on the roof, design the roof to facilitate an efficient solar array layout. This will maximize the amount of solar power that can be generated while also reducing solar project costs by simplifying design and installation. A solar array that is efficiently laid out is easier to maintain, will fit more solar panels and therefore generate more electricity.

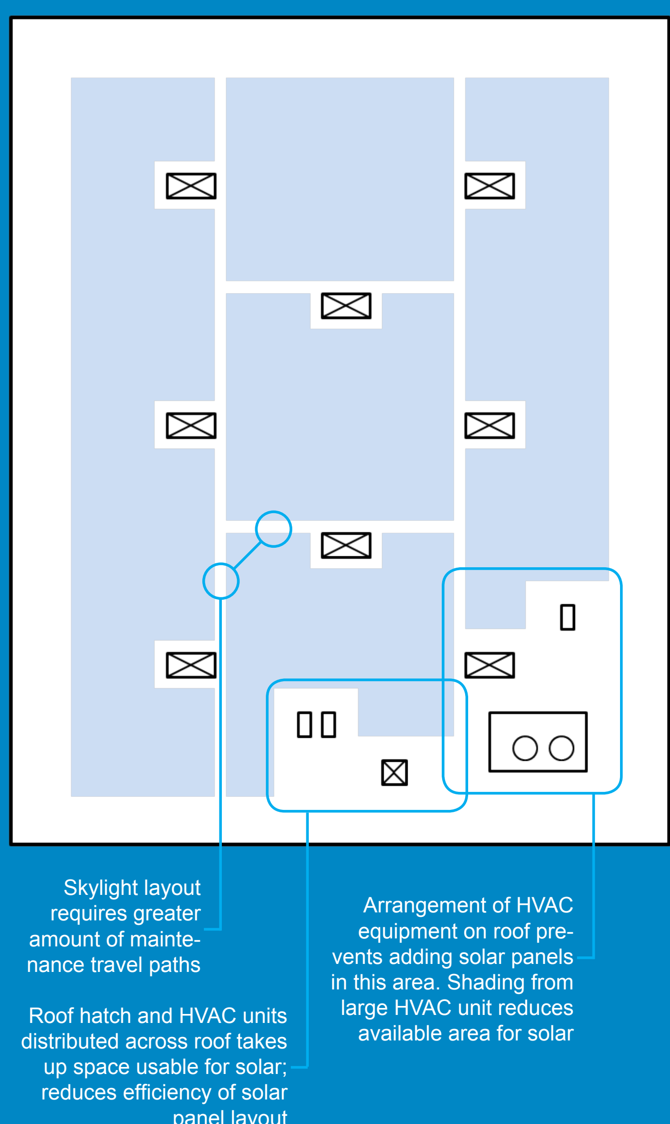
The location of rooftop equipment and rooftop obstructions affects the amount of energy that can be produced by a roof. The illustrations on this page compare features of a roof that has been designed to support an efficient solar layout (Figure 17) with a roof that has not (Figure 16). Designing for solar on the roof of a building can be accomplished by considering where rooftop equipment such as HVAC units, skylights and roof hatches will be placed. This will allow the designers to optimize the roof layout without adding costs or having to change designs in the field during construction.

- Align skylights so they can be accessed with direct walk paths that take up a minimum amount of roof space.
- Locate rooftop equipment, including roof hatches, toward the perimeter of the roof. Most solar arrays will have a 10- to 20-foot setback from the roof perimeter that can be used for placing small equipment.
- Wherever possible, locate larger HVAC units to minimize the extent that they cast shadows on the roof.

Shaded areas are unsuitable for solar panels. Ideally, tall equipment should be located on the northwestern corner of the building so it does not cast shadows on open areas of the roof where the solar array could be located.

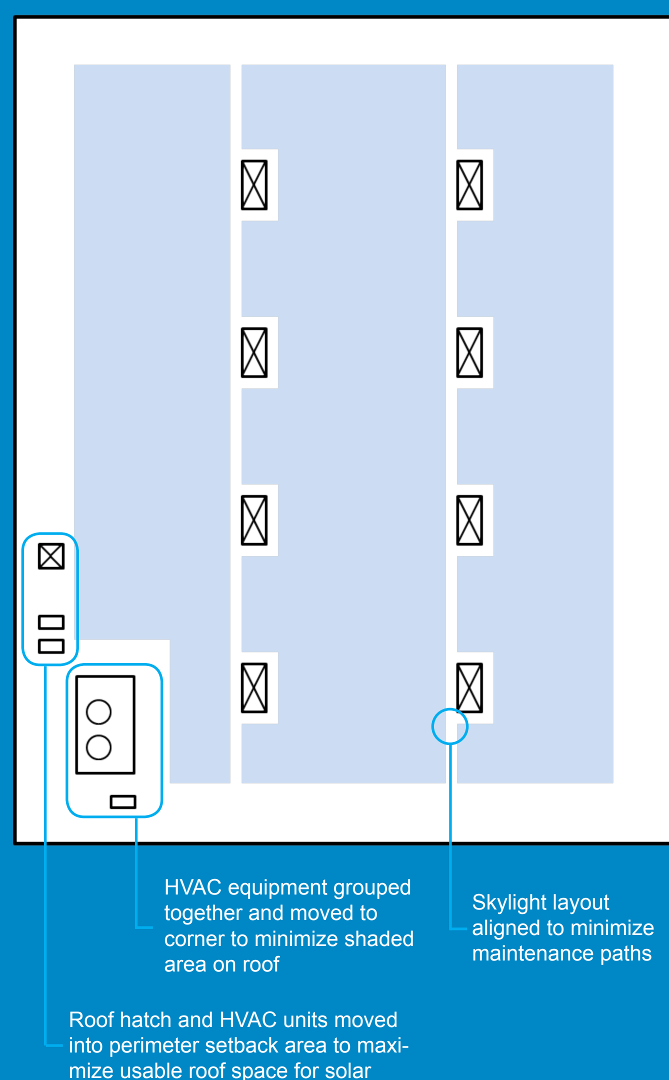
Solar projects can be designed for most roofs, but incorporating a few simple considerations during the design of a building can go a long way toward maximizing the area of the roof suitable for a solar array. This can often be done without affecting building costs, and these changes also help to simplify solar project design and installation when the time comes.

Figure 16: Inefficient Roof Layout for Solar



North

Figure 17: Efficient Roof Layout for Solar



Inspecting Roofs

Before installing any solar products on a building's roof, it is essential that you determine whether the roof is suitable for the project. The roof should be in good condition and have sufficient expected life that it will not need replacing during the operational life of the solar project.

Perform a roof inspection to identify maintenance needs. Walk the roof with the solar project developer and your roof maintenance contractor and agree on the condition of the roof prior to construction commencement. Make any needed repairs prior to construction.

Perform a post-construction roof walk to identify areas of construction-related roof damage or excessive wear due to the solar project. Performing a pre- and post-inspection alongside the contractor will help ensure a successful project and alleviate disputes about who is responsible for roof damage.

When inspecting a roof, pay special attention to areas of poor drainage. Standing water can not only damage the solar equipment over time, the weight of standing water plus the solar equipment can over-stress the roof and produce an unsafe condition. In general it is best to repair areas where water ponds, and avoid them entirely if that is not feasible.

For roofs that are new or nearly new, consider investing proactively in a white roof coating that will extend the roof's life, help resist wear from construction traffic, and reduce performance-robbing high roof temperatures. The white coating has the added advantage of reducing roof temperatures that can reduce solar module performance and degrade equipment.

These simple steps will help identify and resolve potential roof issues before they become real problems.

Construction Considerations

Construction of solar projects can be affected by the choice of technology and the project site. This in turn affects the project's cost. A large rooftop solar project may require thousands of solar panels, miles of cabling and conduits, and many tons of racking and ballast to be delivered to the project site.

Solar projects installed as part of the construction of a building can readily be integrated into the contractor's schedule. Projects at existing buildings require a high level of planning so construction does not interrupt occupants, block parking or otherwise interfere with the use of the building. Projects require a work area to receive materials, lay down, sort, and assemble the components of the solar project. A crane is often needed to deliver materials to the roof or installation location.

The time required for the installation of a solar project varies by technology and site. Project installation rates can vary considerably based on project scope, manpower and technology. This could range from a few tens of kilowatts per day up to 100 kW per day on large, well-staffed projects.

There are often days or weeks of prep work before modules arrive. Electrical interconnection, sitework, cleanup and commissioning can also extend for days or weeks after modules are installed. Roof work pertaining to the project, such as a roof coating or replacement, should be added to this schedule.

Roof warranties can be voided due to wear from excessive foot traffic. Rooftop projects should specify temporary protection to prevent damage from construction activity. Under normal circumstances a roof may have a few people on it a few times a year for inspections and maintenance. A solar project could put dozens of workers on the roof for a month or more.

Inadequate roof protection such as not using walk mats and slip-sheets could void the roof warranty. Review the roof protection plan with the roof warranty provider and roofing manufacturer prior to construction. Get a sign-off at the completion of construction stating that the roof manufacturer has inspected the roof and that their warranty remains in force.

Rack-mounted systems -- where components including racking materials, ballast, conduits, wiring and modules are delivered to the site and assembled in the field -- can be the most time-intensive projects to install. However, they are often the most flexible and customizable, since the design can be modified to account for any site constraint. Assembly of these systems requires tools and field fabrication, which may increase the possibility of roof damage during construction.

Composite frame products are usually faster to install, and they cut down on staging needs. The module and its racking unit are joined in the factory, so they can be installed quickly as a single unit in the field. Composite systems have been designed for tool-less assembly and there is little need for field modifications. Because there are fewer materials delivered to the site from different suppliers, the staging and construction process can occur more quickly.

Both rack-mounted systems and composite frame systems require ballast - masonry blocks added to resist wind uplift forces. The lower profile of the composite system typically requires less ballast. To reduce the amount of ballast required, both categories of systems can be anchored to the roof structure to resist wind uplift.

Adhered BIPV systems can be installed quickly if the site is clean and clear of obstructions. A number of thin flexible modules are typically installed on a secondary roof membrane. These membranes are laid out on the roof atop the existing roof surface. The secondary membrane is adhered to the existing roof underneath and provides a good deal of additional protection against damage or degradation.

Adhered BIPV products may be delivered to the site as large roofing rolls. Ballast is not required since the membrane is adhered to the existing roof. This is one of the reasons adhered BIPV products are lighter than other solar products. **Installation does not require tools aside from those used to bond the product to the existing roof.**

Some adhered products such as flexible crystalline BIPV modules are adhered directly to the existing roof membrane or metal roof. There is no sacrificial membrane. Ballast is not required for this BIPV system either, which contributes to its low installed weight. Installation does not require tools.

Adhered BIPV products rely on a strong bond to the existing roof of the building. Careful roof preparation is critical to ensure proper installation. The existing roof must also be assessed to ensure that it is suitable as a substrate for BIPV products. These products are not intended for areas of the roof that may have standing water.

Structural BIPV systems are often installed at the time of building construction due to their integration with the building facade or roof. As a result there is little additional staging area required. The installation process is similar to the traditional building products they are integrated into, save the additional effort required to wire up the system. These systems are usually customized for the building system they are installed in such as a curtain wall or roof canopy, making it difficult to replace or modify the system once installed.

The construction process for each type of solar technology can affect the suitability of a product for a particular building. Where staging areas are limited, it may be advantageous to specify a solar product that can be delivered directly to the site ready-to-install, such as a composite frame product. For sites where there is no large open expanse of roof, a rack mounted system may provide more customization. On buildings with a much greater facade area than roof area, structural BIPV facade products may be advantageous.

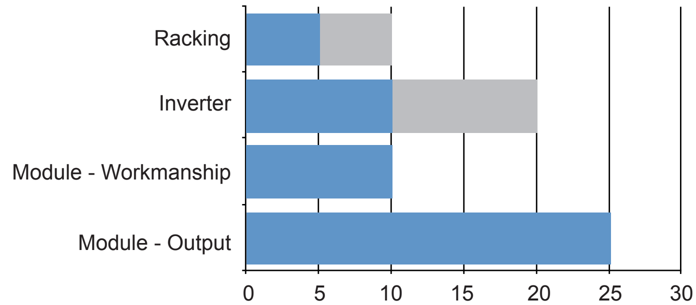
Table 9: Construction Considerations

	Rack Mounted Module Systems	Composite Frame Module Systems	Adhered Building-Integrated Modules	Structural Building-Integrated Modules
Construction Overview	• Assemble racking on-site • Install ballast • Install solar modules on racking • Install conduits and wiring • Construct electrical room • Install electrical equipment	• Install solar modules and racking • Install ballast • Install conduits and wiring • Construct electrical room • Install electrical equipment	• Clean and prep roof • Install solar modules • Install conduits and wiring • Construct electrical room • Install electrical equipment	• Install solar modules with building elements • Install conduits and wiring • Construct electrical room • Install electrical equipment
Staging Requirements	• Deliveries • Racking pre-fabrication • Ballast storage • Module storage and sorting • Conduit and wiring storage and pre-fabrication • Electric room gear • Crane, lifts, scaffolding • Construction trailer	• Deliveries • Ballast storage • Module storage and sorting • Conduit and wiring storage and pre-fabrication • Electric room gear • Crane, lifts, scaffolding • Construction trailer	• Deliveries • Module storage and sorting • Conduit and wiring storage and pre-fabrication • Electric room gear • Crane, lifts, scaffolding • Construction trailer	• Deliveries • Module storage and sorting • Conduit and wiring storage and pre-fabrication • Electric room gear • Crane, lifts, scaffolding • Construction trailer
Roof Protection	• Walk mats • Slip sheets • Pads for materials staged onto roof • Break areas for construction staff	• Walk mats • Slip sheets • Pads for materials staged onto roof • Break areas for construction staff	• Walk mats • Slip sheets • Pads for materials staged onto roof • Break areas for construction staff	• n/a
Install Time / 500kw	• 10 to 30 days	• 8 to 25 days	• 8 to 25 days	• 15 to 30 days

Warranties

Warranties provide assurance for the quality and reliability of the components that are used in a solar array. The term and coverage of warranties varies based on the type of equipment. Solar module warranties include materials and workmanship as well as a warranty on energy output.

Figure 18: Warranty Terms



The materials and workmanship warranty typically extends for 10 years. Energy output warranties for solar modules typically extend 25 years. Warranty terms are structured in a stepped manner such as: "minimum output of 90 percent at 10 years and 80 percent at 25 years". Virtually all solar modules offer this type of warranty, both in terms of duration and two-stage performance guarantee. The output warranty provides solar project investors protection against the loss of revenue due to downtime.

Warranties of 25 years require that the creditworthiness of the company backing the product be considered. When working with companies that have a limited operating history or a smaller balance sheet, it is becoming more common to provide a third party insurance guarantee that backstops the warranty for their products. This helps to address concerns of the module purchaser that the manufacturer will be around to service the warranty in the future. Companies with less-proven technologies may also purchase insurance policies to reduce technology and performance risks.

Inverters are an electrical device that takes incoming direct current (DC) electricity from the solar array and turns it into alternating current (AC) electricity for building use. Inverter warranties are typically 10 years. However, inverter reliability is improving and warranties are steadily getting longer; extended warranties of up to 20 years exist. In time, inverter warranties may align with solar module warranties so the major high-value components of the solar array can be expected to perform for the same amount of time. This can also add certainty to the operations and maintenance costs associated with solar facilities. This makes projects more attractive to solar investors and operators because it reduces financial risks.

Racking is made of non-corrosive materials such as aluminum, stainless steel, or composites and does not typically have moving parts. This makes racking systems highly durable and largely maintenance free. Care should be taken to not let incompatible metals come into contact with one other. Racking equipment is typically warranted for 5 to 10 years.

Roof warranties should be closely matched to the solar array's lifespan -- 20 to 25 years. Roofing manufacturers are introducing extended life roof membranes to provide greater compatibility with the anticipated lifespan of solar projects.

Connecting to the Grid

Solar projects on commercial buildings need certain permits in order to be connected to the utility grid. This is essential when the array is operating as a small rooftop power plant (referred to as 'distributed generation') by feeding its power to the grid and by-passing the building host.

The need for grid interconnection also applies if the building is the intended consumer of the power (referred to as a 'net metered' project). This is because it is possible for electricity to back-feed to the power grid in cases where the solar array produces more energy than the building can use. This is the case even where the output of the solar array is significantly lower than the building's energy needs.

Utilities are becoming increasingly careful about where and how they allow solar projects to connect to their grid in order to minimize the possibility of grid instability. Switches and breakers are required on solar projects to temporarily allow the array to be physically isolated from the utility grid if needed for safety reasons.

Where the grid cannot readily accommodate the additional demands placed on it by a solar array, upgrades to feeders and sub-stations may be required. Depending on the utility and the solar project, these costs may need to be paid by the solar project sponsor. This can drastically affect the project's economic viability if upgrades are extensive and the project cannot absorb the costs.

The process the utility goes through to assess the grid's ability to support solar capacity in a given location can take weeks or months to determine. This can become a critical path item for solar project feasibility analysis by the solar developer.

Utility companies are working to upgrade the grid and make it 'smarter' so it can handle distributed and net metered solar projects. This is not a fast process because solar can affect the grid in various ways.

Utility interconnection plays a large part in the cost and feasibility of solar projects, and answers to these questions are needed before a project can be underwritten accurately and planned with certainty.

Conclusion

As more states adopt solar programs, the solar industry in the United States is poised to continue its upward trajectory of growth. Combined with global growth in the scale of solar module manufacturing, costs for solar modules and equipment can be expected to continue to decline and drive even wider adoption.

While established technologies compete for market share, new technologies are being researched and brought to market that promise higher efficiencies and novel form factors. Many of these will not be successful, but a few will succeed and have a transformative effect on the industry. Many promising advancements are focused on ever more cost-effective ways to manufacture solar modules. Engineers and installers are working to improve the speed of installation, reduce weight and lower project costs for all solar technologies.

There have been several recent notable solar industry failures that have cast a shadow on the entire solar industry. Evergreen Solar, a producer of rectangular crystalline silicon modules that used a proprietary manufacturing process, shuttered its operations because it was unable to compete on cost as the industry grew and module prices dropped precipitously in the past few years.

Solyndra, a U.S.-based solar module producer, sought to combine a promising new solar technology with a unique form factor tailored for commercial rooftop applications. In the face of massive declines in traditional rectangular PV module costs, they were unable to scale up manufacturing and reduce costs quickly enough to survive. Until recently, this product had been considered a potentially disruptive new entrant for rooftop projects, best placed into this guide's category of composite frame PV module systems.

Solyndra tubular solar module.
Image: Solyndra

It is widely acknowledged that not every solar technology will achieve commercial success. Some of the failures will surely prompt discussion about the pros and cons of the solar industry. It is worth remembering that in any industry growth and innovation are essential elements to its ongoing success. There will be both success stories and failures along the way but it will ultimately lead to better products that meet the needs of customers at ever-lower costs.

This is particularly true when it comes to the emerging recognition that tailoring solar products for commercial buildings serves an unmet need for many property professionals. These advancements will deliver higher quality products and will have fewer unwanted impacts on commercial buildings. At the same time costs will continue to decline, which will drive ever-wider adoption in the real estate industry.

The level of innovation taking place in the solar industry today is encouraging. This focus on solar technologies that promise to deliver new and better solutions is particularly interesting to those in the commercial real estate industry. This guide provides a practical approach to understanding the solar product solutions that can be used on commercial buildings today and establishes a framework to allow a better understanding of the products that emerge tomorrow.

Glossary of Terms

- **Alternating current (AC)** = The type of electric current used in buildings and appliances.
- **Array** = A group of solar modules. A solar project can contain one or many arrays.
- **Balance of System (BOS)** = All the parts of a solar electric system excluding the solar panels and the inverter. Balance of system often includes racking, wiring, conduits and raceways, sitework and roof protection.
- **Ballast** = A heavy material -- usually masonry, concrete blocks or gravel -- used to resist wind forces.
- **BIPV (Building Integrated Photovoltaic)** = Solar modules that are permanently affixed to the exterior of a building.
- **Cell** = The smallest part of a solar panel that converts light into solar electricity.
- **Direct Current (DC)** = The type of electrical current produced by solar cells. Direct current electricity must be converted into alternating current before it is usable in a building.
- **Distributed generation** = Generation of electricity near its point of use throughout a utility territory.
- **Interconnection** = The process of connecting a solar electrical system to the electrical grid.
- **Inverter** = An electrical device that converts direct current (DC) electricity into alternating current (AC) electricity.
- **Kilowatt** = One thousand watts.
- **Kilowatt-hour (kWh)** = 1,000 thousand watts produced or consumed over a period of one hour.
- **Megawatt** = One million watts.
- **Miami-Dade** = A set of building code requirements originating in Miami-Dade County, Florida that contain stringent requirements for withstanding extreme wind and weather events such as hurricanes.
- **Module** = A group of solar cells assembled into an electricity-generating device; also referred to as a "solar panel."
- **Monocrystalline** = A solar cell composed of a large, single silicon crystal and has a patchwork pattern.
- **Multicrystalline** = A solar cell composed of silicon oriented in various directions. Also referred to as "polycrystalline."
- **Net meter** = Regulatory requirements that allow an electric utility to measure electricity based on energy consumed minus energy produced. In simple terms it refers to an electricity meter that spins both forward and backwards.
- **Net-to-gross** = The percentage of a typical roof that can be used for a solar array, after accounting for perimeter setbacks, shaded areas, access walkways and other limiting conditions.
- **Panel** = A group of solar cells; also referred to as a "solar module."
- **Photovoltaic** = The conversion of light into electricity.
- **Power purchase agreement (PPA)** = A contract between a power consumer and a power producer.
- **Racking** = The support structure for a solar modules.
- **Roof protection** = Measures taken during solar array construction to minimize damage to the roof.
- **Staging** = A part of construction where materials are sorted, prepped and organized for installation.
- **Watt** = A unit of power equal to amps times volts.
- **Wind zone** = A designation in building structural codes describing the wind forces a structure (or solar project) must be designed to withstand.

End Notes

1. Global Solar Power Growth Doubled in 2010: Study. February 14, 2011. Reuters.com. Accessed September 2, 2011: http://www.reuters.com/article/2011/02/14/us-energy-solar-idUSTRE71D4WJ20110214
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7. Examples include: Rack mounted module systems: First Solar FS3, Yingli Panda 265 Series, SunPower E20, Suntech STP280, TSolar TS390. Composite frame module systems: SunPower T5, Solon Solfixx. Adhered BIPV modules: UniSolar PVL144, Ascent Solar WaveSol Light 5 meter, Lumeta Powerply 400, Solon SOLbond. Structural BIPV modules: Canadian Solar BIPV, BP Solar BIPV, Pythagorus Solar PVGU, Zytech ZT60 DS.
8. Examples include: First Solar FS Series 3 module (26 lb.); Yingli Panda 265 series module (42 lb.); Suntech STP 280 module (59.5 lb.) Solyndra Series 200 module (69 lb.)
9. TSolar TS390 solar module (200 lb., 86 in., x102 in.)

10. Kimber, A and L. Mitchell et al. "The Effect of Soining on Large Grid-Connected Photovoltaic Systems in California and the Southwest Region of the United States." Powerlight Corporation. 2006. Page. 6. Accessed September 21, 2011: http://ericwalstad.com/portfolio/images/IEEE_2006_Full_Paper_r3.pdf
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13. Examples include: Rack mounted module systems: First Solar FS3, Yingli Panda 265 Series, SunPower E20, Suntech STP280, TSolar TS390. Composite frame module systems: SunPower T5, Solon Solfixx. Adhered BIPV modules: UniSolar PVL144, Ascent Solar WaveSol Light 5 meter, Lumeta Powerply 400, Solon SOLbond. Structural BIPV modules: Canadian Solar BIPV, BP Solar BIPV, Pythagorus Solar PVGU, Zytech ZT60 DS.
14. The term "Net-to-gross layout" describes the percentage of a typical roof that can be used for a solar array after accounting for perimeter setbacks, shading setbacks, access walkways and other limiting conditions. For example, a 60,000 square foot roof may accommodate a 500kW of solar array if 100 percent of the roof could be covered with modules. This is the "gross" area. This would be impractical in most cases as it would prevent access to the roof for maintenance, inspections and other operational needs. Accounting for these needs reduces the amount of space on the roof where solar modules can be installed. This is the "net" area. See page 15.

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