

FLEXIBLE MODULE SOLAR POWER OPTIONS

Presented by:



Figure 1 Solar power systems can help commercial buildings and residential home owners avoid the unexpected fluctuations in energy prices as well as help reduce carbon emissions from fossil fuel power sources.

By Andrew Hunt

INTRODUCTION TO SOLAR POWER GENERATION

Solar power is created through a process of collecting, and often storing, solar radiation through sunlight, and transferring that energy into a form that can be easily used to replace the power provided by standard sources of electricity such as burning fossil fuels. For example, solar power can be used to provide electricity for buildings, boats, cars, or personal electronics—anything that requires electricity to function.

In the most basic sense, the sun's radiation is collected through materials and devices, usually a photovoltaic (PV) cell—commonly known as a solar cell—strategically placed to capture the sun's rays in the most direct manner. This

holds true whether energy is being generated to power small consumer technology, such as a cell phone or laptop, whether it is used to provide energy to heat and light a residential or commercial building, traffic signs and signals, or even satellites orbiting the Earth. PV systems are increasingly affordable and are being used more frequently because they are the least expensive option when considering onsite power generation.

In order to know whether solar power is appropriate for a particular location or purpose, you must first know the average amount of sunlight that falls in that location throughout the year. This value is usually referred to as *total radiation on a horizontal surface*, or as *total radiation on a surface tracking the sun*, and is estimated by measuring the amount of sunlight

LEARNING OBJECTIVES

At the end of this program, participants will be able to:

1. Describe how traditional solar power generation operates in residential and light commercial applications.
2. Identify some of the common limitations and challenges with traditional solar power generation arrays.
3. Compare the differences between flexible solar modules and traditional rack mounted units.
4. List the benefits of flexible lightweight solar power systems.

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for a specific location at different times of the year. The geographic location, time of day, season, local landscape, and local weather of a site all factor into the decision of whether solar technology is beneficial.

Radiation data is critical in determining the benefits of using solar power in a given situation, and it has standard representations that are used worldwide. The amount of sunlight available in a specific location is often expressed as kilowatt-hours per square meter (kWh/m^2), however, direct estimates of solar power may also be expressed as watts per square meter (W/m^2). The radiation data for systems that provide solar water heating and space heating are usually represented in British thermal units per square foot (Btu/ft^2).

Over the last decade, solar technology has started to become an affordable alternative to fossil fuel based energy, and technological advances continue to make it more versatile every year. Already, in areas with good solar availability and high utility prices, solar power is competitive with traditional sources of electricity. Some estimates suggest that within the next ten years, solar power will be competitive with traditional sources of electricity in all locations

OVERVIEW OF SOLAR SYSTEMS

Photovoltaic solar systems are constructed of individual solar cells, which are then combined into modules that can then be connected to arrays. These solar arrays make up the primary part of a solar system. The cells themselves can be as small as a few inches across, however when connected together into modules they can be several feet long and several feet wide. Regardless of the size, solar cells are used collect solar energy, and convert it into electricity.

Solar cells are constructed of semiconductor materials, which are used to convert the absorbed energy from sunlight into useful energy. This process works by having the absorbed light transferred to the electrons in the atoms of the semiconductor. The electrons then escape from their standard positions within the atoms and that energy becomes part of the electrical flow, or current, of the electrical circuit. Solar cells have a special electrical property called a "built-in electrical field", which is used to separate the electrical charges, and to provide the specific force, or voltage required to push the current through an external load. This process is how solar energy can be used to provide light or heat, or to charge an electronic device.

A common technology used to create photovoltaic semiconductors is to use crystalline silicon cells. These cells are made of silicon atoms that are connected to form a crystal lattice, which provides the solid material of the PV cell's semiconductors. Silicon atoms have 14 electrons, however only four can be shared with other atoms. These four valence electrons are at the heart of how solar energy is produced.

In brief, in crystalline solids, such as those in PV cells, each silicon atom normally shares one of its valence electrons in a covalent bond with each of its neighboring silicon atoms. This ends up as the crystalline lattice, which, is made of the original one atom, plus the additional four shared valence electrons, for a total of five silicon atoms.

THE SCIENCE BEHIND SOLAR

In order to create useful energy from the silicon atoms, electrons must be dislodged from their covalent bonds; when they are dislodged, they become part of the electrical circuit. The energy required to dislodge the electrons is called the bandgap energy. When sunlight hits the silicon crystalline of a PV cell, it includes packets of light energy, known as photons. The only way an electron can be released is if a photon is at least as great as the bandgap energy. PV cells need to have their molecular structure tuned to best accept and make use of the photo energy so that they don't create any extra heat, which can happen in the photon's energy exceeds that of the bandgap energy. Crystalline silicon has a bandgap energy of 1.1 electron-volts (eV), and the ideal bandgap range for PV semiconductors is from 1.0 to 1.6 eV.

Solar systems can be very basic, or much more complex. For example, they can include batteries to store electricity for days when the solar modules cannot collect enough energy to meet the needs of the system. They can also be constructed to include electrical connections, mounting hardware, and power-conditioning equipment, to ensure that they can provide seemingly energy output.

The two ways that solar energy is usually used in homes and other buildings are to provide power to the structure and to heat water through direct or indirect solar radiation. There are many different types and configurations for both ways to harness solar energy, and those vary depending on local climate, particularly whether temperatures generally go below freezing or not. Electricity is acquired through solar cells such as PV modules, solar thermal modules are used to acquire immediate heat, and are often used to heat water as it passes through pipes to a central storage area. These water heaters can save considerable energy costs in a home or business since the water is passively heated rather than actively heated in a boiler. Once the investment of the modules is paid off, the hot water is virtually free.

ADVANTAGES OF SOLAR FOR HOMEOWNERS AND LIGHT COMMERCIAL PROJECTS

Homeowners and light commercial project developers can both benefit from implementing solar technology onto their buildings. While the investment for the initial purchase and installation costs may seem higher than connecting to the electrical grid, the long-term savings can be significant, with a return on the

initial investment accrued within the first few years of use. In addition to cost savings, solar modules allow homeowners and owners of commercial buildings to take advantage of valuable tax incentives, reduce their carbon footprint, lower susceptibility to changing energy prices through energy independence, reduce maintenance costs, and increase property values.

Recently, the US government has set in place numerous financial rewards to encourage both homeowners and businesses to integrate solar power systems. There are many incentives in place, such as the Investment Tax Credit, which gives business owners a 30% tax credit on installed systems, no matter what the system costs. New metering policies that charge only for energy used are another type of incentive. These policies allow businesses that integrate solar energy to bank unused solar energy to offset their electrical bills, and residences to more closely monitor their own energy use.

Both homeowners and commercial properties can often take advantage of cost recovery programs to help lower tax liability on the up-front costs of installing purchased systems. Alternatively, leasing is an option for residential and commercial properties that enables people to benefit from solar power systems for 15–20 years without committing to the upfront purchase and installation costs.



Figure 2 Onsite power generation, like solar power, is becoming more affordable and attractive to many homeowners.

Regardless of whether solar modules are purchased or leased, the energy savings can be significant, as well as immediate. Homeowners will benefit from avoiding volatile energy prices through using solar modules. If they do not wish to own the modules, they can instead lease them and take part in solar power purchase agreements (PPAs), which allow homeowners to finance their solar modules. In this model, homeowners pay the solar

provider, rather than the utility company, for electricity, and the costs are considerably less.

For businesses that choose to purchase or lease solar systems, the advantages of using this alternative power source can be significant. Most notably, businesses can drastically reduce operating costs for the building, and those reduced costs can quickly pay for the initial investment of the solar system. Unlike power obtained from utility companies, solar power is much more stable. Businesses can then treat their power costs as more of a fixed expense, which can, in turn, stabilize an otherwise volatile element of business operation costs. This stability can significantly benefit businesses that operate 24 hours a day, such as manufacturing firms, or companies that have data centers. For larger commercial buildings that require water heating—for example, units that include rental tenants or businesses such as laundromats—indirect solar radiation heating can reduce energy costs significantly and can stabilize costs during energy-intensive months, such as winter or summer.

As noted earlier, solar systems are highly reliable, durable, and they require very little maintenance. Most solar module manufacturers provide warranties that last for roughly 25 years, however because the modules are passive with no moving parts, they tend not to require much in the way of repairs. This guaranteed performance provides property owners with the benefit of a long-term, secure investment of energy independence.

Green buildings and sustainable design are quickly becoming recognized as something to strive for in newer buildings and retrofits. Installing solar modules can lower an individual or business's carbon footprint, all while increasing the property value. For example, a recent study by the National Bureau of Economic Research found that in California, PV systems added a \$20,194 premium to the sale price of homes. In addition to having property values increased, businesses that integrate solar energy into their initial building design, or add solar modules to existing structures, may find that their decision to “go green” is positively recognized by both customers and the media.

ADVANTAGES TO GOING SOLAR

Building industry professionals, whether architects, builders, or designers, can all benefit from knowing how to best integrate solar systems into their work while at the design

or build stages of construction. Solar energy is increasing in popularity for both residential and light commercial properties, and so building professionals need to be informed of the advantages so that they can discuss design options with clients who are interested in energy efficient, or even passive energy buildings. As an example of the electricity-saving benefit, it has been reported that a 2.4-kilowatt solar electric system installed in a California housing development can offset 40 to 50 percent of the electricity needs of an energy-efficient home.

There is a distinct difference between choosing solar for new buildings versus integrating solar into an existing structure, and building professionals need to be knowledgeable about and experienced in energy-efficient building design and construction. For new buildings, architects must have a full understanding of the building site, so that they can tailor their design to optimize sun access. Solar heating also allows for creative designs when it comes to energy efficiency of the whole building, and architects will be able to provide clients with a secure energy option that will immediately increase the value of the home or building.

Architects, builders, and designers who work with solar must also be informed of the challenges of integrating solar systems—particularly traditional rack-mounted systems—on older buildings. While some customers may wish to retrofit their property with solar, the roofs of the buildings themselves may not be strong enough to support the weight of the system. These older buildings should be fully inspected prior to having solar integrated during the design stage to avoid any potential safety hazards or damage to the building.



Figure 3 New technologies in solar power generation include flexible peel-and-stick style modules.

From a professional standpoint, building professionals who use solar often tend to have green building accreditation, such as

Leadership in Energy and Environmental Design (LEED), which can be a distinct advantage in a competitive market. LEED standing identifies these professionals as understanding energy efficient building practices in a broader and deeper context than their non-accredited counterparts, and will help make sure that when solar is considered an option, it is done in the context of whole-building efficiency.

LIMITATIONS OF TRADITIONAL SOLAR MODULES

Rack-mounted solar modules have been the industry standard for both residential and commercial projects. Modules are typically mounted to rooftops, and thus are vulnerable to the elements, particularly in areas where weather can be severe. While solar modules are designed to be strong and durable, they are not indestructible, and in extreme cases they can be damaged by the impact of high wind, wind-blown debris, and hail. In many cases, the tempered glass of the modules may survive impacts, but the rack itself may be damaged.

Because of their exposed location on rooftops, the module arrays may experience sustained winds and higher wind loads than other parts of the building. In extreme conditions such as hurricanes, gusts have been known to exceed 150 mph, and roof-mounted solar modules may be torn from the mounting hardware, or the hardware itself may be damaged if the potential wind load was not calculated properly prior to the installation. Hurricanes are known for exceptionally high winds that often carry with them random debris, such as metal signs or building fixtures, all of which can damage solar modules upon impact.

Most solar modules are built with tempered glass and are tested against industry standards for strength, however some modules may be more fragile and thus risk damage from hail and debris during extreme weather. These challenges can compromise the potential benefits of including this alternative power source in the design.

While not a physical limitation, traditional rack-mounted solar modules are increasingly considered outdated from an aesthetic point of view. Architects will be challenged by the appearance of rooflines and the overall look of a building when they integrate a rack-mounted system onto the roof of a building. The modules are usually quite large and they add additional height onto the structure.



Figure 4 Flexible and flat, modern solar modules can help increase overall solar collection capacity while not interfering with the roof aesthetics.

FLEXIBLE SOLAR MODULES

Solar energy is an increasingly affordable and energy efficient alternative to energy drawn from utility companies. However, traditional rack-mounted solar modules are limited in their weight, installation requirements, and susceptibility to wind and debris damage. They also affect the aesthetics of building design, and as such may either be disregarded as an energy option, or present architectural challenges to better integrate the technology into the roof design.

A material that addresses many of the challenges with traditional solar modules is Copper-Indium-Gallium-Selenide or CIGS. This thin-film solar material has been demonstrated to be a viable replacement to rack-mounted solar modules because of its high efficiencies, durability, and versatility. CIGS can be manufactured through a number of different processes, but most include some version of having copper, indium, gallium, and selenide deposited overtop a backing, which is often glass or plastic, but sometimes stainless steel foil. Electrodes are attached on the back and front to collect the current when the cells are exposed to sunlight. The backing is treated, often with a physical vapor deposition process, and the end product is an extremely controlled, stable, and powerful flexible copper indium gallium selenide (CIGS) solar cell. The result is a solar module that performs with high efficiency under low light conditions and produces high energy yields.

QUIZ

- Which of the following is a name for the value referring to the amount of sunlight that falls on a location throughout the year?
 - Sunlight squared times latitude
 - Refraction indifference
 - Ray's Method
 - Total radiation on a horizontal surface
- What is one major consideration when planning to install a traditional rack-mounted solar panel system on an existing older home?
 - The weight of the system on the roof
 - Too much total radiation overwhelming the system
 - The cost will go up once the warranty expires in 25 years
 - Older buildings don't store enough power to charge basic appliances
- How are traditional solar panels typically mounted?
 - Tongue and groove
 - Rack mounted
 - Gravity balanced
 - With elaborate pulleys
- Which of the following can flexible solar panels be installed on?
 - Boats and Planes
 - House or Commercial building
 - Clothing
 - All of the above
- True or False: Flexible solar panels cannot be installed without reinforcing and retrofitting a roof.
- Generally, how thick are flexible solar panels?
 - 2mm to 3mm
 - 10mm to 25mm
 - 40mm to 50mm
 - 100cm to 200cm
- What type of roofing material is ideal to bond solar panels to?
 - Wood
 - Asphalt
 - Metal
- How many years is a typical warranty on power output for flexible solar panels?
 - 1 year
 - 2 years
 - 5 years
 - 25 years
- Which is an immediate benefit of installing flexible solar panels?
 - Increased property values
 - Free installation on all models and types
 - Coupons for home improvement stores
 - Do it yourself TV show exposure
- What does CIGS stand for?
 - Calcium, Iron, Gold, Silver
 - Cobalt, Iodine, Gadolinium, Silicon
 - Carbon, Iridium, Gadolinium,
 - Copper, Indium, Gallium, Selenium

SPONSOR INFORMATION



MiaSolé is a producer of lightweight, flexible and powerful solar cells. The innovative solar cell is based on the highest efficiency thin film technology available today, and its flexible cell architecture makes it ideal for a wide variety of solutions ranging from commercial roofing solar panels to flexible mobile devices.



This article continues on
<http://go.hw.net/AR216Course2>.

Go online to read the rest of the article and complete the corresponding quiz for credit.

Once this cell structure is deposited on the backing, it is covered first with a layer of transparent conductive oxides. In some cases, it is then covered with a specialized plastic-cell interconnect mesh-wire system. The plastic backing has an internal film that protects the cells from water and other contaminants that may erode the stainless steel CIGS cells. The mesh-wire system is laminated on top of the cell structure and is protected by solar barrier plastics. The transparent solar barrier protects the entire component and makes it both resilient and highly efficient.



Figure 5 Unlike traditional rack mounted solar collectors, flat and flexible solar modules add very little weight to the roof.

GENERAL ADVANTAGES OF FLEXIBLE SOLAR MODULES AND CURRENT APPLICATIONS

Because of their flexible nature, flexible module solar cells can be used in ways that simply are impossible for rigid, rack-mounted solar modules. For example, they can fit around curved surfaces to make better use of the sun as it crosses the sky, and they can easily be integrated into other materials to improve the aesthetics of the building. Their lightweight design, which makes them useful for consumer goods, is also beneficial for built structures since the modules don't add too much additional weight. This is particularly important for older buildings, which would otherwise need to be retrofitted to accommodate heavier, rack-mounted module arrays.

Flexible modules also bond directly to surfaces, which drastically reduces installation costs and also makes them much more resistant to theft when installed in high-traffic areas. Installation is also much safer and less costly than with rack-mounts, which require teams of experts to secure the racks to the roof, and then the modules to the racks.

RECENT ADVANCES AND APPLICATIONS IN FLEXIBLE SOLAR MODULES

The limiting factors with flexible solar modules have traditionally been tied to cost and overall

efficiency. Recent advances, however, have led to much more durable and energy efficient materials that make flexible solar modules an increasingly strong alternative to rigid solar modules. In some cases, innovative designs have enabled flexible solar to be more powerful than their silicon counterparts, with more watts per KG possible from solar films that are a fraction the thickness of polysilicon. The versatility of these newer materials means that they can be used for an even wider range of applications. These modules can be integrated into almost any product imaginable, whether it is onboard a boat or plane, a house or commercial building, a consumer device, or even clothing. The options are increasing every day, and as the materials become more efficient and more widely used, the options for more energy efficient homes and buildings will increase.

THROWING SHADE ON SOLAR

Solar modules perform best when they are situated in fully sunlit locations, however sometimes it's simply not possible to avoid partial shading. Partial shading usually happens when the shadow of a tree, a pole, or some other object near the building is in line with the solar modules, although passing clouds will cause the same effect. The effect is, in short, a drop in the output of the shaded cells within the solar array, which is much like having them be turned on and off. For example, if 25% of the solar module is in temporary shade, the overall module will produce $\geq 25\%$ less power than if it was in full sun. Moreover, this fluctuation can degrade the individual cells, and reduce the overall effectiveness of the modules themselves.

Rigid silicon modules have the most trouble with partial shade because of their fixed nature, but also because of their mono-crystalline composition, which isn't efficient in shade situations. CIGS modules, however, are designed to be more resistant to shading and low light in general. New designs are activated by a low level of light, which means they depend less on direct solar radiation. They are the most light-sensitive solar option on the market today, and research is showing that CIGS can produce more electricity per day in comparison silicon modules partly due to their shade tolerance and their ability to perform well in low light.

From a materials standpoint, the thin layer of copper, indium, gallium, and selenium in CIGS modules can absorb 99% of the available light within the first micron of material. This is converted to energy production for the building. This lightweight, flexible material can also be used in different configurations to avoid shade in the first place, and but when it does encounter shade, it can still generate power at a relatively stable rate.

COMPARISON OF FLEXIBLE CELL AND RIGID RACK-MOUNTED SOLAR MODULES

Flexible cell solar modules have numerous advantages over rigid rack-mounted solar modules. These benefits stem from the physical characteristics of the flexible cells, in particular its lightweight, flexible, and durable nature. These physical attributes aren't the whole picture though; flexible cell solar modules are also powerful, safe, and aesthetically pleasing, and these characteristics make them good choices for architects and builders.

PHYSICAL COMPARISON OF FLEXIBLE CELL AND RACK-MOUNTED SOLAR MODULES

When flexible cell and rack-mounted solar modules are compared side-by-side, the advantages of flexible cells are notable. They are more powerful, with more watts per square foot. Traditional modules are not nearly as powerful, with 60-cell house modules checking in at 260 to 290 watts. Utility sized 72-cell field modules are only 290 to 310 W.

The lightweight and flexible nature of flexible cells means that they can be used in a much wider variety of situations than their rack-mounted counterparts, which require carefully considered roof space that can handle the additional load. Where rigid modules require installation racks and roof reinforcements, flexible cells can be installed without retrofitting a building. From a durability standpoint, flexible cells are designed in a way that makes them incredibly strong and resistant to damage. Unlike rack-mounted modules, they are not at risk of developing microcracks in the cells, and they can't shatter. They also tend to be easier to maintain, since they are generally directly mounted to surfaces, and have fewer parts that require maintenance.

Another advantage of flexible solar modules over rack-mounted panels is that they are very thin and can be integrated into other materials and bonded directly to surfaces. This means that they are resistant to theft, have lower installation costs, and are much more resistant to wind forces than their rack-mounted counterparts. Flexible modules generally range from 2mm to 3mm thickness, and can lie virtually flush against a surface. Rigid solar panels are often 40mm–50mm thick, and require heavy rack-mounts; in high or extreme wind situations, the elevated panels are subject to wind uplift and pull-off. In hurricane situations, for example, rack-mounted panels could detach from the structure and damage the entire solar system, the building, and could injure people. In addition, flexible solar modules are safer because

the cells won't degrade at high voltage, and there are no grounding wires that can corrode. All of these characteristics make flexible solar modules preferable to rigid, rack-mounted panels in environments where high winds are common.

FLEXIBLE SOLAR CELLS— RESILIENCY AND SAFETY

Another benefit of flexible solar modules related to their overall resiliency is that they have a better chance of providing buildings with energy independence in disaster situations. For example, in locations subject to hurricanes, damage to homes and commercial property can be extensive, and buildings are often without power for weeks. Resilient solar modules could help alleviate some of these problems by providing home and business owners with energy independence.

AESTHETICS

Safety and resiliency aside, flexible solar modules are more aesthetically pleasing than rack-mounted modules. Their ability to be installed flush against the rooftop means that they can have a uniform appearance, and the wiring is easily hidden. In addition to being able to be bonded directly to the rooftop surface, they can be applied in areas not accessible to rigid modules, such as curves. Meanwhile, rack-mounted modules tend to look clunky and out of place, as the modules sit atop, rather than immediately next to, the roof. They stand out as an addition, rather than an integrated design element.

ROOF OPTIONS

In urban areas, roofs provide the best placement for solar modules, and so they must be carefully considered before modules are installed. Aside from making sure that the roof itself is physically strong enough to support the additional load of solar modules, as well as any snow load that might accrue during winter, traditional asphalt and shingle roofing can be problematic, since they are susceptible to weathering and may need to be replaced more often than the solar system. One solution is to use metal roofing, which can have a service life of 30 to 50 years, and is highly durable. Metal roofing is also very energy efficient, and can help reduce the heating and cooling loads of the building. It can also be green certified, and it is sustainable in that it can be recycled at their end of life. It also works very well with flexible solar modules.

As has been mentioned before in this course, one of the advantages flexible solar modules have over



Figure 6 Metal roofs are ideal application for flexible peel and stick style solar power modules. Collection units can be custom made to fit between the metal panel seams without interfering with the visual look nor adding substantially in weight.

rack-mounted systems is that they are lightweight and can be bonded directly to surfaces. This is especially useful for buildings with metal roofs, which may not be able to handle the load of the heavier rack-mounted modules. Flexible solar modules can be installed over a wide range of standard metal roof types, whether they are flat, striated, sloped, or corrugated. The range of roof types means that flexible solar modules can be used to power many different structures, from warehouses to parking canopies.

ROOFS CAN BE BROKEN DOWN TO TWO BASIC TYPES—STEEP SLOPE ROOFS AND LOW SLOPE ROOFS.

Steep slope roofs tend to be covered with asphalt shingles, tile or metal roofing. Standard glass solar modules can be installed directly over asphalt and tile shingles with racking or rails attached with specific fastening systems to prevent roof leaks. Flexible PV modules are generally not installed over steep shingle or tile roofs due to the geometry of these roof materials. Architectural standing seam metal roofs with a pan width of 16" -to- 18" are especially suited for flexible thin film solar modules as they fit in-between the metal panel seams and blend in with the metal roof not interfering with the visual aesthetics. Although standard glass solar modules and racking can also be installed over metal roofs, these silicon glass modules may not be visually appealing to many homeowners. In snow country, metal roofs should have snow guards to prevent snow from falling on occupants and standard glass modules and rails will require additional fasteners to resist the weight of snow buildup.

On low slope commercial roofs—both standard crystalline modules with racks and flexible thin film solar modules can be installed. Depending on the roofing system and location the crystalline solar modules and racking systems

are either mechanically attached to the deck or use ballast to keep the solar modules and racking in place. Roof penetrations, which can number in the thousands on large roofs, open up the risk of roof leaks. Ballasted rack systems add anywhere from 4 -to- 10 pounds of weight per square foot to the roof and may not be suitable for seismically active or high wind areas. By contrast, large format flexible thin film modules can be bonded directly to the low slope roof systems. The advantage of flexible thin film modules is low weight, often less than 0.5 pounds per square foot, while offering the same seismic performance of the building and roof design. Flexible thin film modules with their self-adhesive bonding directly to the roof membrane become part of the roof system and will have the same wind uplift design of the roof system. Application and installation of flexible thin film solar modules is relatively quick with the benefit of lower labor cost in comparison to crystalline solar racking systems that have many parts and pieces.

WARRANTIES

Finally, most manufacturers of flexible solar modules offer 25-year warranties on the power output and guarantee installation for five years. While rack-mounted solar modules may have similar warranties on the modules, the mounts are more susceptible to wear and tear from the elements, and may be the limiting factor for warranties.

CONCLUSION AND ASSESSMENT

In conclusion, this course explores the increasing benefits of solar energy in residential and light commercial properties and highlights the advantages of flexible solar modules over rack-mounted module arrays. Building professionals can benefit greatly from encouraging clients to consider integrating flexible solar modules into both new and retrofitted projects in that they can help create considerably more energy-efficient buildings, all while immediately increasing the property values. ■

RESOURCES

<http://energy.gov/eere/energybasics/articles/photovoltaic-cell-basics>

<https://www.quora.com/How-durable-are-solar-panels-Is-hail-and-wind-damage-going-to-be-a-major-concern>

<http://www.endlessunsolar.com/pages/why-cigs>

<http://miasole.com>