Racked, Integrated or Direct Attached
Three Options for Rooftop Solar Mounting Systems

A White Paper

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By Spice Solar, Inc.

Spice solar™

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Acknowledgments and Disclosure
This White Paper was written by Spice Solar, Inc.

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1. Executive Summary

Over 400,000 homes in the U.S. have rooftop solar arrays. By 2016 the number of rooftop arrays is likely to exceed one million, or roughly 5 gigawatts (GW) of solar capacity. And by 2024 – just ten years from now – rooftop solar arrays are likely to be more common than satellite dishes. All of these arrays will require rooftop mounting systems.

There is probably no more expensive and inconvenient place to work than a steeply sloped residential rooftop. Unfortunately, that is where the sun is -- and that is where modules, racking, roof mounts, module electronics, wiring and grounding must be assembled and installed. As a result, mounting system parts and installation represents over 10% of the cost of a residential installation. Of the 4.93/watt[1] installed cost of a rooftop system in the U.S., mounting components for these systems cost $0.30/watt[2], and installation labor (including direct labor and preparation work) costs $0.24/watt[3]. Finding ways to reduce module installation costs represents a substantial cost reduction opportunity for the solar industry.

Instead of getting easier and cheaper, parts and labor costs for rooftop mounting systems are likely to get more expensive. Starting on January 1st, 2015, the UL 1703 Standard for Safety for Flat-Plate Photovoltaic Modules goes into effect, requiring solar modules and mounting systems to be tested *together* for rooftop fire resistance. The UL 2703 Standard for Solar Module Mounting Systems is also going into effect in 2015, requiring mounting systems and modules to be tested *together* for grounding effectiveness and mechanical strength. Although safety will be improved, these two new standards require changes or re-testing for virtually all existing mounting systems used for residential rooftops. Because of these system tests, modules, racks and roof mounts can no longer be easily mixed and matched among manufacturers

This White Paper characterizes three common methods used to install solar modules on rooftops: Ordinary Racking, Integrated Racking, and Direct Attachment. Advantages and disadvantages of each mounting system are summarized below:

- **Ordinary Racking** is applicable to all roof types. However, ordinary racking is expensive, primarily because of the amount of aluminum in the racking. The large number of individual parts and fasteners required on the roof -- as well as the need to transport, cut and splice long sections of aluminum racking -- means that installation labor costs are also high with these systems.
- **Integrated Racking** offers low parts and labor costs. However, special module frames must be used by the module manufacturer, limiting the number of companies that offer modules with integrated racking.

[1] Wiser, et al. "Tracking the Sun VI," LBNL, August 2013
[2] Racking and accessory costs per job via regional distributor, including tax and freight costs
[3] Morris, et al. "Reducing Solar PV Soft Costs," Rocky Mountain Institute, December 2013

- **Direct Attachment Racking** is an alternative for composition shingle rooftops (not suitable for tile, metal, tilt-up or flat roofs). These systems are designed to work with most standard solar modules. However, there is concern about roof leaks because some systems require multiple screws through composition shingles into the underlying roof decking. Since there are no long racking components to install, labor costs of direct attachment racking have the potential to be lower than ordinary racking.

Innovations in solar mounting systems continue at a rapid pace. In fact, at recent national solar conferences there have been more mounting system companies exhibiting than module companies. These mounting system companies are all striving to reduce total installed system costs in one of two ways (sometimes both): by reducing the cost for parts, and by reducing the installation labor. Systems that are able to achieve both lower parts costs and lower labor costs are likely to be most popular with rooftop installers.

From an efficiency standpoint, the biggest cost savings opportunity relates to pre-assembling as many components as possible at the time the module is manufactured, or minimizing the number of parts and fasteners that must be installed on rooftops. Indeed, a recent study found that “integrated racking” with pre-assembled mounting components has the potential to save $0.40/watt in total costs[4].

Unfortunately, most module manufacturers focus on cost reductions within the module itself, and do not consider the “big picture” as it relates to reducing total installed costs with integrated racking. Indeed, the statement: “Our goal is to reduce the cost of our modules; making enhancements to our module frame for easier installation is not our problem -- it is up to the installer” was a common refrain from module companies. Fortunately, this reluctance on the part of manufacturers is eroding as module companies strive to differentiate their products, gain market share in a very dynamic module business, and capture additional downstream mounting system margins.

2. Types of Rooftop Mounting Systems

Solar modules installed on residential rooftops have historically been attached using an underlying mounting system composed of long sections of aluminum racking. In 2007 Andalay was introduced, which was the first integrated racking solar module mounting system. In addition, over the past dozen years various direct attachment mounting systems have been offered for composition shingle roofs. Each of these mounting systems is described in more detail below.

This overview focuses on mounting systems designed for ordinary framed solar modules -- by far the most common design for residential rooftops. Solar tiles, unframed modules, direct applied flexible solar materials, and trackers are not covered in this overview. It is important to note that, regardless of the type of mounting system, care

[4] Morris, et al. “Reducing Solar PV Soft Costs,” Rocky Mountain Institute, December 2013

must be taken to properly flash and/or seal all roof penetrations to ensure a durable, maintenance-free installation[5].

2.1 Ordinary Racking

As shown in the figure below, ordinary racking systems consist of a series of parallel extruded aluminum racking sections (also referred to as rails) that provide the underlying rigid planar surface to which the solar modules are attached. Racks are attached to roof mounts at rafter locations; attachment to rafters is required to resist the substantial upward (pull out) forces caused by wind lift. In this example, 12 flashed roof mounts are required to securely attach the racking to the roof surface. Once the racks are installed and leveled, the solar modules are each attached to the racks with four clips installed at the edges of the modules (clips are shared between adjacent modules). As the modules are being installed and aligned, module electronics (if applicable) are attached to the racking or back of modules, wiring between modules is connected, and grounding conductors (sometimes integrated with the racking) are attached.

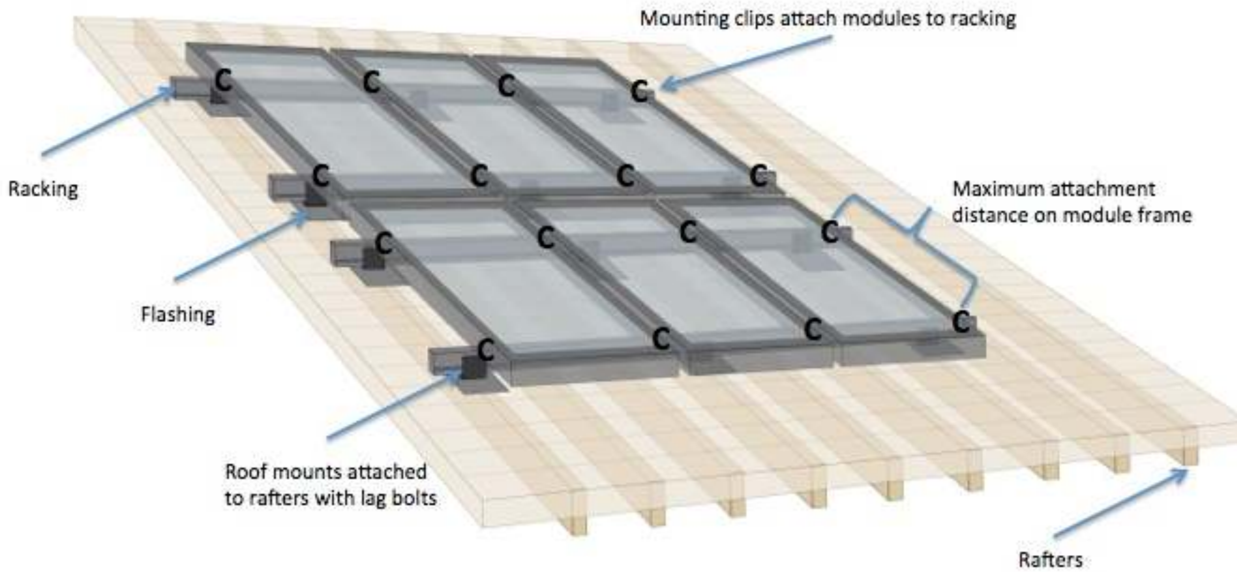

Figure 2-1 Ordinary Racking

Ordinary racking is compatible with virtually all framed modules and roof types including composition shingle, flat and barrel tile roofs, standing seam metal roofs, flat roofs (tilt up arrays) and corrugated metal roofs. Generally, the only variation among roof types is that different roof mounts are used depending on the roof type – the racking, clips, wiring and grounding remain the same. Nevertheless, new UL 1703 and 2703 standards may necessitate that modules, racking and roof mounts be tested *together* to meet new

[5] "The Importance of Reliable Solar Mounting Systems – A White Paper," March 2014. http://cinnamonsolar.com/resources-2/

fire safety and grounding requirements; in other words, modules, racks and roof mounts can no longer be easily mixed and matched among manufacturers. Companies providing ordinary racking solutions include IronRidge, Haticon, Orion, ProSolar, Schletter, UniRac and others.

2.2 Integrated Racking

In order to reduce the equipment and labor costs related to ordinary racking, systems were developed that incorporate the racking in the frames of the solar modules themselves. A diagram of an integrated racking system is shown in the figure below. These module frames are designed so that, when connected together, the frames provide the necessary rigidity to resist the expected wind and snow loads on the array. Modules are connected together with splices or interconnects, and the exterior frames of the modules have grooves to which the roof mounts are attached. In this example, nine flashed roof mounts are required to securely attach the modules to the roof surface. Since the modules are rigidly interconnected, two adjacent rows can share roof mounts. Grooves along the frames of the module allow the interconnected modules to be attached to rafters at any point along the module frame.

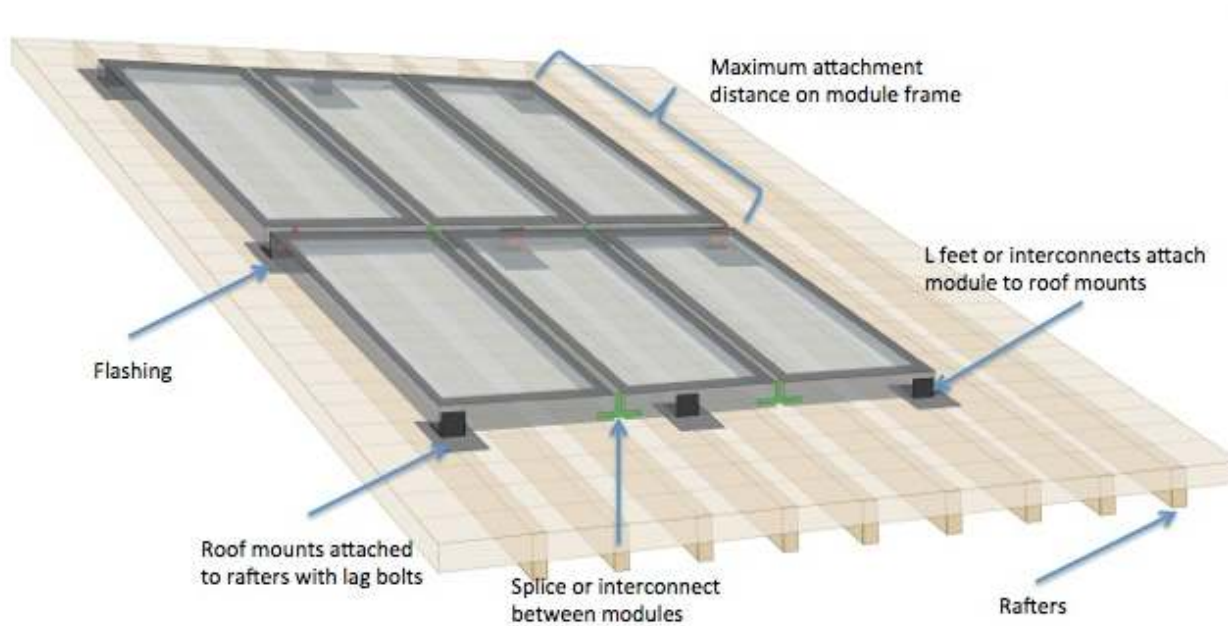

Figure 2-2 Integrated Racking

These integrated racking systems are generally compatible with all roof types, although specialized roof mounts may be required. However, the frames of the modules are different than ordinary modules – requiring additional work on behalf of module manufacturers and limiting the selection of modules to installers. Companies providing these integrated racking solutions include Andalay Solar, Spice Solar and Zep Solar/SolarCity.

2.3 Direct Attachment

In order to eliminate the cost of the aluminum racking and to find a way to simplify the installation of standard modules, a number of direct attachment systems have been developed over the years. These direct attachment systems typically use clips that are integrated with roof mounts (which are shared by adjacent modules) in such a way that each module is directly attached to the roof in four places. As shown in the figure below, because the dimensions of a row of modules never matches the variable locations of the rafters, these direct attachment systems generally mount directly through the shingle surface to the underlying wood sheathing. Direct attachment systems have also been developed that use a cantilevered roof mount or offset module clamp assembly so that the roof mounts can be attached to rafters, and the module clamps can be attached to the sides or corners of modules. With these direct attachment designs, the location of the module clamps does not have to align vertically with the location of rafters. In this example, 16 flashed roof mounts are required to securely attach the modules through the composition shingle roof surface to the underlying roof sheathing.

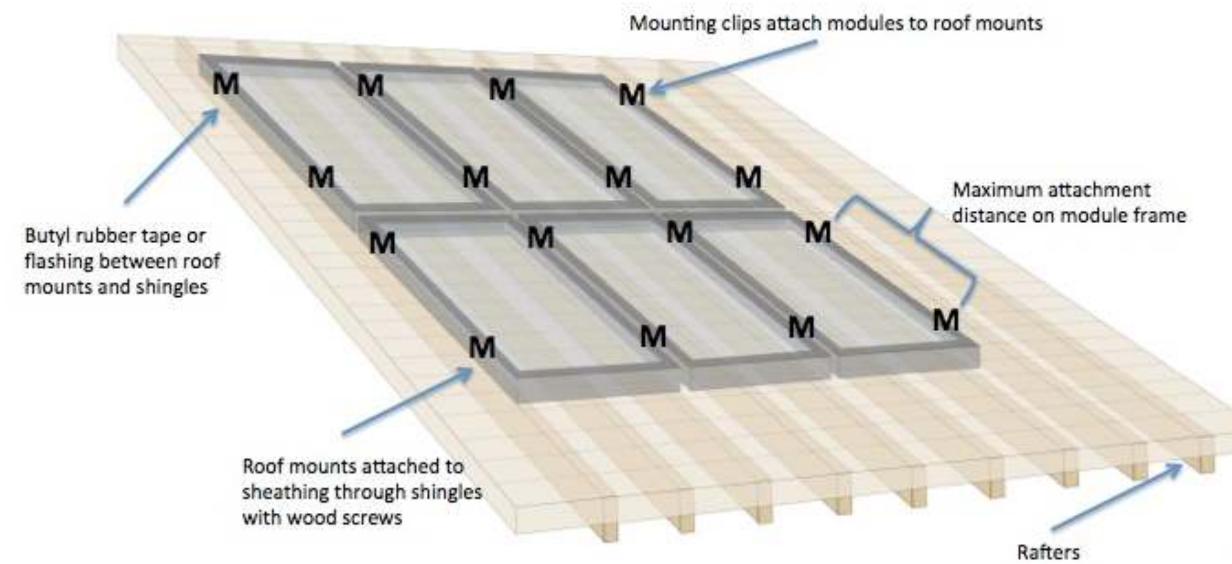

Figure 2-3 Direct Attachment

Direct attachment systems currently on the market are generally designed for composition shingle roofing materials. To accommodate uneven roof surfaces (many composition rooftops are not level), some direct attachment systems have height adjustments.

Direct attachment systems generally do not work with tile, metal or flat roofs because the location of the roof mounts is determined by the intersection between modules, and it may not be possible to attach a roof mount to the edge or peak of a tile at exactly that point. BP Solar Integra and SunPower Smart Mount were the first direct attachment systems to be offered; however, these systems are no longer available. In response to the industry's efforts to reduce mounting system costs, a number of new direct attachment systems have been released or announced, including DynoRaxx Evolution, Enable Energy Avanza, QuickRack, Roof Tech E Mount, Solar Clamp-P, SpiderRax Red Widow and Zilla Phantom.

3. Key Design Considerations

The following table summarizes the key design considerations for each general type of rooftop mounting system. Appendix A provides more detail on each of these design considerations.

Feature	Ordinary Racking	Integrated Racking	Direct Attachment
Module compatibility	All modules	Modules require special frames	Most modules
Snow and wind load limits	High loads	High loads for thick frame versions Low loads for thin frame versions	High loads for mid-frame attachment Low loads for end-frame attachment
Orientation	Portrait, landscape, mixed	Andalay – portrait Spice – portrait, landscape, mixed Zep – landscape	Landscape
Module electronics	Yes	Yes	Yes
Wire and trunk cable management	Good	Good	Good
Maintenance	Good	Spice – Good Andalay, Zep –remove all adjacent modules	Depends on design of mounts/clamps
Grounding	Weebs or Clips, may require separate module listings	Integrated	Weebs or Clips, may require separate module listings
UL 2703 compliance	May need to test module-racking combination	Good – tested as integrated system	May need to test module-racking combinations
UL 1703 fire code compliance	Array skirt may be required	Good – modules can be attached close to roof	Good – modules can be attached close to roof
Adjustable mount height	Yes – adjustable L feet	Yes – adjustable L feet or screw	Some mounts have fixed heights, some are adjustable
Roof types	All	Andalay, Spice – All types Zep – requires rails for tile	Generally composition shingle
Tilt up arrays	Yes	Andalay, Spice – Yes Zep - No	No
Roof mounts for 20 modules	36	Andalay, Spice – 27 Zep - 35	44
Roof penetrations for 20 modules	36 lags	Andalay, Spice – 27 lags Zep – 35 lags	176 – 264 sheathing screws or 44 lags
Special tools	Racking cutoff saw	Andalay, Zep – special wrenches Spice – None needed	None needed
Long term durability	Good	Good	Concern about leaks around sheathing screws

4. Engineering and Code Requirements

Most modules offered for sale in the U.S. have been tested and certified to meet load requirements of 2,400 Pascals (Pa) upforce (50.1 pounds per square foot, or 867 pounds on a 60 cell module) and 5,400 Pa downforce (113 pounds per square foot, or 1956 pounds on a 60 cell module). Upforce indicates the module's ability to resist the lift that occurs as high winds pass over modules. Downforce indicates the module's ability to resist heavy snow loads combined with wind loads. To put these forces in perspective, a 100 mph wind can create uplift forces of 30 pounds per square foot, or over 500 pounds of uplift force on a standard 60-cell module. 36" of heavy snow can weight 60 pounds per square foot – the snow weight plus additional wind loads can generate over 1,800 pounds of downforce on a standard 60-cell module.

Installation manuals for modules specify exactly how the module must be installed, including the maximum allowable attachment distances on frames. Installation manuals for racking systems in conjunction with Technical Engineering Reports (TERs) specify the type and location of attachment points that are necessary under the expected wind, snow, tilt angle, location on the roof, and environmental conditions at the site.

Modules can fail when the wind or snow forces on the module cause the frame to flex to such a degree that the tempered glass of the module cracks, and is pulled out of the module frame. These frame-flexing failures occur under high loads when the modules are mounted on the racking or roof at distances that exceed the maximum frame attachment distance for the particular roof conditions.

The figure below shows a top view and side view indicating how the frame of a module flexes under high load conditions. When this flexing or bowing exceeds one or two inches at the center of the long frame section, the glass in the module often pulls out from the tape or adhesive holding the glass to the frame. Many standard modules with ordinary racking (racking shown with dotted lines) can support a load of up to 5400 Pa. Some integrated racking modules can also support a load of up to 5400 Pa; note, however, because the module is attached at the corners the frame of this module *must* be thicker to prevent excessive flexing under these high load conditions. A standard module with direct attachment racking should also be able to support 5400 Pa when attached at the midpoints of the frame (as shown with ordinary racking on the far left); however, this module may only support 2400 Pa or less when attached at the corners of the module (as shown on the far right).

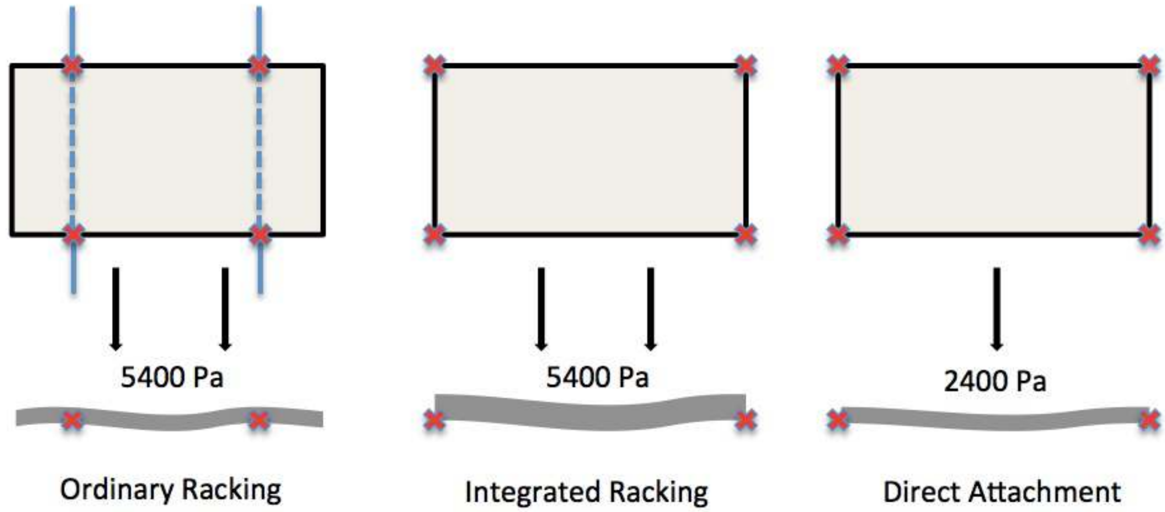

Figure 4-1 Module Flexing Under High Loads

Manufacturers design their module frames to support the maxiumum anticipated loads while using the least amount of aluminum -- which usually means thinner frame profiles. The industry trend towards thinner frames also means that more modules can be packaged in a crate, reducing containerized shipping costs. Some modules with relatively thin frames employ an additional aluminum crosspiece to minimize frame flexing under high loads, or use specially strengthened tempered glass.

Mounting systems fail when the wind or snow forces on the system exceeds the design rating of the roof mounts or racking as installed. Failure usually occurs when the roof mounts pull out, the racking clips pull out, racking fasteners shear or pull out, or the racking itself bends. It is exceedingly rare for properly installed modules and racking to fail.

Failures on rooftops more often occur when modules and racking are installed improperly. One failure mechanism occurs when the roof mounts pull out from the roof under high wind conditions. These failures are generally a result from either the installation of insufficient roof mounts, or from moisture degrading the strength of the lag bolts or screws holding the fasteners in place. Another failure mechanism occurs when the clips securing the module frame are faulty or not properly fastened.

Installers must be careful to follow both the module installation manual and the racking installation manual to ensure that the system is properly installed. Indeed, this combined module-racking system approach is one of the key reasons for the new UL 2703 standards (see Appendix B).

5. Total Cost Summary

Almost all rooftop solar installers strive to install high quality equipment in a safe and reliable way, while at the same time minimizing costs. These two conflicting goals –

good and cheap – are continuing to drive innovation in solar equipment and installation technology. The previous sections described factors that relate to high quality installations; this section considers the costs of different equipment types and installation methods.

The following table summarizes the parts and installation costs incurred by an installer for a 20 module system (5,000 watts using 250 watt modules), assuming the equipment is purchased and shipped from a regional solar distributor, sales tax of 6%, average fully-burdened installer labor costs of $50/hr[6], and current mounting component costs[7].

	Ordinary Racking	Direct Attachment	Integrated Racking
Parts Cost to Installer			
Racking and clips	$797.83		
Splices/Interconnects			$612.00
Roof mounts	$83.16	$880.00	$94.50
Flashings	$504.00	$440.00	$378.00
Grounding hardware	$46.88	$4.01	$4.50
Module premium			$104.00
Freight	$125.00	$50.00	$50.00
Sales tax	$85.91	$79.44	$65.34
Total parts	$1,642.78	$1,453.45	$1,308.34
Total parts per watt	$0.32	$0.28	$0.25
Installation time per module	1.25	1.00	0.75
Total installation labor	$1,250.00	$1,000.00	$750.00
Total installation labor per watt	$0.24	$0.19	$0.14
Total Cost	$2,892.78	$2,453.45	$2,058.34
Total Cost per watt	**$0.56**	**$0.47**	**$0.40**

Figure 5-1 Parts and Installation Costs

Small installers are particularly sensitive to low upfront parts costs because their labor costs are generally counted in units of a full day; saving a small amount of time on a job means that crews still need to be paid for a full day. If it usually takes a crew 3 days to install a system[8], and a new mounting system enables them to save 25% of the time on

[6] Morris, et al. "Reducing Solar PV Soft Costs," Rocky Mountain Institute, December 2013 – labor costs are the U.S. average of $40/hr roofer costs and $60/hr electrician costs

[7] Ordinary Racking: black rails and module clamps, L feet, black flashings, module grounding clips and array skirt for fire code compliance; Integrated Racking: black frame modules and fasteners, L feet, black flashings, integrated grounding, additional module costs for strengthened frame; Direct Attachment: black mounts and module clamps, black flashings, integrated grounding.

[8] Morris, et al. "Reducing Solar PV Soft Costs," Rocky Mountain Institute, December 2013 – most residential installations in the U.S. take three days to complete.

a job (2.25 days total), the crew still may spend 3 days on the job. Therefore, it is not certain that small installers will save a meaningful amount of money with incrementally faster installation technology.

For this reason, small installers place a greater premium on low-cost equipment (they know they will save money on parts) rather than labor-saving mounting components (for which the labor savings are not guaranteed). On the other hand, large installers with multiple, specialized crews may indeed be able to squeeze in another job if installation work is 25% faster – hence they place a greater value on reduced installation time.

The analysis above considers two relatively easy-to-measure cost components: upfront equipment costs and on-the-job labor costs. The third, very significant "soft cost" component -- indirect labor overhead – is difficult to measure. These overhead costs include sales design work, engineering, purchasing, warehousing, logistics, back end IT systems and kitting. Simple, standardized mounting systems that work on all roof types – even if sold at a premium price – can very well be more cost-effective if these standardized systems reduce overhead costs.

6. Conclusion

Many large-scale solar installers have found that simplifying their installation process with a standardized – albeit expensive – mounting system leads to greater operational efficiency and cost savings. By designing installation processes that limit the variety of components installed on a job, soft costs can be minimized. Moreover, by using equipment and components that are easily assembled using as few parts as possible, rooftop labor is reduced. For these reasons, installers limit their suppliers -- purchasing modules, inverters and racking from only one or two sources.

The solar industry's cost reduction goals have spurred the development of new mounting systems, particularly integrated racking systems and direct attachment systems. Because these new systems generally do not use racking, they reduce the costs associated with extra aluminum, as well as transporting and cutting racking. Moreover, many of these new systems utilize clever designs that minimize the number of parts and fasteners, reducing direct and indirect labor costs.

To date there is no "magical" roof mounting system that is good, fast and cheap. Efforts to develop simple mounting systems that easily attach to different types of sloped residential rooftops run into the realities of snow and wind loads, roof leaks and local building codes. Nevertheless, two design approaches have the potential to substantially reduce overall costs compared to ordinary racking.

Direct attachment systems save money on composition shingle rooftops because there is no aluminum racking. Although there may be more individual roof mounts, these roof mounts can be installed more quickly since there is no need to locate and attach to rafters. In addition, these direct attachment systems are designed to work with a wide range of module designs. The primary downside of sheathing mounted direct attachments is that some installers are concerned about roof leaks since there are more roof penetrations, and the butyl rubber sealant used with these roof mounts may not last for the lifespan of the modules and shingles. Direct attachment systems using cantilevered roof mounts and flashed rafter lags are more leakproof, but are more expensive and time consuming to install because there are more complicated parts.

In terms of overall installation costs, integrated racking systems offer the best cost saving opportunity[9]. These integrated racking system minimize costs by eliminating the need for aluminum racking, as well as almost all of the individual attachment and grounding components associated with ordinary systems. Integrated racking systems are also appropriate for all roof types, so installers do not have to inventory ordinary racking when they install on tile, metal or tilt-up roofs. As more module manufacturers realize that they can capture additional downstream mounting system margins -- and more installers realize they can reduce both their parts costs and labor costs -- integrated racking systems are likely to become more commonplace.

[9] Morris, et al. “Reducing Solar PV Soft Costs,” Rocky Mountain Institute, December 2013 – “…next gen integrative racking can save $0.40/watt but has a high degree of implementation difficulty…”

7. Appendix A – Key Mounting System Design Considerations

- Module compatibility – Virtually all modules are compatible with ordinary racking; in fact, modules are attached to racking systems as part of the testing and certification process. There is a more limited choice of manufacturers that offer integrated racking modules since these modules require different frames and certification.
- Snow and wind load limits – In general, modules that are attached to ordinary racking can withstand higher load limits. Integrated racking modules, since they are attached at the farthest edges, require extra-strong module frames to withstand high load limits, or installation in landscape orientation to minimize the stress on frames. If direct attachment modules are attached to the roof in the same locations as with ordinary racking, then the modules can support higher load limits; if direct attachment modules are attached at the farthest edges of the frame, then load limits may be relatively low.
- Orientation – The majority of rooftop systems are installed using portrait orientation for modules; this orientation minimizes wire lengths and racking. With ordinary racking, modules can be installed in either portrait or landscape orientations. Integrated racking modules from Andalay are optimized for portrait orientation (because of the frame design), modules from Spice can be installed in both portrait and landscape orientations, and modules from Zep are optimized for landscape orientation (because of frame load limits in portrait orientation). Direct attachment systems are usually installed in landscape orientation to stay within the module's maximum loading capabilities.
- Module electronics – Microinverters and DC optimizers were originally designed to be directly attached to the grooves in ordinary racking; there is usually enough space under the combined height of the racking and module for these components. With ordinary racking the installation and wiring of module electronics components must be done on the roof as the racking is assembled. For integrated racking modules, specialized brackets are available so that these components can be mounted directly underneath the module – usually on the ground or off-site (reducing rooftop labor). Since direct attachment systems are generally designed to work with a wide range of modules (each with its own frame design), specialized brackets may be required for each different module type.
- Wire and trunk cable management – Wires and cables must be securely attached so they do not rest on the roof and abrade. Clips or zip ties are customary to secure DC wires and AC cables to ordinary racking systems. Integrated racking modules have specially designed clips that fit in the grooves of the modules to securely attach wires. Since direct attachment systems are generally designed to work with a wide range of modules (each with its own frame design), specialized wire management clips may be required for different module types.
- Maintenance – Modules and module electronics very occasionally need maintenance, in which case modules need to be removed for servicing. Removing modules from ordinary racking is relatively simple: four clips are

loosened and the module can be removed. Andalay and Zep integrated racking use a design in which all adjacent modules are connected together and the fasteners must be removed from the side, meaning that a module cannot be removed from the middle of an array. Spice Solar integrated racking modules have side connections that can be disengaged from the top, allowing a module in the middle of a row to be removed. Most direct attachment systems allow a module to be removed from the middle of a row by removing module clips.

- Grounding – All major racking components and modules must be grounded. With ordinary racking, modules are either independently grounded with a separate grounding conductor, or modules are grounded to the racking with grounding washers (also called weebs) or grounding clips; the racking itself is used as the grounding conductor for the array. Some jurisdictions require compatibility tests among the combinations of racking systems, modules and grounding washers. Integrated racking modules use the connections between modules as the grounding conductor. Direct attachment modules use a separate grounding conductor to each module, grounding washers or clips/special fasteners. As with ordinary racking systems, some jurisdictions require compatibility tests among the combinations of direct attachment systems, modules and grounding washers.
- UL 2703 compliance – This new standard applies to the combination of modules and mounting systems, and particularly focuses on loading and grounding integrity. There is a large number of module and mounting system combinations; therefore, for ordinary racking and direct attachment systems, not all combinations will be acceptable to all jurisdictions. Integrated racking system designs have been tested to comply with applicable standards.
- UL 1703 fire code compliance – This new standard requires the solar module and the racking to which they are attached to have the same fire rating. In areas with fire danger, Class A roofs are required – hence both the modules and the racking must be rated Class A as a system. Ordinary racking may require a skirt or low profile (close to the roof) design. Integrated racking modules, since they are usually attached close to the roof, are generally compliant. Direct attachment systems are likely to require a skirt or low profile to be compliant.
- Adjustable mount height – Many roofs do not have a level surface. Variations in shingle thicknesses and sagging rafters require arrays to be adjusted vertically so that all the modules are in a single plane. Roof mounts that have adjustability are therefore an important requirement for an aesthetically appealing array.
- Roof types – Rooftop solar systems are installed on a wide variety of roof types in the U.S. Although composition shingle roofs are the most common in northern climates, tile roofs and metal roofs are more common in southern climates.
- Tilt up arrays – To maximize use of available roof space and system performance, some installations utilize tilt up arrays. For example, if there is limited south roof space, a north-facing roof can be used by tilting up the array so the modules face south. Tilt up arrays are also commonly used on flat roofs.
- Number of roof mounts for 20 modules (two rows of ten modules) – Purchasing and installing roof mounts is a significant variable cost for every installation. The number of roof mounts for a typical 20 module system is estimated, assuming standard 60 cell modules, rafter spacing of 24”, and 48” maximum roof spans.

- Number of roof penetrations for 20 modules (two rows of ten modules) – Every penetration in a roof is a potential source of water leakage. The number of roof penetrations, whether lag screws (one per roof mount for ordinary and integrated systems) or wood screws (four to six screws into the roof sheathing for most direct attachment systems), is estimated for a typical 20 module system.
- Special tools – Installers typically have the standard tools required for an ordinary rooftop installation. Systems that require special tools are an inconvenience and added expense.
- Long term durability – Responsible installers are concerned about the long-term durability of the systems they install. Historically, the biggest durability issue has been roof leaks. Minimizing the number of roof penetrations (especially in areas where water can pool), understanding the type (plywood or oriented strand board-OSB) and thickness of roof sheathing, and using roof flashings dramatically reduces the possibility of roof leaks.

8. Appendix B – Applicable UL Standards

8.1 UL 1703 – Solar Modules

As per UL: “These requirements cover flat-plate photovoltaic modules and modules intended for installation on or integral with buildings, or to be freestanding (that is, not attached to buildings), in accordance with the National Electrical Code, NFPA 70, and Model Building Codes. These requirements cover modules and modules intended for use in systems with a maximum system voltage of 1000 V or less (residential systems are not allowed to exceed 600 V per NEC requirements). These requirements also cover components intended to provide electrical connection to mounting facilities for flat-plate photovoltaic modules and modules.”

In other words, UL 1703 tests for module strength, grounding effectiveness within the module and as connected to a grounding conductor, and the module’s ability to resist damage from corrosion, humidity and temperature. The module is tested according to the manufacturer’s installation manual, generally fastened to a rack at a certain height from the roof with attachment points at defined locations along the frame of the module.

8.2 UL 2703 – Solar Module Mounting Systems

As per UL: “These requirements cover rack mounting systems, mounting grounding/bonding components, and clamping/retention devices for specific (manufacturer/model designation) flat-plate photovoltaic modules and modules that comply with the Standard for Flat-Plate Photovoltaic Modules and Modules intended for installation on or integral with buildings, or to be freestanding (i.e., not attached to buildings), in accordance with the National Electrical Code, ANSI/NFPA 70 and Model Building Codes. These requirements cover rack mounting systems and clamping devices intended for use with photovoltaic module systems with a maximum system voltage of 600 V. These requirements cover rack mounting systems and clamping, retention devices pertaining to ground/bonding paths, mechanical strength, and suitability of materials only. Revisions and improvements to this standard have been in progress since 2013. These revisions are nearing completion and UL 2703 is anticipated to become an American National Standards Institute (ANSI) accredited standard sometime in 2014.”

In other words, UL 2703 is intended to test the module and mounting system together as a system, particularly related to module-racking strength, clamping mechanisms, grounding and resistance to environmental conditions. UL 2703 is not yet recognized as an ANSI standard, although we expect that sometime in 2015, all jurisdictions will eventually require compliance with these standards

8.3 Fire Class Ratings

New UL 1703 fire class ratings go into effect on January 1, 2015, and are particularly relevant to the solar industry. Roofs are classified by their degree of fire resistance, Class A, Class B or Class C. Homes in fire-prone areas generally require Class A fire resistant roofs. The new UL fire class ratings require that the combined module-racking system have a fire rating that is the same or greater than the required rating for the roof.

So areas in the U.S. that require Class A roofs will require module-racking systems that meet Class A fire ratings.

There is some urgency with regards to these new standards, because all rooftop systems installed after January 1, 2015 must meet these requirements. Class A fire requirements are common, as are composition shingle rooftops. Modules must be defined by “Type” and then must be fire tested. All mounting systems must be tested with modules of a certain Type to determine if the module-racking combination meets the Class A fire ratings.

Testing every single module-racking combination is impractical. Instead, modules are categorized into a certain Type (1, 2, 3, etc.); these types refer to the module’s general framing, glass and backsheet composition. Modules are then tested in a fire chamber on a roof mockup, installed on a mounting system as specified by the manufacturer. To meet the Class A requirements, the spread of flame between the roof and module must be less than 6 feet over a ten minute period during which an ignition source is placed at the leading edge of the modules and on the top surface of the modules. Mounting systems must also be tested in a fire chamber to confirm that modules of a certain Type (1, 2, 3, etc.) meet the desired fire class requirements when used with that racking design.

There are two general mounting system approaches to meet these Class A fire requirements with ordinary framed modules. One approach is to mount the modules closer to the roof, in the range of 2-3”; this proximity to the composition shingle roof surface reduces the chimney effect under the module, thereby reducing the spread of flame. Closer mounting of the modules is easily accomplished with integrated racking and direct attachment systems (modules can be attached without a racking structure underneath). However, ordinary racking – which is typically 2-3” thick – creates a large air gap under the module. To achieve compliance, some manufacturers of ordinary racking are designing a fairing or skirt that is installed at the front edge of the module.

