Tile Roof Applications
Roofing Systems and Array Mounting Approaches
By Jeff Spies and Johan Alfsen
INSTALLING PV arrays on tile roofs is more time consuming, complicated and expensive than installing on asphalt shingle roofs. Yet, despite the added difficulty, tile-roof solar installations are growing dramatically in active solar markets like those of Hawaii, California and Arizona. High utility rates, robust incentive programs, a plentiful solar resource and rapidly dropping module prices have helped make solar on tile roofs a reality. Aiding this growing market, new PV array mounting systems for tile roofs and improved techniques are making installation faster, easier, more reliable and less expensive.

In this article, we examine the most common tile roof systems that installers are likely to encounter and address three array mounting and weatherproofing approaches developed specifically for tile roof applications. But first, a word of caution: Tile roof construction varies widely throughout the US, and some configurations make installing an array difficult or impossible without reroofing or using advanced mounting techniques. Be aware that solar installers cannot easily tackle applications like fully adhered tiles (hello, Florida and Hawaii), elevated underlayments, skip sheathing and other atypical tile configurations. In these situations, you would be wise to subcontract a capable roofing contractor to ensure reliable waterproof penetrations and the structural integrity of the array and affected portions of the roofing system.

Replacing Tile Roof Underlayment

Tile roofs installed by a skilled roofing contractor can last many decades because tile dissipates heat better than asphalt shingle roofs. In addition, this heat-dissipating capacity lowers air conditioning bills, which is why tile roofs have become the norm in the southwestern US over the last three decades.

While the tiles themselves can typically last 50–75 years, homeowners are often surprised to learn their roof underlayment may need replacing in as little as 15 years. This has major implications for PV installers. Most underlayments used on tile roofs are made from asphalt-impregnated felt paper. Unfortunately, felt paper decomposes at an undesirable rate when exposed to excessive heat, UV and moisture.

Replacing the tile roof underlayment beneath an installed PV array is a major undertaking, as it requires the removal of the PV modules, racking, wiring, mounts, roofing tiles and battens. The cost of removing and reinstalling a PV array on a tile roof typically ranges from $0.75 a watt to $1.25 a watt, plus the cost of any necessary roofing repair work. This equates to a whopping 20%–40% of the cost of a new PV system. Since the average tile roof needs to have the felt underlayment replaced every 15–25 years, homeowners should be strongly encouraged to replace the underlayment and battens beneath the array prior to the installation of a new PV system. The use of a high-quality underlayment ensures that the roofing system will last the 25-year life of the array.

Underlayment condition

Be sure to inspect the tile roof system’s underlayment prior to installing the array. Curling felt paper is an indication that the underlayment requires replacement.

Types of Roofing Tiles

Roofing tiles come in a dizzying array of materials, sizes, shapes and colors. Clay tiles are less common than concrete tiles, but many high-end homeowners opt for clay tiles to achieve that traditional old-world look. While clay tile roofs can be very attractive, they are usually more expensive to install. One-piece clay tiles are very strong, unlike the classic sand-cast Mediterranean-type two-piece tiles. Sand-cast clay tiles are brittle and crack when walked on. Array installations on roofs that use cast two-piece tiles are best approached with the strip-and-go method we describe later in this article. Concrete tiles are more common in residential roofing. A skilled roofer or solar installer can walk on them with minimal breakage.

Since breaking tiles is a reality, installers address this challenge by repairing dog-ear breaks with tile adhesive and relocating the repaired tiles in less visible areas under the array or elsewhere on the roof. Larger breaks require replacing the tile.
Finding replacement tiles is not too difficult, but an exact color match is unlikely. Installers often remove original tiles from less visible areas of the roofing, replace them with off-color tiles, and use the original tiles in the visible areas around the array. If the color needs to be consistent over the whole roof, painting an off-color tile to match the other tiles might be the only option. 

Roof tiles can be either flat or curved. Installing a PV array on flat, or low-profile, tiles tends to be a bit simpler than installations on curved tiles since the tile flashing used to seal roof penetrations does not need to be molded to the tile. However, unless the roof system has a vented eave riser, a flat-tile roof is not as well ventilated as a curved-tile roof. There are two types of curved tile: high-profile S tiles and medium-profile W tiles, also called villa tiles. Curved-tile roofs often require more time for array installation, especially if you use conventional stand-offs and double flashing to secure the array to the roof structure.

Underlayment Options

Wind-driven rain routinely gets up under the tiles, so the underlayment is where the waterproofing of a tile roof actually happens. A roof’s tiles contribute to the waterproofing system, but their more important function is protecting the underlayment from damage caused by UV exposure and heat.

Most tile roofs employ a single or double layer of 30-pound or 40-pound felt underlayment. Unfortunately, common roofing felt materials degrade quickly when exposed to high heat or moisture. The good news is that newer developments in tile-roofing construction methods, improved underlayment materials, drainage-friendly battens and weather-blocking products can extend underlayment life to 50 years or more. These systems are well matched to the operational life of PV arrays and take array removal and reinstallation out of the customers’ ROI equation.

Underlayment selection is critical for homeowners to ensure that the roof lasts as long as the array. When co-author Jeff Spies recently had the underlayment replaced on his 16-year-old home, the poor condition of the felt material surprised him. The roofer advised replacing the 30-pound felt underlayment with a 90-pound mineralized rolled roofing material with a granulated surface. This is the same material used to make conventional asphalt shingles and is an approved roofing system by itself. It is commonly found underneath sand-cast two-piece tile roofs in the classic mortar-jointed Mediterranean style.

Many roofers also recommend synthetic or plastic underlayment. These sophisticated materials can last for 30–50 years and do not break down when exposed to extended periods of moisture. Synthetic underlayments offer additional benefits over felt, including less weight on the roof, higher fire resistance, and the ability to bend and twist around corners and crevices without tearing, which commonly occurs with felt underlayment.

Battens, Weather Blocking and Eave Risers

Tile roofs with a high-quality underlayment can maintain their weatherproofing integrity over the operational life of a PV array. Several additional roofing system components are also important to consider prior to a solar installation.

**Battens.** Allowing water to drain quickly from behind the battens is critical to extending underlayment life. Conventionally installed 1x2-inch wood battens act like a water dam. When wind-driven rain gets under the tile, it flows down the underlayment and hits the uphill side of the wood batten, where dirt accumulates. This dirt tends to hold moisture, and over time this moisture-capture area degrades the underlayment and the wood battens. Flow-through or drainage-friendly battens allow water to drain through or under the battens, down the roof and over the edge to promote rapid drying. Drainage-friendly designs include elevated battens with plastic discs that raise the wood batten off the underlayment and Boral Roofing’s Tru-Flow battens with wide drainage channels.

**Weather blocking.** Another beneficial upgrade for tile roofs is installing weather blocking that prevents rain from entering spaces between the tiles on a roof’s hips and ridges. Until fairly recently, felt underlayment often fulfilled this function. Regrettably, felt is a poor weather...
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When exposed to UV radiation, it deteriorates after 10–15 years, allowing rainwater to reach the hip and ridge beams and the roof sheathing in the impacted area.

**Eave risers.** Eave risers support the front edge of the tile at the eave to raise it to the same angle as the other tiles. Vented “bird-stop” eave risers allow air to circulate under the leading edge of the tile to cool the roof as well as prevent birds from nesting, both of which can shorten underlayment life. In past decades, many tile roofs used eave risers made from a wood board nailed to the fascia to prop up the leading edge of the first row of tiles. Roofers commonly used a piece of foam as a spacer to fill the gap, with the underlayment covering the foam spacer. Unfortunately, this approach results in a reduced slope angle near the eave, which slows water drainage and negatively impacts underlayment longevity.

Newer vented bird-stop eave risers can increase airflow and reduce temperatures between the tile and the underlayment. Installing additional attic ventilation, such as powered fan vents, ridge vents, O’Hagin vents and so on, can further reduce attic temperatures, extending underlayment life and lowering electricity bills.

**Array Mounting Options**

Once you have determined a tile roof’s materials, installation details and remaining lifespan, you have the information you need to specify the optimal array attachment and waterproofing products and installation methods. Three mounting options are available for tile roof applications: standoffs and double flashing, tile hooks, and the strip-and-go method.

### STANDOFFS AND DOUBLE FLASHING

Standoffs, which typically consist of an aluminum base and extruded post, combined with a double-flashing system, are the most commonly used code-compliant form of mounting and waterproofing array attachments on a tile roof.

Standoff mounts can be installed on almost any style of tile roof, including batten or battenless and curved- or flat-tile profiles. Standoffs attached to rafters typically stand about 4–6 inches from the decking on a flat-tile roof and approximately 6–8 inches on higher-profile curved-tile roofs. Standoff mounting allows for the use of virtually any racking system. Common L-foot mounted systems often provide lateral and vertical adjustability, and the L-foot’s slotted mounting holes simplify array installation.


### PV Array Tile Mounting Methods

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<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
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| Standoffs and double flashing | Traditional roofing method  
Higher load capacity  
Works with all tile heights | More labor intensive, especially on curved tile  
More expensive than tile hook |
| Tile hooks              | Attractive with no visible flashing  
Faster installation time  
Lower cost  
Fewer parts | Many hooks lack underlayment flashing  
Many hooks have lower load capacity  
May not work with all tile heights |
| Strip and go            | New shingle roof under array lasts life of array  
Uses less-expensive and easier-to-install mounts  
Perimeter tile gives array an aesthetically pleasing low-profile appearance  
Leftover tiles available for future roof repairs | More labor intensive at time of install  
Requires subcontracting to roofer |

**Weather blocking** A tile roof’s ridges and hips are prone to water intrusion. Weather blocking minimizes underlayment degradation caused by exposure to UV and moisture.
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Standoffs and double-flashing systems may require more installation labor and tile cutting but are often stronger than tile-hook mounting systems. Cutting a small hole in the tile can be challenging, but with the right tools, you can complete the process with little effort. Most tile roofers use diamond blades on angle grinders for this task.

While tile hooks have deflection limitations, a standoff base-and-post mount provides greater strength because it is secured to the rafter and attached directly to the racking system. The standoff must pass through the surface of the tile and requires flashing at the penetration for proper waterproofing. In the past, roofers used malleable lead for the top tile flashing. Due to environmental concerns and the high cost of lead, today most installers use dead soft aluminum flashing. Though dead soft aluminum flashings are not quite as malleable as lead, they work on all tile roofs. Aluminum is nontoxic and recyclable, can be anodized for resistance to salt air corrosion and holds up to the elements for decades.

The installer must seal standoffs at the underlayment level using an approved metal flashing bibbed with underlayment or sealed using the three-course method described in SolarPro’s “Tile Roofing Systems” article (December/January 2011).

Tile hooks Manufacturers including Schletter (left) offer a variety of tile hooks that are compatible with various tile profiles. Quick Mount PV (right) offers a tile hook product with flashing, which in this example is sealed using the three-course method.

TILE HOOKS

The use of tile hooks for array attachment has grown over the last few years. One major advantage is the lack of visible flashing, which makes for a more attractive array. Another benefit is faster, easier and less expensive installation using fewer parts, compared to the more conventional standoffs and double-flashing method.

When determining whether a roof is suitable for tile hooks, you need to know how high the tile is spaced off the underlayment. Tile hooks are often designed for a specific tile height and installation configuration, like common S tile or flat tile installed on standard 1x2-inch battens. They may not work with battenless tile installations or with elevated battens, as the tiles’ height off the underlayment might be too short or tall for the hook.

Some tile hooks offer vertical height adjustment using a two-part bolted hook with a vertical adjustment mechanism, but be aware that these adjustable-height hooks might not be as strong as single-piece hooks. Also, tile hooks tend to have lower pullout values compared with standoffs, so you must verify that the specific hooks have the required pullout and compression strength to secure the array properly for 25-plus years. We recommend reviewing third-party engineering test data to validate that a tile hook’s load capacities meet your local permitting requirements for pullout and shear loading.

When installed properly, the tile hook passes between two tiles and does not penetrate the tile surface. When using tile hooks, you have to remove part of the weather-guard lug from the bottom of the top tile. You can do this with a tuck-pointing diamond blade on an electric grinder.

One of the benefits of using tile hooks is the elimination...
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of tile-level flashing. However, many installers fail to install the base flashing mandated by the IBC, the IRC, tile roofing manufacturers and the TRI. The TRI guidelines require installation of flashing at the underlayment or base level on all tile roof penetrations. Flashing at the base level protects the hooks’ fasteners from rainwater running down the underlayment.

**STRIP AND GO**

In the third array mounting method for tile roof applications, referred to as *strip and go*, a roofing contractor removes tiles from the array installation area and replaces them with composition shingles. The installer surrounds the array with the original tiles to make the installation look as though it is on a tile roof, even though it is installed on a composition asphalt shingle roof. The strip-and-go method is desirable when working on traditional clay tile roofs (cap-and-barrel or Spanish tile), and is also popular on battenless tile roofs. Some types of clay tile break easily when you walk on them, and the strip-and-go method circumvents this issue.

Once you have removed the tiles in the array field, you can install composition shingle mounts. Composition shingle roofing acts as an underlayment and provides a lower-profile installation that tends to look more like BIPV, yet still promotes airflow under the array. In strip-and-go systems, the two mounting options are standoffs with flashing installed on the underlayment before shingle installation, or all-in-one flashed mounts installed after the shingles are in place. Typically, roofers install step flashings where the composition roofing meets the tile roofing.

A reputable roofing contractor who understands the overall scope of the array installation process and the planned PV attachment and flashing systems should complete the strip-and-go method. If you are not a licensed roofing contractor, you should establish a close working relationship with a competent and trustworthy roofer.

**Industry Perspectives and Best Practices**

For input and suggested best practices, we reached out to five integrators who have significant experience installing arrays on tile roofs. The methods and products they use vary considerably.

**What are the biggest challenges to installing PV arrays on tile roofs?**

- Tile roofs add labor cost and time. It is a large job to remove tile and install deck flashing to preserve the integrity of the underlayment. Three-coursing the base flashing with roofing cement is messy. Removing tile dust is challenging, and many flashing installations require the removal of battens. Care must be exercised to seal the batten nail holes properly. Tile-level flashing often requires tile cutting with a grinder, which is messy and time consuming. Often the cutting required for each standoff is a custom project, especially for mounts located on or near a tile seam, or those near roofing hips or valleys. Broken tiles are another problem with tile roof installations. Some tiles are as weak as cornflakes and break very easily, and fixing broken tiles or finding replacements can take time and be expensive. We would love to see better tools and equipment to help minimize tile breakage when installing a solar array. We often find the best way to reduce tile breakage is to remove tiles in walkway areas.

  —Joe Messner, chief operations officer, Sun Valley Solar Solutions, Chandler, Arizona

- Educating clients on their tile roofing system is the biggest challenge, because they are typically more interested in the PV system purchase than in the roof. The easy part is the investigation of the roofing system and the determination of the type of tile roofing used, along with its remaining serviceable life. We find it a challenge to communicate to the clients exactly what trimester or quarter of the system’s serviceable life their roof is currently in. Once the clients’ expectations on the remaining serviceable life of the roofing system are set, any required or recommended repairs or maintenance can be tackled, up to and including a full tile removal and reinstallation.

  —Will Herndon, executive VP of construction, American Solar Electric, Scottsdale, Arizona

- One of the challenges is getting access to surplus tile prior to the PV installation, since it is a given that there will be some...
roof tile breakage during the installation. The roof tile industry has undergone a tremendous amount of consolidation in the last 15 years, and most of the roof tile mold designs and colors have changed.

—Tony Diaz, roof and solar consultant, Century Roof & Solar, Hayward, California

Working with tile roofing presents a number of challenges to the installer. Lightweight or brittle tile can be difficult to walk on and work with, and you never truly know the latent condition of the roofing felt until you tear into the roof. Proper installation practices and material selection are essential to expedite permit processing, to maintain existing roof warranties, to pass AHJ inspections and to deliver a product that we can confidently stand behind. We must know we have done everything we can to avoid any future water intrusion issues for our customer.

—Keith Randhahn, operations manager, Baker Electric Solar, San Diego, California

Everyone who has installed on tile roofs knows that the biggest installation challenge is getting around on them without breaking more tiles than necessary. Another big challenge is waterproofing the mounting penetrations at the underlayment level. We use mounting technologies that ensure the flashing of the underlayment penetration will last for decades and through wide temperature differentials.

—Heath Galloway, installation practices manager, Sungevity, Oakland, California

What is the typical cost range to remove and reinstall (R&R) an array in your service area?

Typically, 50 cents per watt is the lowest starting price for simple installations that involve a single-story roof, asphalt

Tile mounting systems  To maximize a customer’s ROI, the service life of a tile roofing system should match that of the array. New products and improved installation techniques are making tile roof installations faster, more reliable and less expensive.
shingles and a rectangular array. However, tile roofs are more involved, especially if there is a lot of conduit replacement or junction box work. Each system has different considerations, but tile roof R&R often costs 75 cents to $1 per watt or more.

—Joe Messner, Sun Valley Solar Solutions

We are still analyzing these costs, but right now we are charging clients about $100 per module for R&R with the understanding that we will reuse most of the original parts for the reinstallation. We also make it clear that we will bill any major rewiring or substantial unforeseen work in addition. It is difficult to price replacement of the underlayment in dollars per watt as the process has so many variables, such as the power density of the array, the cost per watt of the PV system in any particular area, and how much of the perimeter tile one chooses to remove and replace. In Phoenix the going rate is approximately $2.50 per square foot.

—Will Herndon, American Solar Electric

It varies depending on the ability to use the original racking. Assuming that we would need to replace the mounting and we would reuse the racking, we could be up to $2 per watt. On a 3 kW system, the untimely need to remove and reinstall an array due to roof mounting blunders surely wreaks havoc on the financial payback promised by the original installer.

—Tony Diaz, Century Roof & Solar

The R&R cost depends on the system size, the racking used and other site conditions, but we can usually remove and reinstall an average size system in just under 2 days for about $2,500.

—Keith Randhahn, Baker Electric Solar

I have received bids ranging from 75 cents to $1.50 per watt, depending on the exact scope of work.

—Heath Galloway, Sungevity

Should the typical home have the tile underlayment replaced prior to a PV installation? How many years can a tile roof underlayment remain in service before it is too old for a PV retrofit?

That’s a really good question. If it was up to me, we would strip every tile roof of the tile in the array field, and we would have a roofer install new underlayment and asphalt shingles. We would then install asphalt shingle mounts for the racking system. While a new shingle roof adds some initial cost, the

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mounts are much easier and less expensive to install, and the homeowner gets a new roof that will easily last the life of the array. After assembling the array on the racking system, we install the roofing tiles around the perimeter of the array, leaving plenty of replacement tiles for future repairs. Unfortunately, most homeowners do not want to pay for this upgrade, even if it does provide a better long-term cost of ownership. We install most tile roof mounts on the existing tile roof. Therefore, the site assessor must have a trained eye to inspect the integrity of the existing roof. An inexpensive 30-pound felt does not last as long as a 90-pound rolled roof underlayment. When we look at the underlayment, visible cracking and curling is always a red flag that indicates the underlayment needs replacing. We have a licensed roofer on our staff who helps determine the best course of action for the roof preparation prior to solar installations if there are complicated roofing issues.

—Joe Messner, Sun Valley Solar Solutions

This is a great question and one that has taken many years of experience to settle into. Rather than basing a solution on how many years of service the roofing system has already provided, we base the solution on our estimation of the remaining years of serviceable life that the roofing system can deliver for the client. Our threshold on this has been that if a roofing report comes back with a serviceable life of less than 5 years, we don’t proceed with a PV installation on top of the roofing system without performing a tile R&R under a separate roofing contract. A tile R&R, of course, is a whole new roofing system that includes a new underlayment.

—Will Herndon, American Solar Electric

In new construction situations, the underlayment often sits in the sun and weather for 6 months or longer waiting for construction to be completed. A felt underlayment is not designed for full sun and weather exposure, and it may lose up to 60% of its service life by the time the tile is installed. So a 5-year-old tile roof with an underlayment life expectancy of 30 years may have considerably fewer years of waterproofing ability in these situations. I recommend having a roofing contractor assess the condition and life expectancy on any tile roof and the underlayment prior to installing solar.

—Tony Diaz, Century Roof & Solar

It depends. Our rule of thumb is that the underlayment should be replaced if it doesn’t have at least 10 years of useful
life left. We’ve seen roofs that are only 5–10 years old where inferior products or installation practices were used and the underlayment already needs replacing. We’ve seen others that are over 30 years old and appear to be in great condition. Our position is to err on the side of caution and recommend at least considering underlayment replacement if there is any doubt or concern, or if the roof is nearing the last 10 years of its expected useful life. In most cases a qualified roofer is happy to provide a professional second opinion at no cost.
—Keith Randhahn, Baker Electric Solar

What tile roof mounting methods do you prefer and why?

We follow the TRI guidelines using a primary flashing at the tile level and a secondary flashing at the base [underlayment] level. We recently started using flashed tile hooks to reduce mounting labor costs and improve aesthetics. The integrated base flashing helps us remain TRI compliant.
—Joe Messner, Sun Valley Solar Solutions

Right now we prefer a traditional stanchion mount with a two-flashing system that includes a base flashing three-coursed at the deck level and a layover flashing at the tile level. This is primarily due to the evolution of residential rooftop PV and keeping in sync with traditional roofing techniques. We are getting excited about some of the new products hitting the market and the willingness of the roofing industry to explore and accept new arguments regarding differentiation between a PV stanchion attachment and, for example, a vent stack roof penetration. We are running some jobs through with these new products, so we will see where things land over the course of the next year or so.
—Will Herndon, American Solar Electric

I prefer tile hooks for tile attachment because the waterproofing for the hook and tile is a sleeved system between the rows of tile, reducing the possibilities of water getting under the tile at the penetration points.
—Tony Diaz, Century Roof & Solar

We perceive electrical hazards and water intrusion concerns to be the two greatest risks associated with any PV installation. While most homeowners understand the electrical concerns and ask detailed questions about the safety and operation of a PV system, many still do not recognize the potential threat of water intrusion. We prefer Quick Mount PV’s QBase Universal Tile Mount. This engineered system is designed, tested and proven to provide a solution that is quick, easy and completely code compliant with properly flashed roof penetrations. Water intrusion is no longer a concern with properly installed and flashed roof penetrations.
—Keith Randhahn, Baker Electric Solar

As a result of the variability of curved- and flat-tile composition, styles and quality, you should always use primary and secondary flashing techniques. If a mounting solution doesn’t have flashing at the underlayment level, the potential for AHJ compliance decreases and the probability of future leaks increases. Also, minimizing the need to cut tiles is preferred to avoid creating a messy and hazardous job site, as well as to mitigate as much silica dust disturbance as possible. Therefore, using a tile hook that requires only a small notch out of the front horizontal portion of the tile works best for us in most cases. Tile roofing products come in many different shapes and get installed in many different ways. Hence, having either one product that is very versatile or a diverse range of mounting solutions from the same vendor, which minimizes installation variability and racking incompatibility, is the preferred strategy to approach the wide range of tile roofs.
—Heath Galloway, Sungevity

Summary
Since the cost of removing and reinstalling a PV array is significant, installers should advise their customers with tile roofs on the benefits of reroofing under the array before installation. In the past, the majority of tile-roof PV arrays were installed on roofs with underlayments that were likely to need replacing within 5–15 years. The resulting wave of solar roof repairs will create a rapidly growing business opportunity for PV installers who are also licensed roofing contractors or are closely partnered with a roofing contractor. Solar and roofing contractors who understand this roofing reality will be well positioned to take advantage of this up-and-coming opportunity.

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