



Evaluation of Installation Time for SMASHmount by SMASHsolar

SMASHsolar has developed an interlocking mounting system integrated with frameless photovoltaic (PV) modules. Among other claimed benefits the intent of the design is to reduce the required installation labor time and skill level. The SMASHmount system is designed to be expandable and faster to install than traditional racking systems. The product is designed for use on residential composite shingle roofs.

The SMASHsolar team believes that a significant reduction in installation time will reduce soft costs, increase crew production, and help to increase the adoption rate of PV systems. The interlocking mounting components are also intended to give homeowners the ability to expand their systems, over time, in a cost-effective and aesthetically pleasing fashion.

The U.S. Department of Energy's SunShot Incubator program provides early-stage assistance to help start-up companies cross technological barriers to commercialization while encouraging private-sector investment. The SunShot Incubator program aims to shorten the time it takes for a young business or company to develop an innovative product concept and make it commercially available, which includes product prototyping, deployment, and, potentially, manufacturing. SMASHsolar was selected as an Incubator awardee to develop a

simple, snap-together, module-integrated PV mounting system in an attempt to dramatically reduce the time, effort, and skill needed to install rooftop solar.

In support of this award, the National Renewable Energy Laboratory (NREL) worked with SMASHsolar to develop a procedure for evaluating the installation time required for the SMASHmount system compared to widely available rail systems. In this evaluation, care was taken to eliminate tasks that would be identical regardless of racking solution, such as time associated with travel, loading, and unloading or establishing roof harnesses.

SUMMARY

Among several installations, NREL found that the SMASHsolar SMASHmount system was installed between 15%–37% faster than tested competing systems after one or two installations of the system. The first crew was unfamiliar with both tested systems and installed SMASHmount 37% faster after one installation of the system compared to the tested rail system. The second crew was an expert in the tested rail system and unfamiliar with the SMASHmount system and the micro-rail system. This second crew installed SMASHmount 15% faster on the first installation and 31% faster on the second installation compared to the tested rail system and 26% faster after

one installation compared to the tested micro-rail system.

The benchmark set in the NREL study on "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016"¹ on soft cost reference indicates an estimated "module installation" time of 18 minutes per module (0.3 hours per module) and "racking installation" time of 30 minutes per module (0.5 hours per module). For a comparable 12-module system as tested here, a total of 9.6 labor hours (576 labor minutes) was estimated. For the SMASHmount system, a total of 2.15–4.9 labor hours (129–294 labor minutes) were observed. Note that the observed times for competing systems installed as part of this report ranged from a total of 2.9–7.25 labor hours (174–435 labor minutes), indicating that the benchmark report may be higher than actual practice or that different starting and ending points are being considered.

Test Conditions

NREL staff traveled to Richmond, California, to witness several installations of a 12-panel solar array consisting of 2 rows of 6 panels arranged in portrait orientation on a 3:12 pitched residential asphalt shingle roof constructed in a warehouse with the lowest edge of the

¹ <http://www.nrel.gov/docs/fy16osti/66532.pdf>.

Installation Crew 1

2 experienced non-profit solar installer with 1 additional day-labor-level supporter. Familiar with rail systems, but had never installed either Ironridge or SMASH.

Installation Crew 2

3 experienced for-profit residential solar installers, intimately familiar with the Ironridge rail system and with some prior knowledge of SMASH, but no experience with installations.

| | Ironridge | SMASH | SMASH | Ironridge | Unirac Microrail | SMASH 2nd Installation |
|--|--|---|-----------------------|---|---|------------------------|
| Training Time (minutes) | 30 | 35 | 31 | 0 | 30 | 20 |
| Practice Time (minutes) | 60 | 75 | 90 | 0 | 120 | 90 |
| Racking & Module Installation Time (minutes) | 145 | 91 (98 original, -7 adj) | 53 | 62.5 (55 original, +7.5 adj) | 58 | 43 |
| Notes on installation: | 2 lag bolts were not fully contained within rafters. | Due to prescribed initial starting location, one column of SMASH feet had to be turned to avoid rafters. 7 minutes removed from total time. | Installed as expected | Installation layout not provided. 1 lag bolt fully missed rafter and was corrected. 2 lag bolts were not fully contained. | Some concern with wire management, module clamps, and alignment with edge of roof. 4x3 array. | Installed as expected. |
| Installation Hours: | 2.42 | 1.52 | 0.88 | 1.04 | 0.97 | 0.72 |
| Total Installation Person-hours: | 7.25 | 4.55 | 2.65 | 3.125 | 2.9 | 2.15 |
| Modules per person hour: | 1.66 | 2.64 | 4.53 | 3.84 | 4.14 | 5.58 |

Crew 1's first installation of SMASHmount 37% faster than the first installation of Ironridge
 Crew 2's first installation of SMASHmount was 15% faster than the first installation of Ironridge
 Crew 2's second installation of SMASHmount was 31% faster than the first installation of Unirac Microrail
 Crew 2's second installation of SMASHmount was 26% faster than the first installation of Ironridge

roof located approximately 3 feet off the warehouse floor. To simulate working on a typical elevated roof, all installers were asked to wear harnesses and remain clipped in at all times while located on the test roof, despite being only a few feet off the ground. When transferring from the warehouse floor to the roof, installers were asked to utilize a ladder located to the side of the roof rather than moving directly from the warehouse floor to the roof. During the installation time trial, materials required for each installation that were located on the floor adjacent to the roof were passed to the installers located on the roof. It is recognized that for all installations, separate equipment and solutions would be required to move the panels from the ground to the residential rooftop in the field; the time associated with this is not included in this time trial. Note also that the dual-glass solar panels used as part of the SMASHmount solution are significantly heavier than a more typical framed module and may require unique considerations for transfer to the

roof. Each installation team was provided with approximately 30 minutes of on-site training for each system, as required; and they were provided 60–90 minutes, as desired, to practice system installation.

Figure 1 shows a visual representation of the primary components of the SMASHmount system.

Timing Evaluation Scope

Working under a stated objective “to measure the speed of installation of baseline systems compared to the speed of installation for the SMASHmount system,” two independent solar installation crews each consisting of three individuals worked to install 12-module systems. The second installation team was present on two separate days, installing the SMASHmount system twice, the Ironridge system once, and a Unirac Microrail system once. Because each crew is unique and each installation has unique conditions, the installations are described below

for context and clarity; however, each followed the same general procedures.

Prior to the timed installation, the following prerequisites were met:

- All PV modules, mounting systems, and tools were staged near the base of the roof.
- Fall protection anchors were installed on the roof, and all workers utilized harnesses.
- Installation manuals were available for each system being installed.
- Approximately 30 minutes of hands-on training by SMASHsolar employees was provided to installers.
- Approximately 90 minutes of hands-on practice time installing the SMASHmount system, including the option to ask questions of the SMASHsolar employees, was provided prior to each installation.

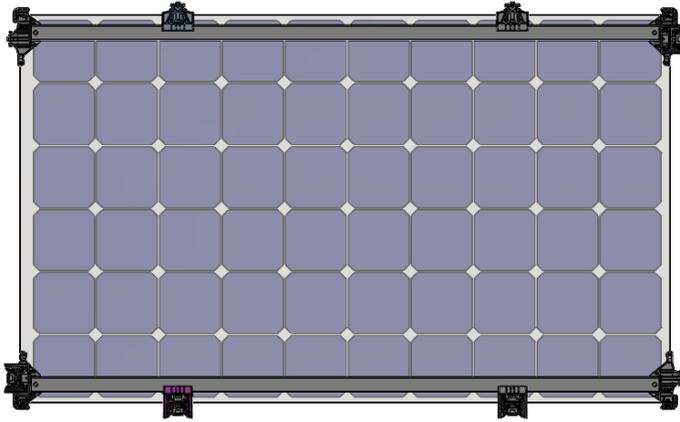


Figure 1. SMASHmount solar PV module

During each installation, each crew was asked to follow these guidelines:

- Two workers should primarily work on the roof, with only occasional support from the third worker.
- One worker should primarily work on the ground, preparing modules and passing equipment or tools as necessary.
- All roof workers should remain clipped in at all times when on the roof.
- During the practice installation time, the crew could ask questions and receive support from SMASHsolar staff.
- During the measured installation, the crew could not ask for or receive support.

Quality control evaluation:

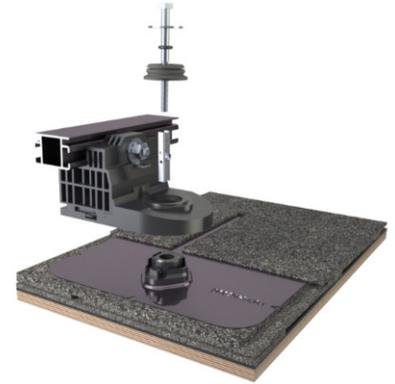
- All modules are adequately secured.
- All PV wires are secured away from the roof.
- Ground wire is installed, as required, and terminated at a junction box.
- All lag bolts or roof toggle bolts are properly installed.

First Installation Crew

The first installation crew comprised two experienced solar installers who primarily

worked for nonprofit solar installation companies and had not previously worked together. They were assisted by one additional worker who had minimal prior solar installation experience; this worker was primarily a laborer to support the two installers by passing equipment, tools, or assisting with other minor activities. Both installers had worked extensively with rail-based solar systems, but they had not previously used the Ironridge product. As a result, the SMASHsolar staff provided approximately 20 minutes of hands-on training on the system, and the crew used approximately 60 minutes for practice and discussion. Following their typical procedures, the installation crew focused on first installing the necessary rails and then placing the 12 solar panels, oriented in 2 rows of 6 with portrait orientation. The measured time stopped when all panels were secure but prior to an individual returning to complete short wire runs between panels. After witnessing other installations, 25 minutes was added to the total installation time to allow for the completion of the wire runs and proper wire management. The total installation time for the Ironridge system was 145 minutes, or 36 person-minutes per panel.

The crew then removed the first system and received approximately 30 minutes of hands-on training on the SMASHsolar system, followed by 75 minutes of



SMASH C-Foot (Composition)



SMASH Snap-Lock

Figure 2. SMASHmount mounting components

practice and discussion. The crew then proceeded to install the SMASHmount system, including wires, and fully finished in 98 minutes. Note that the SMASHmount system is designed such that the feet connecting the system to the roof are secured through roof decking, not in rafters, and as such they must be installed precisely to avoid conflict. In this installation, the third column of feet ended up aligning with the rafters; consequently, the installation team had to reverse the direction of the SMASHsolar feet in accordance with the provided instruction manual. This took approximately 7 minutes, time that would have been avoided if the start location had been properly identified. This error was caused by unclear instruction by NREL and SMASHsolar to the crew regarding their starting point on the roof.



Figure 3. First installation crew working on the SMASHmount system



Figure 4. First installation crew working on the Ironridge system

Without adjusting for the complication associated with the feet and including the adjustment for the short wire runs for the Ironridge system, the first installation crew installed the SMASHmount system approximately 31% faster than the rail system (or 37% faster excluding the foot adjustment), at a production rate of 2.64 modules per person hour for the SMASHmount system.

Second Installation Crew

The second installation crew consisted of three experienced solar installers, including one experienced crew leader who directed the activities of the other two individuals. Each had extensive experience working together and extensive experience working with the Ironridge rail racking system.

This crew was present at the test site for 2 days, and as such the crew was able to complete two SMASHmount installations as well as one Ironridge installation and one Unirac Microrail system. The installation crew had no previous experience using the Microrail system and no prior experience installing the SMASHsolar product though they did have some prior knowledge of the system. In accordance with the procedures, SMASHsolar staff provided approximately 30 minutes of training for each new system prior to each installation, and the crew utilized between 90–120 minutes to practice

installations and become familiar with the equipment prior to the start of the time trial.

The crew installed the SMASHsolar system first, completing the entire installation in 53 minutes. Note that this is significantly faster than the first installation crew; this represents their improved team communication, familiarity with each other's work practices, and defined roles and responsibilities. This is also relevant when evaluating future installation procedures. Upon completion, the installation was inspected for wire management and roof anchoring in accordance with the quality metric evaluation, and the installation was found to fully meet requirements.

The second installation was an Ironridge rail system with which the installation crew was extremely familiar and experienced. Installation was completed in 55 minutes; however, after completion quality inspection checks identified one lag bolt that completely missed the roof rafter and two that were not properly installed along the centerline of the rafter and were visible. Although it is recognized that it is unlikely that an inspector would catch this improper installation, to ensure a fair evaluation the crew was asked to remove and reinstall the lag bolt. The time required to remove one panel, withdraw, and reinstall one lag bolt was measured as 2.5 minutes;

consequently, 7.5 minutes were added to the initial installation time of 55 minutes to compensate for this improper installation. Including this compensation, the SMASHmount system was installed 15% faster than the Ironridge system, with a production rate of 4.53 modules per person hour for the SMASHmount system.

As mentioned above, the installation crew returned for a second trial day and were asked to complete a second SMASHsolar installation. Prior to this second installation, the SMASHsolar staff provided approximately 30 additional minutes of training and allowed the crew to practice for approximately 90 minutes prior to the measured time trial. The second installation completed by this crew was completed in 43 minutes, representing a 19% improvement over their first installation and the final time is approximately 31% faster than the experienced Ironridge installation. This resulted in a production rate of 5.58 modules per person hour for the SMASHmount system.

Finally, the second installation crew was asked to install a Unirac Microrail system. The crew had no experience with the Unirac Microrail system, and consequently they received approximately 30 minutes of training and completed 2 hours of practice time prior to the timed installation. The timed installation took 58 minutes. The final system inspection



Figure 5. Second installation crew working on the SMASHmount system



Figure 6. Second installation crew working on the Ironridge system

identified some module wiring that was looser than would likely be accepted by code officials and one loose module. Because these issues would likely not occur following repeated installations and familiarity, the installation time was not adjusted to accommodate these issues. The time required for this first installation of the Unirac Microrail system was approximately equal to this installation crew's first installation of the SMASHmount system and experienced installation of the Ironridge system.

Installer Feedback

Although not explicitly the purpose of this evaluation, both installation crews provided their thoughts on the SMASHmount system and their experience with installation, generally summarized as follows:

- The SMASHmount system has fewer total parts and pieces, simplifying preparation.
- The ability to locate panels in portrait or landscape position is an important benefit of the competing systems.
- The use of rails allows for easier access and correction should wire management be an issue during inspection.

- The first installation crew had some concerns regarding the potential complications from their strategy to place flashing as they went and the potential transference of tar to solar components. This can likely be resolved through an adjustment to processes.
- Both crews commented on the experienced of alignment with the roof edge, with the SMASHmount system varying by less than 1/8-in. along the length of the 6-panel system compared to up to 1/2-in. for other systems installed.
- The weight of the dual-glass panels was somewhat challenging. Systems for getting the panels to the roof should be evaluated and understood.
- The test roof was very well built, with no waviness. The crews expressed some concern about how the SMASHmount system would work on an imperfect roof.

Conclusion

The intent of this report is to witness and summarize the installation time required for multiple solar panel racking solutions. It is not intended to fully evaluate many other relevant properties critical to the

overall evaluation of a mounting solution, including but not limited to price, availability, structural properties, design flexibility, or final installation quality. Similarly, it is impossible to compare this installation time to measured industry standards for installation labor without fully understanding the breakdown of travel time, stocking time, setup time, inspection requirements, complete electrical installation, and other elements. For the purpose of this report, we attempted to compare only the aspects of an installation that would be different between the SMASHsolar system and other racking or mounting solutions.

Within these constraints, the SMASHsolar system installation time ranged from 15%–37% faster, depending on whether it was the first or second SMASHmount system and the system to which it was compared. To further validate this claim, the authors of this report recommend an additional evaluation of installation time required on actual residential roofs compared to a statistically significant number of installations.