Edmund G. Brown, Jr.
*Governor*

# SCHOTT BUILDING INTEGRATED PHOTOVOLTAIC MOUNTING APPROACHES FOR NEW CONSTRUCTION

PIER FINAL PROJECT REPORT

*Prepared For:*
**California Energy Commission**
Public Interest Energy Research Program

*Prepared By:*
RWE Schott Solar Inc.

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***Prepared By:***
RWE Schott Solar, Inc.
Miles C. Russell
Sillerica, Massachusetts 01821
Commission Contract No. 500-00-034

***Prepared For:***
Public Interest Energy Research (PIER) Program
**California Energy Commission**

Hassan Mohammed
***Contract Manager***

Linda Spiegel
***Office Manager***
***Energy Generation Research***

Laurie ten Hope
***Deputy Director***
***ENERGY RESEARCH AND DEVELOPMENT DIVISION***

Robert P. Oglesby
***Executive Director***

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# Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

*Schott Building-Integrated Photovoltaics Mounting Approaches for New Construction* is the final report for the SMUD ReGen project (Contract Number 500-00-034), conducted by RWE Schott Solar Inc. The information from this report contributes to PIER's Renewable Energy Technologies program.

For more information on the PIER Program, please visit the Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

# Table of Contents

Abstract ..... ix
Preface ..... iii
Executive Summary ..... 1
Introduction ..... 1
Objective ..... 1
Project Outcomes ..... 1
Conclusions ..... 2
Recommendations ..... 3
Benefits to California ..... 3
1.0 Introduction ..... 5
1.1 Background and Overview ..... 5
1.2 Project Scope and Objectives ..... 6
1.3 Report Organization ..... 7
2.0 Project Approach ..... 9
2.1 Develop Functional Requirements for Mounting System ..... 9
2.2 Develop Concept Designs ..... 9
2.3 Fabricate Prototype ..... 9
2.4 Finalize Design ..... 9
3.0 Project Outcomes ..... 11
3.1 Develop Functional Requirements for Mounting System ..... 11
3.2 Develop Concept Designs ..... 13
4.0 Conclusions and Recommendations ..... 51
4.1 Acomplishments ..... 51
4.2 Project Termination ..... 51
4.3 Recommendations ..... 51
4.4 Benefits to California ..... 51
Glossary ..... 52

# List of Figures

Figure 1. InDax-100 PV Array Installed on a Tile Roof in Germany ..... 2
Figure 2. InDax-100 2-kW PV Array Prototype During Installation at RSSI Testbed in Billerica, Massachusetts ..... 4
Figure 3. Headquarters, Billerica, MA (left); Sales, Marketing, and Project Engineering, Rocklin, CA (right). ..... 5
Figure 4. ASE-300 PV Module, Largest in the World at 300W. ..... 6
Figure 5. Completed Indax-100 PV Array Installation in Germany. ..... 14
Figure 6. Mounting System Components ..... 15
Figure 7. Flashing Components ..... 16
Figure 8. Installation of Battens and Starter Row Components ..... 17
Figure 9. Partial Installation Showing Extra Battens ..... 18
Figure 10. First New Batten Secured in the Prescribed Location ..... 19
Figure 11. Additional Battens Installed Using a Simple Template for Spacing. ..... 19
Figure 12. Securing of Module Bracket Starter. ..... 20
Figure 13. Left End Compound Flashing Piece Installation. ..... 20
Figure 14. Middle Piece of the Compound Flashing Installation. ..... 21
Figure 15. Installation of Flashing Across Bottom of the Array. ..... 22
Figure 16. Securing Fasteners Holding Module Base Starters. ..... 23
Figure 17. Lower Edge Appearance with Starter Brackets and Bottom Flashing Pieces are all in Place. ..... 23
Figure 18. Lower Edge of Module Base Mates with the Module Base Starter. ..... 24
Figure 19. Lower End of Module Bracket Mated to Upper End of the One Below it. ..... 25
Figure 20. Module Brackets Hook Over Batten. ..... 25
Figure 21. All Module Brackets and Module Bases in Place. ..... 26
Figure 23. Cables Strung Beneath Mounting Brackets. ..... 28
Figure 24. Preparation for Installation of the Side Flashing Pieces. ..... 28
Figure 25. Lower Right Flashing Fits over Studs in Module Base. ..... 29
Figure 26. Tab on Flashing Nailed to Batten. ..... 29
Figure 27. Tab on Module Base Folded to Lock in Flashing. ..... 30
Figure 28. Right Side Flashing Piece. ..... 30
Figure 29. Module Lift Barriers at Top of Array Fastened to Batten. ..... 31
Figure 30. Roof with All Side Flashing Completed. ..... 31
Figure 31. First Module Placed in top Position. ..... 32
Figure 32. Quick Connector Cable Mated to First Module. ..... 33
Figure 33. Second Module Positioning. ..... 33
Figure 34. Module Overlap Seal Installation. ..... 34
Figure 35. Overlap Seal Secured. ..... 34
Figure 36. Module Side Clamps Fasten PV Laminate to Supports and Flashing. ..... 35
Figure 37. Module Side Clamp Tightened to Lock Laminate into Position. ..... 36
Figure 38. Module Eaves Vent Placed Below Bottom-Row Module. ..... 37
Figure 39. Top Right Flashing Piece Put in Place. ..... 37
Figure 40. Top Batten Prepared for Installation of Top Flashing. ..... 38
Figure 41. Top Flashing Piece Positioned. ..... 38
Figure 42. Flashing Detail. ..... 39

Figure 43. Top Flashing Piece Secured with Fastener. ..... 39
Figure 44. Top Edge of the Flashing Nailed into Place. ..... 40
Figure 45. Module Side Clamp Slides Beneath Edge of Upper Flashing Piece. ..... 40
Figure 46. Top Flashing Pieces Installed Over Each Column of Modules. ..... 41
Figure 47. Upper Left Flashing Piece. ..... 41
Figure 48. Wiring Detail. ..... 42
Figure 49. Foam Strip Placed at Edge of Side Flashing and Under Tiles. ..... 42
Figure 50. Lower Flashing Formed to Shape of Tiles. ..... 43
Figure 51. Flashing and Foam Strip Detail at Lower Right Edge of Array. ..... 43
Figure 52. Finished Array Except for Perimeter Tiles. ..... 44
Figure 53. Tiles Fill in Along Sides, Overlapping Flashing and Foam Strips. ..... 45
Figure 54. Excess Trimmed. ..... 45
Figure 55. Example Array, Completely Installed. ..... 46

## List of Tables

Table 1. System Characteristics. ..... 45

Note: All tables, figures, and photos in this report were produced by the authors, unless otherwise noted.

# Abstract

RWE Schott Solar, Inc. began the development of a new photovoltaic array mounting system, designed to produce an integrated photovoltaic array for tile residential roofs. This document is the final report of the Public Interest Energy Research contract "Schott Building Integrated Photovoltaics Mounting Approaches for New Construction," under which this development was conducted.

Over the course of this project, specifications for a building integrated photovoltaic residential system were generated, products used in Germany and the Netherlands were reviewed, experience was gained with installation of these existing building integrated photovoltaic shingle photovoltaic arrays, and the new InDax-100 mounting system from RWE Schott Solar GmbH was selected for further development. Project activities included development of functional requirements for the mounting system, development of concept designs, fabrication of a prototype, and a finalized design.

A prototype array was constructed at the RWE Schott Solar, Inc, testbed in Billerica, Massachusetts, for engineering evaluation. Business decisions, including unfavorable currency exchange rates, led to the premature curtailment of this development effort.

**Keywords**: Solar, photovoltaic, building integrated photovoltaics, BIPV, PV

# Executive Summary

## Introduction

The market for photovoltaic systems that operate in parallel with existing grid electricity supply, safely and simply installed on the rooftops of newly constructed houses, is growing rapidly in the United States. In the residential market, the photovoltaic (PV) systems that are most appealing to homeowners are those in which the PV modules integrate cleanly with tile roofs, producing an addition to the roof that is less noticeable to the casual observer. The InDax-100 is such an integrated PV array design that was developed by the RWE Schott Solar, Inc, parent company in Germany, RWE Schott Solar GmbH, for the residential market in Europe. This product was introduced in Europe in 2003, and market response has been favorable. In this project RWE Schott Solar set out to evaluate building integrated photovoltaic mounting concepts and develop a solution for the United States. The InDax-100 was chosen as it demonstrates improvements over other products, and there is extensive experience with the product in the Netherlands, Austria, and Germany.

## Objective

This project was to develop and document building integrated PV mounting approaches for a target residential new development market. Project goals were to:

- Identify focus areas and develop the functional requirements for building integrated PV mounting approaches.
- Develop the concept product designs.
- Develop all drawings and documentation necessary for architectural / engineering firms.
- Fabricate a prototype, finalize the product design, and bring the product to market.

## Project Outcomes

RWE Schott Solar, Inc, began investigating the products developed and sold in large quantities in Europe and Japan. RWE Schott Solar, Inc, was to evaluate issues for their use in the United States, such as Underwriters Laboratories (UL) listing, adaptability to United States roof construction methods, adaptability to American roofing tiles, and wiring and National Electric Code. code compliance. The project was to have continued through design concept, development of a product, prototype development, and preparation of design documents required for Underwriters Laboratories listing.

Thoughout this project, specifications for a building integrated PV residential system were generated, products used in Germany and the Netherlands were reviewed, and experience was gained with installations of existing building integrated PV shingle arrays. At the early stages of this project, the InDax-100 design concept was reviewed with an audience of stakeholders, including several experienced PV installers/builders.

A number of negative comments on the InDax's appearance were raised. **Figure 1** shows the appearance of a completed InDax installation. In addition, the custom PV module and all fabricated mounting pieces in the InDax system are produced in Germany. The current exchange rate between Euros and American dollars is such that the cost of these imported components is unfavorably high. In addition, RWE Schott Solar, Inc, determined that the InDax-100 would need significant changes to comply with Underwriters Laboratories and National Electrical Code issues in the United States. In light of these major issues facing the InDax-100, and the fact that other products are in the market, it was felt that the InDax-100 system would not be competitive. Accordingly, the decision was made to not pursue completion of the InDax-100 for the nation's market, bringing the project to a premature close.

**Figure 1. InDax-100 PV Array Installed on a Tile Roof in Germany**
Photo Credit: RWE Schott Solar GmbH

## Conclusions

The project did not continue through to its intended conclusion, but lessons were learned and reported. The groundwork undertaken led to greater understanding of construction methods, practices, preferences, and the challenges of designing a product with broad applicability for a demanding market application. Differences between the major European markets and United States markets were amplified in the stakeholder review process. Work completed on this project will be valuable to RWE Schott Solar, Inc, and others developing building integrated PV products in the future.

The primary reasons for the company decision to abandon the development of the InDax-100 for the United States market are the cost of the system, owing to its foreign

manufacture and unfavorable currency exchange rates, the initial negative market reaction to the appearance and complexity of the design, the potentially daunting modifications that could be required to achieve a Underwriters Laboratories listing, and the weak position this product would have in the marketplace in view of other competing building integrated PV products now on the market. In light of these considerations and the pending significant company committment that would be required to promote and support this new product, the company decided to terminate the project.

## Recommendations

The market for residential PV is growing rapidly, and no single solution will serve everyone's needs or desires. Accordingly, it is recommended that a diverse portfolio of options be available in the marketplace. Low-power modules have found a home in the current building integrated PV or PV shingle approaches in the market. Traditional stand-off mounting uses 150-watt panels. As RWE Schott Solar, Inc. is the manufacturer of the world's highest power module at 300 watts, the author recommends that RWE Schott Solar, Inc, seek to enhance the unique attributes and value-added features of the company's standard product and tailor a new offering with a real difference to maintain diverse options in the residential market.

## Benefits to California

The project was started as it supports PIER Program objectives of improving energy cost/value of California's electricity by creating diverse methods of generating electricity. This product, if developed for American markets in the future, can help reduce California's dependence on fossil fuel power plants and reduce air emissions.

**Figure 2. InDax-100 2-kW PV Array Prototype During Installation at RWE SCHOTT SOLAR, INC. Testbed in Billerica, Massachusetts.**

Photo Credit: RSSI

# 1.0 Introduction

This section of the report provides an overview of RWE Schott Solar and the background of the development of the InDax-100 residential PV mounting system. The InDax-100 residential PV mounting system is a roof integrated system approved for use in Europe. This report describes the attempt to bring the solution to the United States.

## 1.1 Background and Overview

RWE Schott Solar, Inc. was formed in 2002/3, bringing together the system design, engineering, marketing and sales of the former Schott Applied Power Corporation and the PV module manufacturing of the former ASE Americas. The company has two principal offices, shown in **Figure 3**. Headquarters in Billerica, Massachusetts, is the location of the PV module manufacturing facility and the product development group. Sales, marketing, and project engineering are located in the Rocklin, California, office, near Sacramento.

**Figure 3. Headquarters, Billerica, MA (left); Sales, Marketing, and Project Engineering, Rocklin, CA (right).**

Photo Credit: RSSI

The company manufactures and sells the 300-Watt ASE-300 PV module (shown in **Figure 4**) and, through the recent merger with Schott Applied Power, now also provides complete photovoltaic system engineering, design, and turnkey PV system installation services.

The systems team has a long history of design and installation of grid-tied PV systems for both pitched-roof residential applications and flat-roof commercial applications. In the mid-1980s, company principals pioneered a mounting system for pitched residential roofs using brackets that sit on top of the roof covering and are secured directly through the shingles to the roof deck. The resulting PV array is supported above and parallel-planar to the existing roof. The majority of residential PV arrays in California and elsewhere have been installed in ways that produce a similar result, with the PV modules supported above the finished roof and highly visible.

As the market for residential PV systems has expanded and matured, the desire has grown for a residential PV array mounting system that reduces the visual impact of the PV modules and mimics, or blends with, the roof covering. Especially in the niche market of tile roofs – an attractive, premium roof covering for upscale homes – an integrated PV array design is highly desirable. This project set out to explore building-integrated PV array concepts for the new-construction tile-roof residential application, generate designs, build a prototype and ultimately introduce a new Building Integrated PV mounting system into the U.S. market.

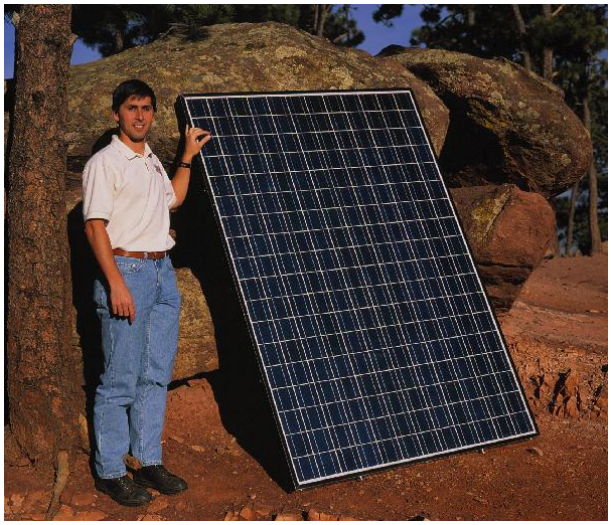

**Figure 4. ASE-300 PV Module, Largest in the World at 300W.**
Photo Credit: RSSI

## 1.2 Project Scope and Objectives

The objective of this project was for RWE Schott Solar, Inc. (RSSI) to develop a system that would allow PV modules to be easily mounted on a new-construction tile roof and achieve a low-profile integrated result. One of the primary goals was to find a solution that was compatible with standard American roof construction and practices, including common roofing tiles used in new construction in the Sacramento area. The design must also be Underwriters Laboratories listed, certified, and proven for rain, wind, and weather protection. The scope of the contract included:

- Identify a specific focus area and review the functional requirements for a Building Integrated PV mounting approach.
- Develop design concepts to meet those requirements, document requirements to bring the product to market in the United States and review with industry stakeholders.
- Fabricate a prototype for engineering evaluation.
- Evolve and finalize the design, including UL listing and all documentation necessary for architects, designers and engineers to promote the incorporation of Bulding Integrated PV in new construction.

## 1.3 Report Organization

The report is organized into four main sections. The first comprises the introductory and background material. Section 2 identifies and describes the specific tasks undertaken in this contract and Section 3 presents the task results and outcome. Section 4 provides conclusions and recommendations.

# 2.0 Project Approach

Four main tasks were defined in this contract. Each is briefly described in the following sections.

## 2.1 Develop Functional Requirements for Mounting System

The objective of this task was to identify the primary markets for Building Integrated PV applications and develop functional requirements for the products. New-construction residences with tile roofs were selected as the focus area. The approach taken was to speak with SMUD and industry stakeholders to refine the focus area and develop the functional requirements. In addition, we built upon our own experience and understanding of the marketplace to help generate the list of requirements.

## 2.2 Develop Concept Designs

The objective of the task was to create conceptual designs for one or more products that met the functional requirements defined in the initial task. The approach taken was to gain familiarity and experience with existing BIPV products that are in wide use in Germany and the Netherlands, to help generate design ideas. The resulting new concept was documented and reviewed with the SMUD staff and industry stakeholders for input that could lead to further refinement.

## 2.3 Fabricate Prototype

This task was to provide a demonstration of one or more concepts by completing the fabrication and installation of a prototype. The prototype would be used for initial evaluation purposes and to help document the design details for stakeholder review. The approach taken was to construct a roof section in the testbed at Billerica, Massachusetts, and procure the InDax-100 PV array components from our parent company in Alzenau, Germany. This initial prototype and the installation process would serve to help refine the design and lead to further improvement of the mounting system for a second generation prototype.

## 2.4 Finalize Design

The objective of this task was to incorporate lessons learned in the previous tasks into the final design of the PV array mounting system. The approach was to prepare drawings and specification to allow engineers and builders to utilize the mounting approach developed. In this task also was the preparation of materials and documentation necessary to obtain UL listing of the product.

# 3.0 Project Outcomes

The results and outcomes of the completed tasks are presented in the following sections.

## 3.1 Develop Functional Requirements for Mounting System

### *3.1.1 Market Focus Area*

The primary market to be addressed in this project is new residential construction in the northern California area. The focus is on sloped roofs covered by flat tiles from various manufacturers. Residential retrofits, or, installation of PV on existing tile residential roofs, are a second market area to be addressed. Other focus areas were given consideration, including awnings and shade structures, but in both cases, standard modules and conventional designs can be used. PV used in curtain wall type applications for commercial buildings is popular throughout Europe and in Japan. The adoption of this use for PV has been slower to catch on in the US, and there is no single module or module design that stands to become a standard for such applications. Given the stated demand for PV products from builder/developers, new residential rooftop construction was selected as the most important market sector for BIPV.

### *3.1.2 Product Requirements*

1. **Compatible with Standard Roof Construction**

   The residential BIPV product must be compatible with the standard construction for new home roofs in the Sacramento area. These homes typically are constructed with some type of flat or barrel tile as the roof covering material. According to a source at Old Country Roofing, one of the largest roofing companies in northern California, a typical new roof is constructed with 2″x4″ or 2″x6″ rafters or trusses, 24″ on center, ½″ thick oriented strand board (OSB), one or two layers of 30 lb felt and 1″x2″ battens running over the top of the felt, side-to-side, spaced 12″-14″ apart. Roof slant height is typically 15 to 17 feet and roof pitch is typically in the range 5/12 (22.6°) to 7/12 (30.3°).

2. **Construction Practices**

   Installation of the BIPV product should not require special PV contractors. That is, the BIPV product should be installed by the same contractor installing the roof tiles. The BIPV system must be easy and quick to install by a two-man crew. In addition the installation of the BIPV array should be integrated in a logical manner with the steps involved in construction of a normal tile roof.

3. **Appearance**

   The residential BIPV product must result in an aesthetic roofing system. Examples of what might be considered a desired appearance are shown in several photos in this report, where the modules integrate seamlessly with surrounding tiles. Attributes that support this aesthetic result may be that the product is shingle-like, with overlapping elements, and an overall height similar to the tiles surrounding the

array and covering the remainder of the roof. Further, an overall uniform dark appearance is also potentially a desirable attribute of the PV array for residential rooftop applications.

4. **Compatibility with Common Roofing Tiles**

   The BIPV mounting system must be compatible with the roofing tiles commonly used in new residential roof construction in the Sacramento area. These include Pioneer, Eagle, Hansen, Westile, and Monier Lifetile. Compatibility means that the BIPV array can be used with any of these tiles as the surrounding roof cover material. This flexibility is necessary to expand the applicability of the product to a broad segment of the new construction market.

5. **Edge Details**

   The BIPV product should include all components necessary for transitioning from the PV array to the surrounding roofing tile at every edge of the installed PV array. These components must insure a robust, weather-tight transition.

6. **Wiring Ease**

   The wiring of the BIPV array should use quick connectors and be simple and rapid to complete in the field. Penetrations through the roof deck for array wiring should be minimized.

7. **Listing and Certification**

   The BIPV module must, at a minimum, be UL-1703 listed for safety. Listings or certifications beyond UL 1703, such as IEC 61215 are desirable and further evidence of product safety and durability. This roofing product should also be submitted for evaluation and certification by the International Code Council (ICC), formerly the International Congress of Building Officials (ICBO).

8. **Rain, Wind, and Weather Protection**

   An essential feature of the BIPV array is that it must provide the necessary protection from rain, wind, and weather, the same as a standard tile roof product. Testing by UL and/or ICC will be required to verify and certify the performance of the array in this regard.

9. **Materials Durability**

   Materials for the mounting hardware, including all fasteners, should be chosen to insure corrosion resistance, galvanic compatibility and long-term durability consistent with a 20-year or longer PV system life.

10. **Condensation Removal**

    The BIPV system design must provide an effective means to remove condensation that can develop beneath the PV modules.

**11. Airflow**

It is desirable to maintain airflow beneath the BIPV modules to promote lower-temperature operation of the solar cells, to the benefit of their conversion efficiency and lifetime. To the extent possible, ambient air should be free to circulate beneath the modules.

## 3.2 Develop Concept Designs

This section summarizes the concept for the building-integrated PV array design for residential applications. The selected design is based upon a 100W PV laminate (unframed module) and associated mounting components designed for roof construction typical of the mid- and upper-tier tile-roofed homes in the major California housing markets. These are homes with pitched roofs, covered with flat or curved tiles of any style, color, and make. A Critical Project Review was conducted on September 23, 2003, at the California Energy Commission's headquarters in Sacramento, California, at which time this PV array design was discussed and reviewed with industry stakeholders. The following sections describe the PV array design pictorially and present results from the stakeholder review meeting.

### *3.2.1 The InDax-100*

It is well established that European countries are ahead of the U.S. in the development and installation of roof-integrated PV arrays and PV shingle concepts. RWE Schott Solar Inc.'s parent company, RWE Schott Solar Gmbh (RWE SS Gmbh), located in Alzenau, Germany, is one of the many manufacturers of roof-integrated PV arrays now active in the European residential BIPV market. The InDax-100 residential BIPV array was developed over the past 24 months by an experienced design team at RWE SS Gmbh working with industry partners, and is believed to represent advancement upon other similar BIPV products in the European marketplace. InDax-100 PV systems are presently being sold and installed in Germany. The approach chosen was to work with our parent company in Germany and adapt the InDax-100 for the U.S. market.

The InDax-100 PV array installs on battens, the same type as those used to mount flat or curved tiles on residential rooftops. The basic concept is described and presented in the photos of InDax-100 installations and rendered drawings that follow.

**Figure 5** displays a completed system on a German roof. **Figures 6** and **7** show the mounting system and flashing components.

**Figure 5. Completed Indax-100 PV Array Installation in Germany.**
Photo Credit: RWE Schott Solar GmbH

**Figure 6. Mounting System Components** Photo Credit: RSSI

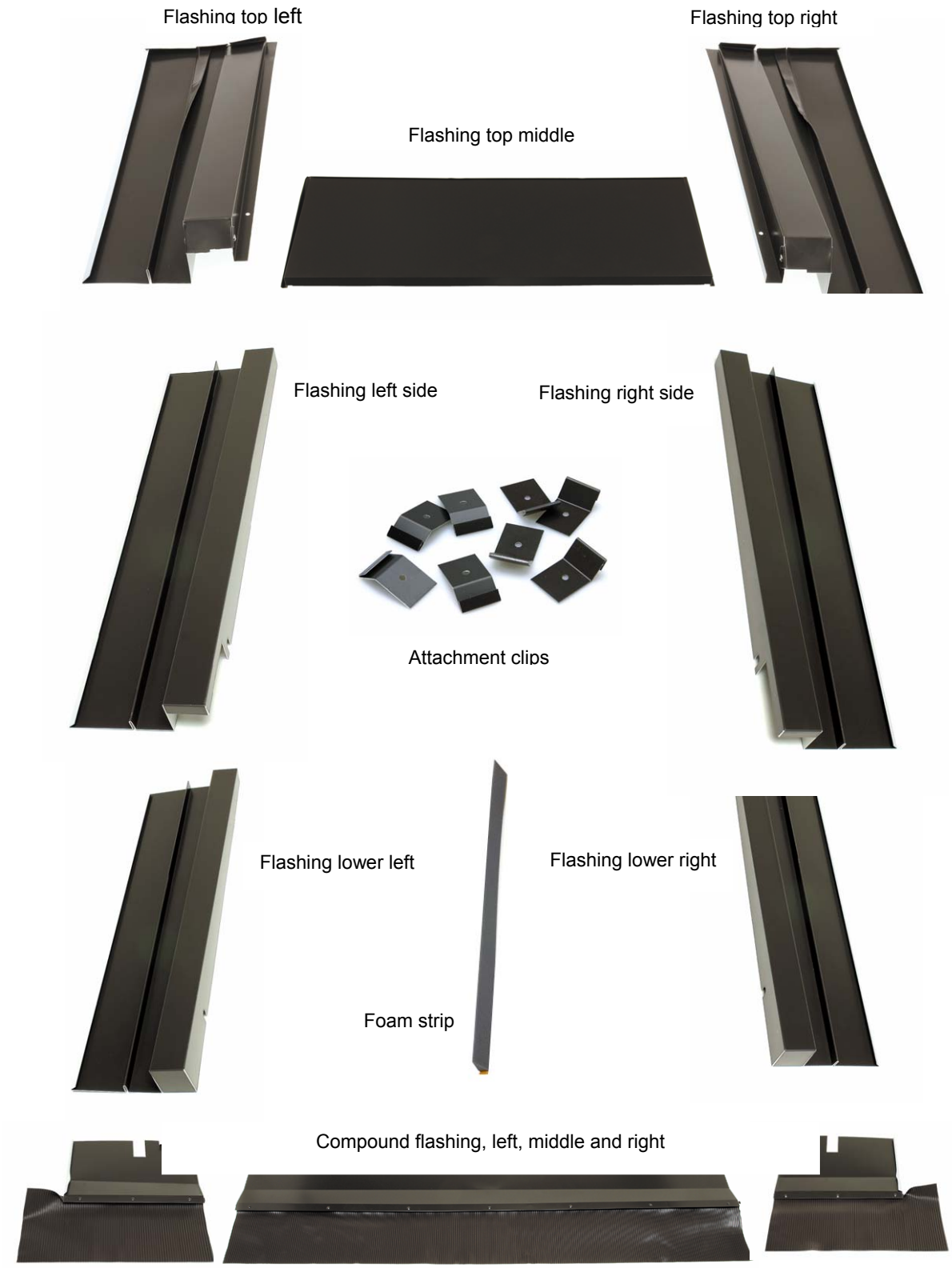


**Figure 7. Flashing Components** Photo Credit: RSSI

**Figure 8** shows a roofer installing battens and the starter row components. The area of the roof where InDax-100 PV array will be installed is not equipped with tiles. The battens shown are those required for installation of the tiles. The dimensions of the space are based on the planned array size.

**Figure 8. Installation of Battens and Starter Row Components**
Photo Credit: RSSI

**Figure 9** shows installation beginning with the attachment of extra battens, since the tile battens will be spaced differently than those for the InDax-100 laminates.

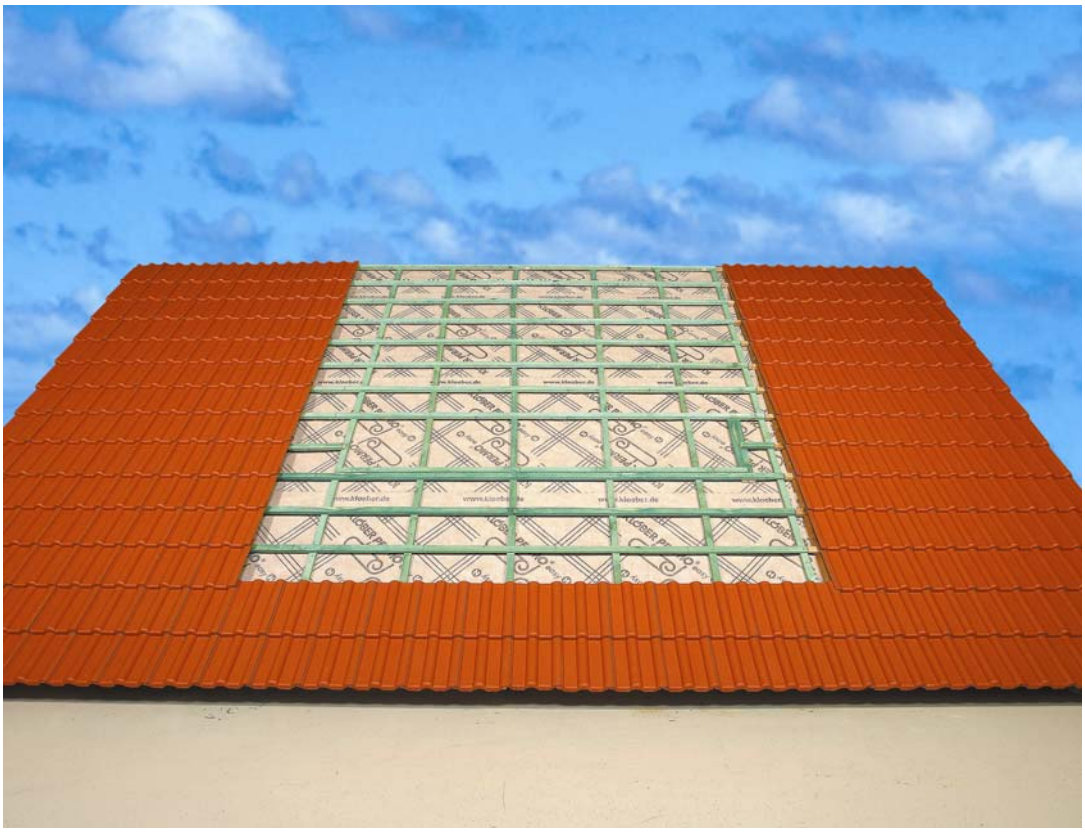

**Figure 9. Partial Installation Showing Extra Battens**
Photo Credit: RSSI

**Figures 10** and **11** show the progressive installation of new battens. In **Figure 12**, the securing of the module bracket starter is shown. These are for module supports between the main module support bases.

**Figure 10. First New Batten Secured in the Prescribed Location**
Photo Credit: RSSI

**Figure 11. Additional Battens Installed Using a Simple Template for Spacing.**
Photo Credit: RSSI

**Figure 12. Securing of Module Bracket Starter.**
Photo Credit: RSSI

**Figure 13. Left End Compound Flashing Piece Installation.**
Photo Credit: RSSI

**Figure 13** shows the installation of the left end compound flashing piece under the module base starter. The compound flashing has sheet metal upper and formable metal lower to shape to the tiles. **Figure 14** shows the installation of the middle piece of the compound flashing. The notches accommodate the module bracket starters and base starters.

**Figure 14. Middle Piece of the Compound Flashing Installation.**
Photo Credit: RSSI

**Figure 15. Installation of Flashing Across Bottom of the Array.**
Photo Credit: RSSI

**Figures 15, 16,** and **17** show the completion of the first step of the installation process. **Figure 15** shows the completion of the flashing pieces across the bottom of the array. **Figure 16** shows the securing of fasteners holding the module base starters with the flashing in place. **Figure 17** shows how the lower edge will appear when the starter brackets and the bottomflashing pieces are all in place.

**Figure 16. Securing Fasteners Holding Module Base Starters.**

Photo Credit: RSSI

**Figure 17. Lower Edge Appearance with Starter Brackets and Bottom Flashing Pieces are all in Place.**

Photo Credit: RSSI

This completes the first step of the installation process. Next install module bases and module brackets.

**Figure 18** shows how the lower edge of the module base mates with the module base starter. The upper end of the module base is secured with a single fastener into the batten. **Figure 19** shows the mating of the lower end of the next module bracket to the upper end of the one below it. The upper end is secured to the batten above. **Figure 20** shows the upper edge of the module bracket hooked over the batten with a single fastener used to secure the module bracket to the batten.

**Figure 18. Lower Edge of Module Base Mates with the Module Base Starter.**
Photo Credit: RSSI

**Figure 19. Lower End of Module Bracket Mated to Upper End of the One Below it.**
Photo Credit: RSSI

**Figure 20. Module Brackets Hook Over Batten.**
Photo Credit: RSSI

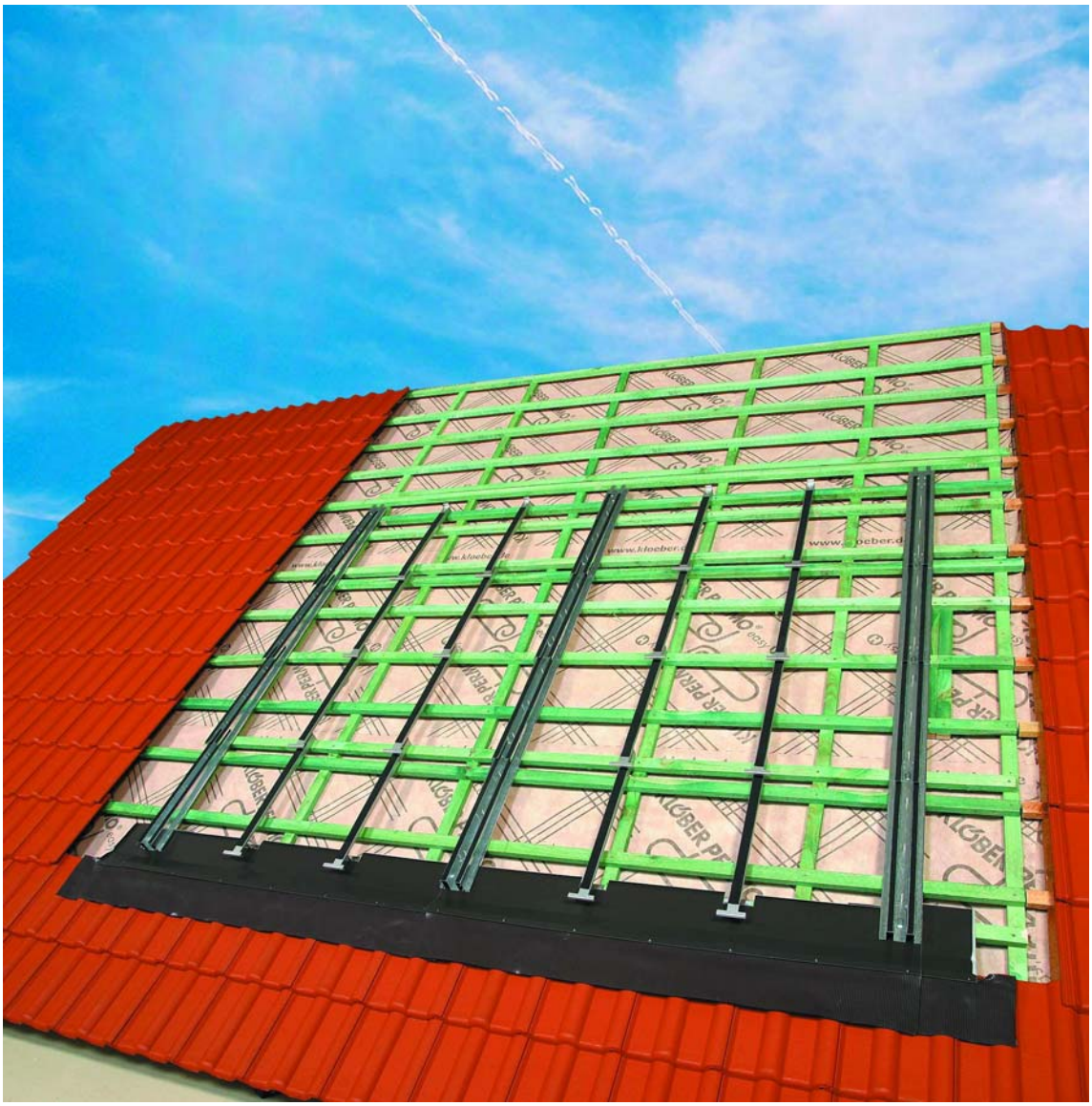

**Figure 21. All Module Brackets and Module Bases in Place.**
Photo Credit: RSSI

**Figure 21** shows how the roof space will appear with all module brackets and module bases in place. Next is the wiring preparation.

## Wiring Preparation

**Figure 22. Runback Wires with Quick Connectors Used to Form String Array.**
Photo Credit: RSSI

**Figure 22** shows the runback wires with multi-contact quick connectors used to form series strings in the array. **Figure 23** shows cables strung beneath the mounting brackets in preparation for their eventual connection to the modules. Next the flashing is installed.

**Figure 23. Cables Strung Beneath Mounting Brackets.**
Photo Credit: RSSI

## Install Side Flashing

**Figure 24. Preparation for Installation of the Side Flashing Pieces.**
**Photo Credit: RSSI**

Flashing is installed next. In **Figure 24**, the small tabs of the lower right and lower left module base pieces are bent over in preparation for installation of the side flashing pieces. **Figure 25** shows the lower right flashing piece fitting over the studs in the module base.

**Figures 26** through **30** show the progressive installation of flashing.

**Figure 25. Lower Right Flashing Fits over Studs in Module Base.**
Photo Credit: RSSI

**Figure 26. Tab on Flashing Nailed to Batten.**
Photo Credit: RSSI

**Figure 27. Tab on Module Base Folded to Lock in Flashing.**

Photo Credit: RSSI

**Figure 28. Right Side Flashing Piece.**

Photo Credit: RSSI

**Figure 29. Module Lift Barriers at Top of Array Fastened to Batten.**

Photo Credit: RSSI

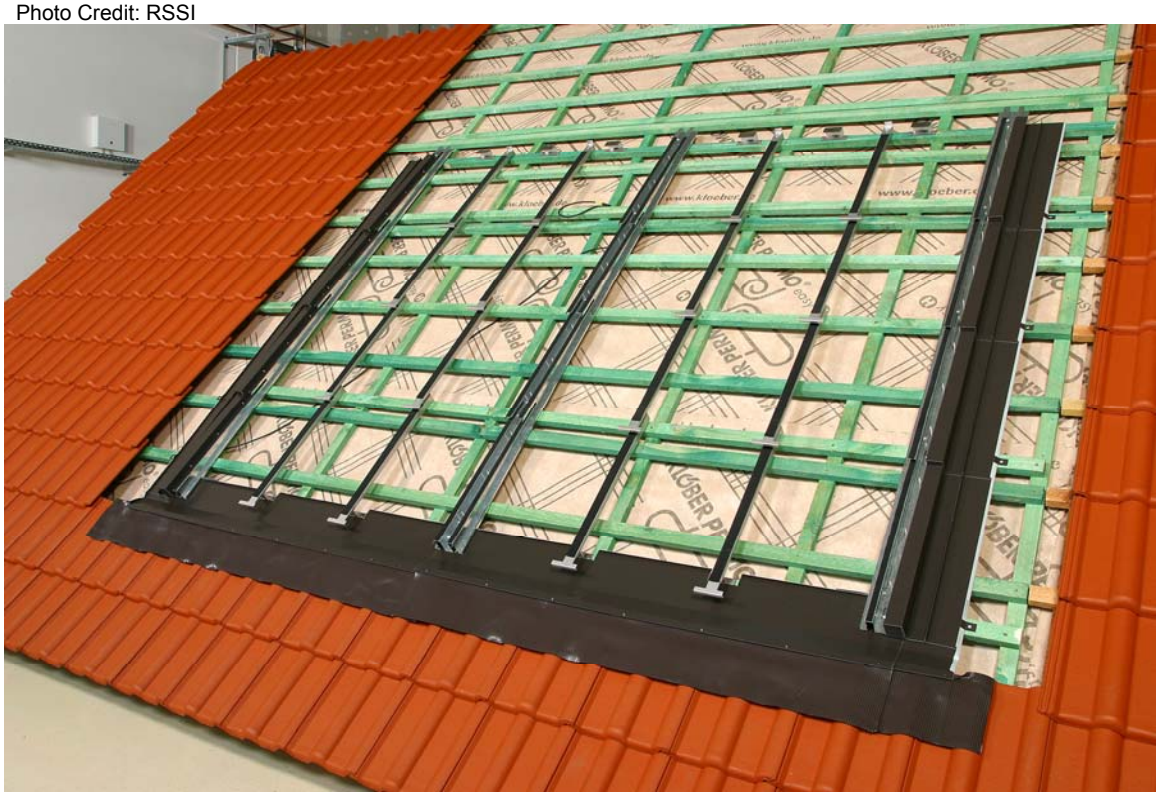

**Figure 30. Roof with All Side Flashing Completed.**

Photo Credit: RSSI

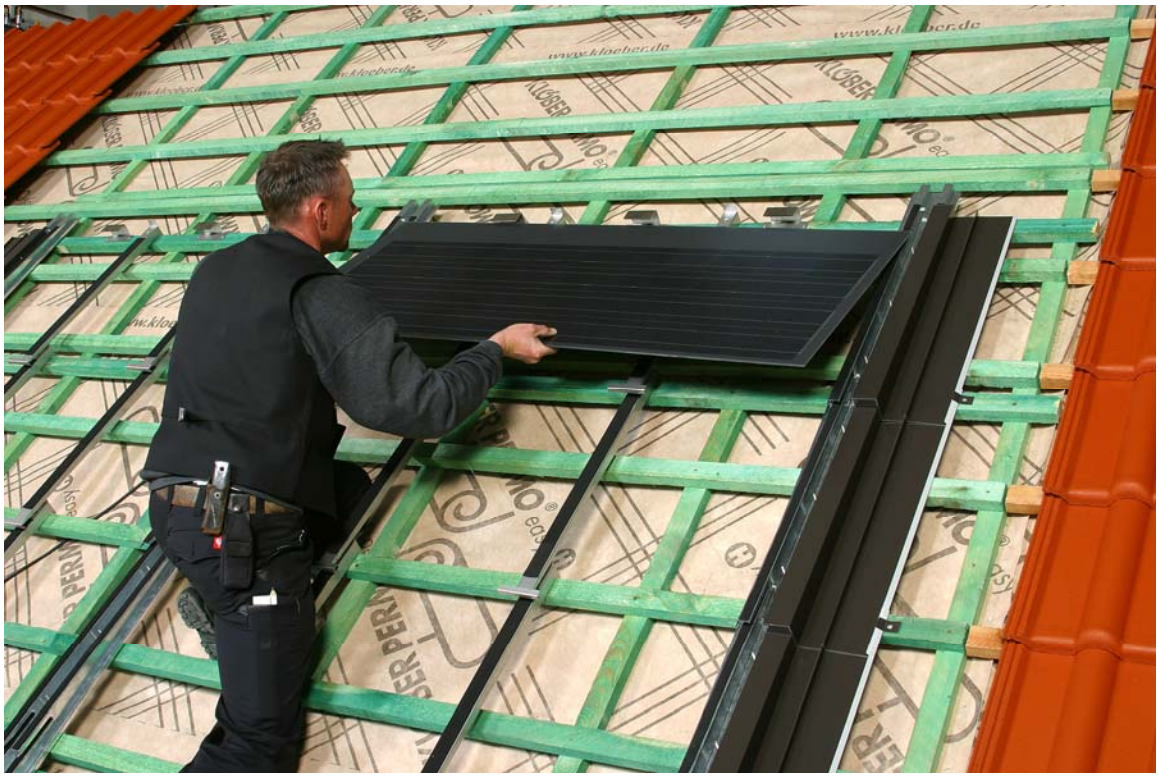

**Figure 31. First Module Placed in top Position.**
Photo Credit: RSSI

**Figures 31** through **55** show the continued progression of module installation and completion of the array.

**Figure 32. Quick Connector Cable Mated to First Module.**

Photo Credit: RSSI

**Figure 33. Second Module Positioning.**

Photo Credit: RSSI

Note in **Figure 33** that the upper module overlaps about 5 inches of the lower module.

**Figure 34. Module Overlap Seal Installation.**

Photo Credit: RSSI

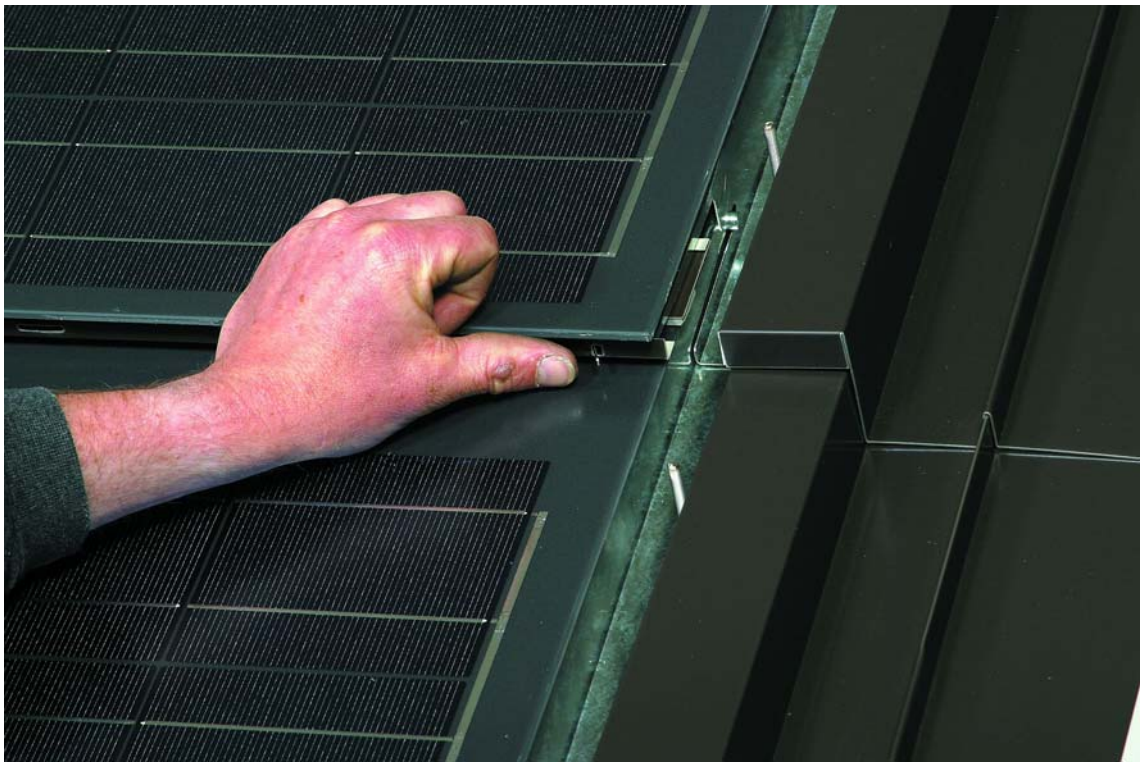

**Figure 35. Overlap Seal Secured.**

Photo Credit: RSSI

**Figure 35** shows how the overlap seal is pushed over the tab and the tab bent to secure the seal. **Figure 36** shows the module side clamps going into position to clamp the PV laminate securely to the supports and flashing. Three threaded studs hold these clamps in place.

**Figure 36. Module Side Clamps Fasten PV Laminate to Supports and Flashing.**
Photo Credit: RSSI

**Figure 37. Module Side Clamp Tightened to Lock Laminate into Position.**
Photo Credit: RSSI

The module side clamp is secured in **Figure 37** by tightening the nuts onto the the three studs. This locks the laminate into position. **Figure 38** shows the module eaves vent put in place below the bottom-row module. Holes in the piece slip over the tabs; the tabs are folded over to secure the eaves vent.

**Figure 38. Module Eaves Vent Placed Below Bottom-Row Module.**
Photo Credit: RSSI

**Figure 39. Top Right Flashing Piece Put in Place.**
Photo Credit: RSSI

**Figure 40. Top Batten Prepared for Installation of Top Flashing.**
Photo Credit: RSSI

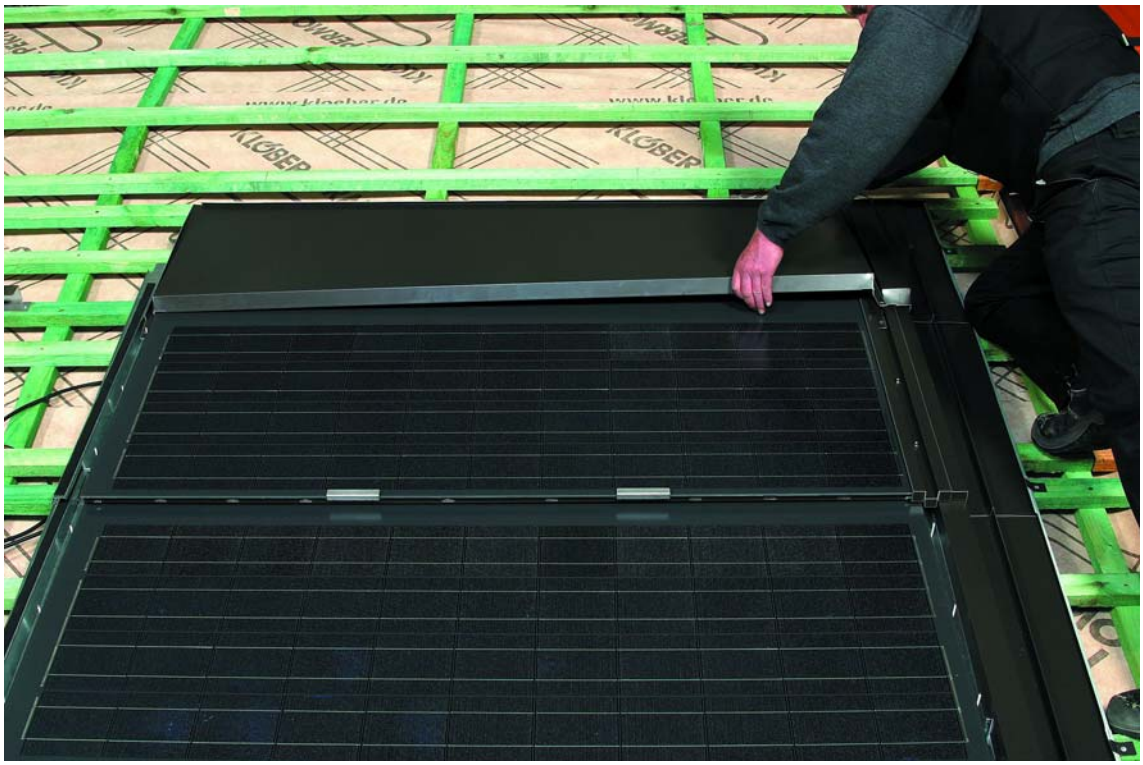

**Figure 41. Top Flashing Piece Positioned.**
Photo Credit: RSSI

**Figure 42. Flashing Detail.**
Photo Credit: RSSI

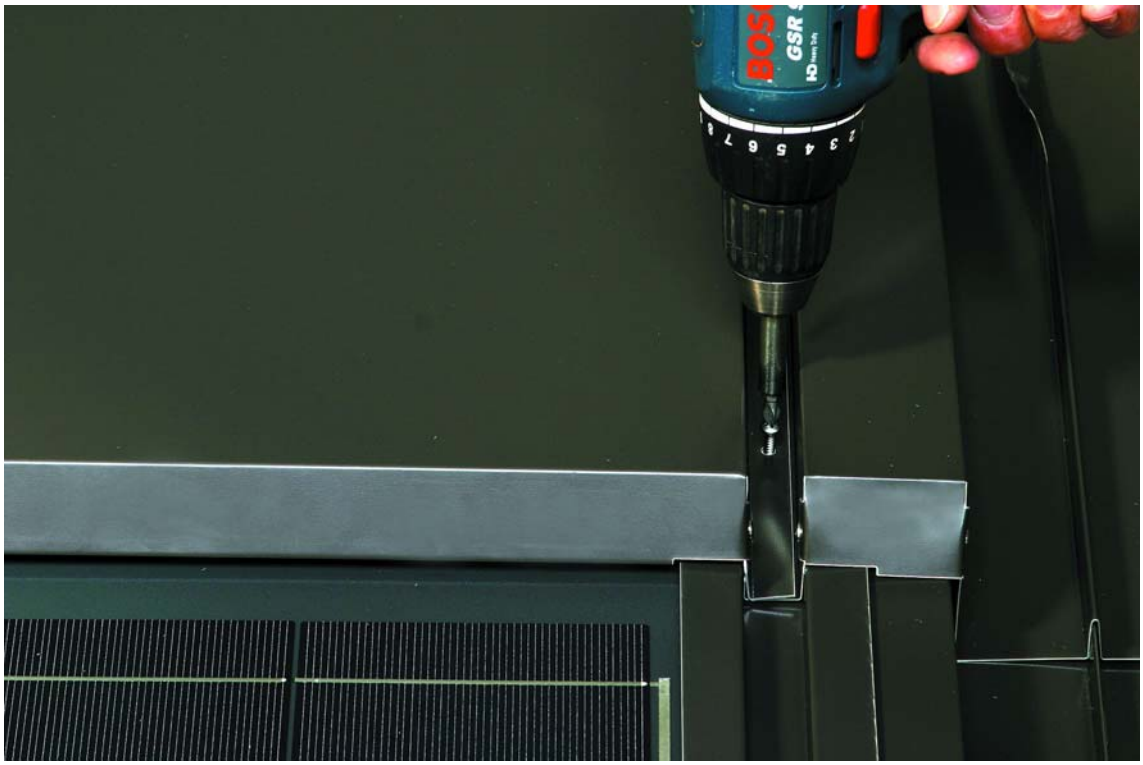


**Figure 43. Top Flashing Piece Secured with Fastener.**
Photo Credit: RSSI

**Figure 44. Top Edge of the Flashing Nailed into Place.**
Photo Credit: RSSI

**Figure 45. Module Side Clamp Slides Beneath Edge of Upper Flashing Piece.**
Photo Credit: RSSI

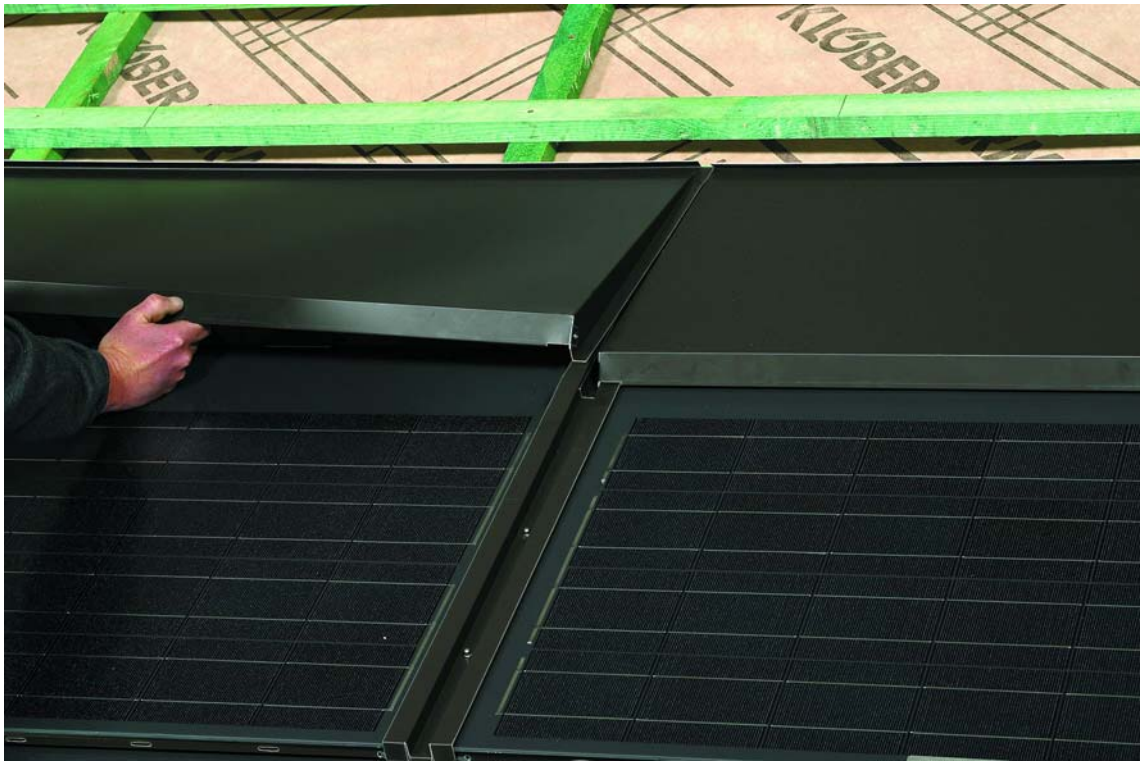

**Figure 46. Top Flashing Pieces Installed Over Each Column of Modules.**
Photo Credit: RSSI

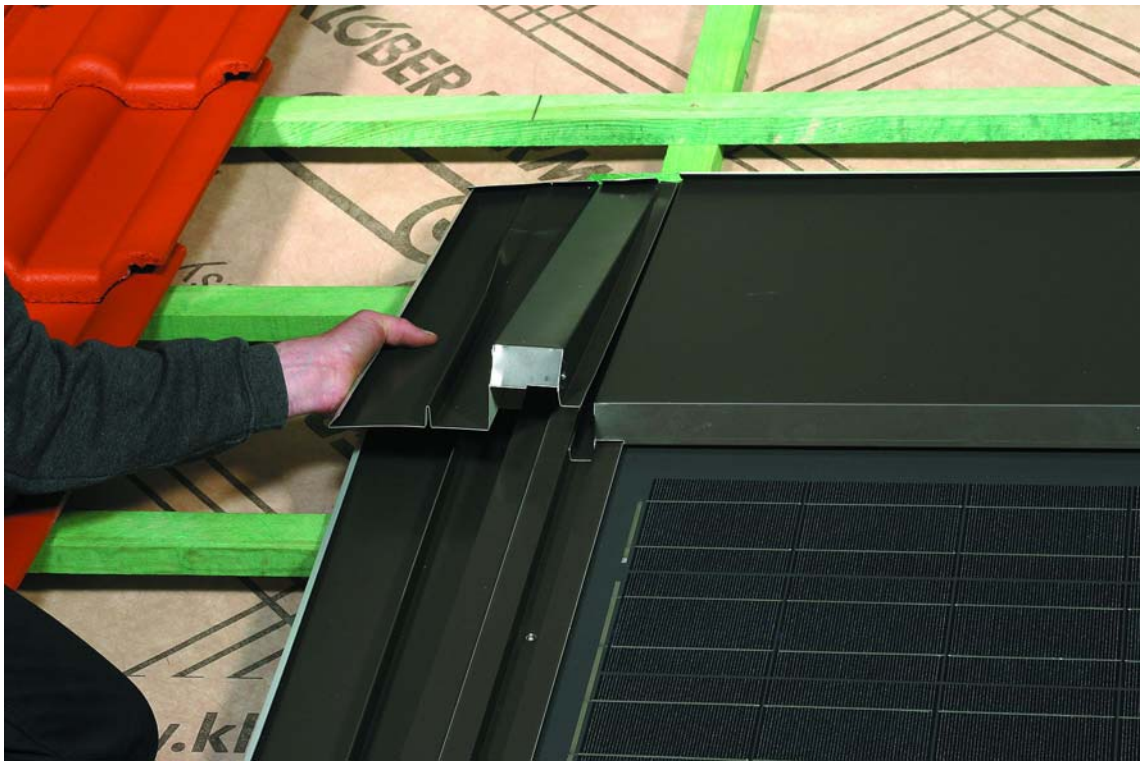

**Figure 47. Upper Left Flashing Piece.**
Photo Credit: RSSI

**Figure 48. Wiring Detail.**
Photo Credit: RSSI

**Figure 49. Foam Strip Placed at Edge of Side Flashing and Under Tiles.**
Photo Credit: RSSI

**Figure 50. Lower Flashing Formed to Shape of Tiles.**
Photo Credit: RSSI

**Figure 51. Flashing and Foam Strip Detail at Lower Right Edge of Array.**
Photo Credit: RSSI

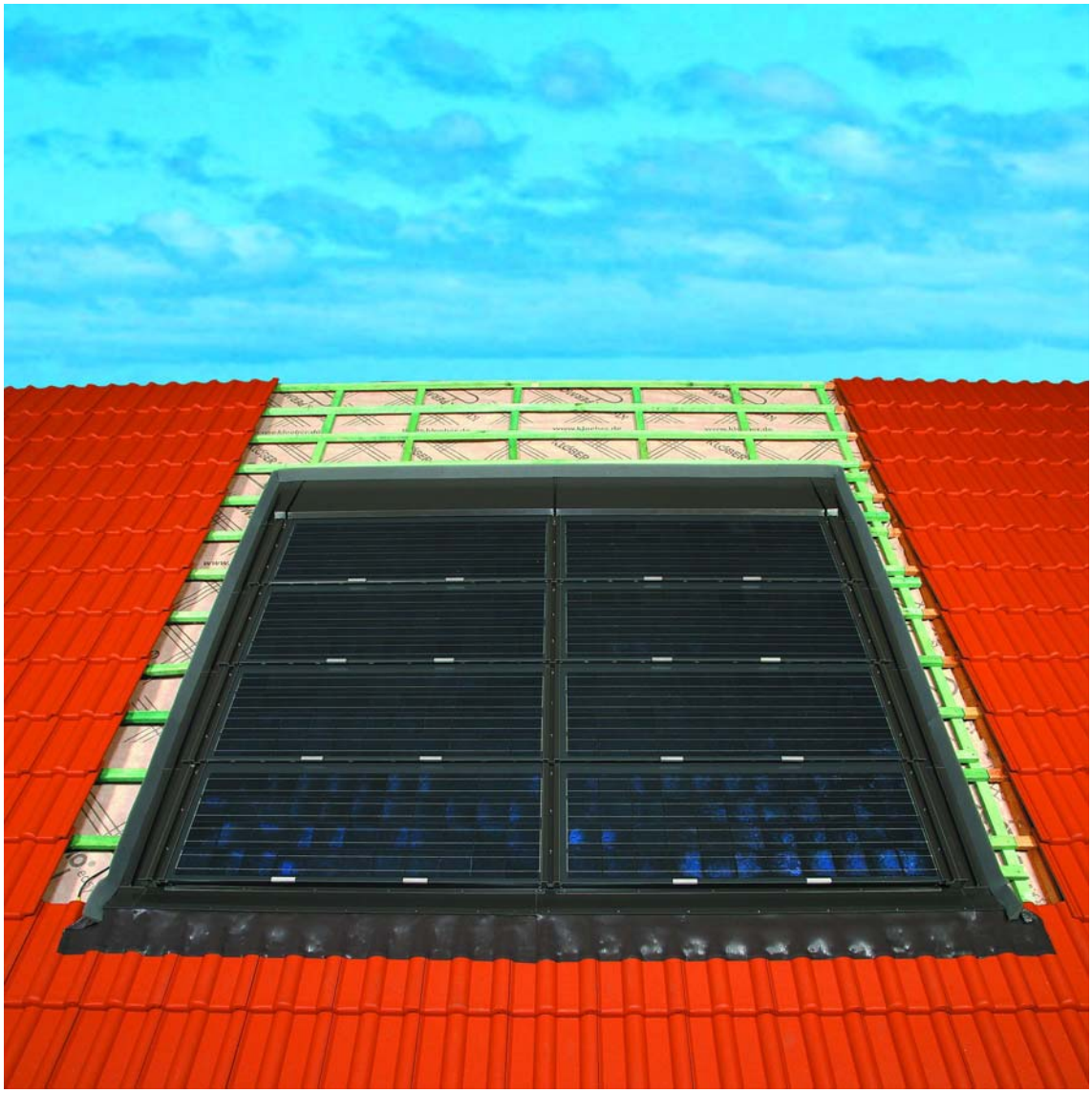

**Figure 52. Finished Array Except for Perimeter Tiles.**
Photo Credit: RSSI

**Figure 53. Tiles Fill in Along Sides, Overlapping Flashing and Foam Strips.**
Photo Credit: RSSI

**Figure 54. Excess Trimmed.**
Photo Credit: RSSI

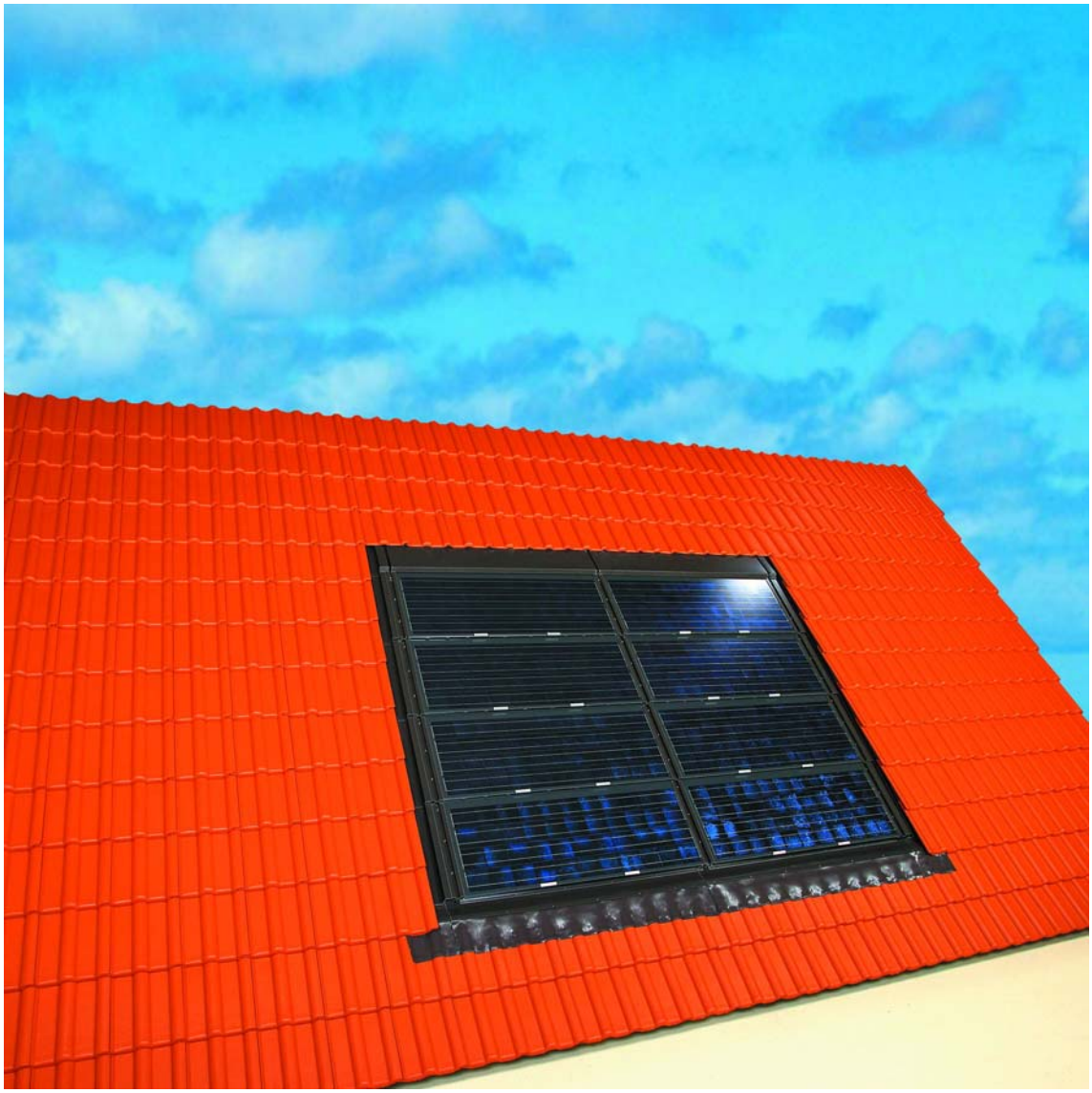

**Figure 55. Example Array, Completely Installed.**

**Table 1. System Characteristics.**

| Parameter | 100-W Module | 2-kW PV Array |
|---|---|---|
| Number of Modules in Series | 1 | 10 |
| Number of Modules in Parallel | 1 | 2 |
| Open-circuit Voltage | 26.8 V | 268 V |
| Max-power Voltage | 22 V | 220 V |
| Max-power Current | 4.54 A | 9.08 A |
| Short-circuit Current | 5.05 A | 10.1 A |
| Max-Power | 100 W dc, stc | 2 kW dc, stc |
| Array width | -- | 20'-7" |
| Array height | -- | 11'-1" |

Data collected by Miles Russell

### *Stakeholder Review*

On September 23, 2003, a panel of stakeholders was assembled and presented with information and photos of the InDax-100 PV array design. The meeting was held at the California Energy Commission in Sacramento to review and discuss the array design. The review panel members included four production builders, two electricians, an electrical engineer, and a roofer. The attendees at the meeting are listed below:

**Joe McCabe**

California Energy Commission (CEC)

1516 9th Street, MS 43

Sacramento, CA 95814

**Greg Nickless**

Prodigy Homes

**Rodger Stanton**

Beazer Homes

3721 Douglas Boulevard, Ste 100

Roseville, CA 95661

**Bob Walter**

Morrison Homes

**Lisa Wagner**

Forecast Homes

**Rich Castillo**

Old Country Roofing

125 B Grobric Court

Suisun, CA 94585

**Mark Cooper**

H&D Electric

5306 Walnut Avenue

Sacramento, CA 95841

**David Yu**

HYA Engineers (electrical engineering firm)

Discussions ranged broadly, from general marketing and price issues to PV technology questions and specific comments on the InDax-100. Following are the comments regarding the InDax-100 array design:

1. PV Array Size and Price

   A PV array size of 4 kW with a final price to the customer of $12,000 or less is desired. This can also be stated as a PV system price of $3/W or less. The desire for systems of this size is to make a significant impact on the customer's electrical bills at a price that is a modest addition to a $350,000 home. The target price of $3/W takes into account the $4/W rebate presently available for residential installations in CA. An installed cost for the InDax-100 at or below $7/W will be required to meet this target.

2. Appearance

   Several in the group felt the InDax-100 did not meet the aesthetic requirements necessary for broad market appeal in the residential sector. Among the comments were that blue cells are undesirable and black is preferred. Another comment was that it looks commercial, like a skylight, and not residential. Others were more willing to defer a final judgment on the appearance of the InDax-100 until they could see a full-scale prototype.

3. Installation

Installation of the array should not require an electrician to be on the roof. Interconnection should use quick-connectors. The roof work should be amenable to completion by a roofer as they are accustomed to working in that environment.

4. Module Size

   It was suggested that ½-size modules be made in order to help fill-out a roof with as many modules as possible. However, this is not possible electrically. The 100-Watt module is larger than other shingle module products on the market and one builder said he thought it would be easier to install because there would be fewer modules needed to build an array.

5. Cooling

   The thermal environment of the module was discussed. In other products, such as the AstroPower and Atlantis shingles, the modules operate very hot as there is little or no back-side heat transfer. The InDax-100 array does provide some back-surface air circulation cooling and should operate cooler than other designs.

# 4.0 Conclusions and Recommendations

## 4.1 Acomplishments

The project did not continue through to its intended conclusion, but lessons were learned. The groundwork undertaken led to greater understanding of construction methods, practices, and preferences, and the challenges of designing a product with broad applicability for a demanding market application. Differences between the major European markets and the U.S. markets were amplified in the stakeholder review process. Work completed on this project will be valuable to future efforts by RSSI and others to undertake development of a BIPV product.

## 4.2 Project Termination

The primary reasons for the company decision to abandon the development of the InDax-100 for the United States market are the cost of the system, owing to its foreign manufacture and unfavorable currency exchange rates, the initial negative market reaction to the appearance and complexity of the design, the potentially daunting modifications that could be required to achieve a UL listing, and finally the weak position this product would have in the marketplace in view of other competing BIPV products now on the market. In light of these considerations, and the pending significant company committment that would be required to promote and support this new product, the company made its decision to terminate the project.

## 4.3 Recommendations

The market for residential PV is growing rapidly and no single solution will serve everyone's needs or desires. Accordingly, it is recommended that a diverse portfolio of options be available in the marketplace. Low-power modules have found a home in the current BIPV or PV shingle approaches in the market. Traditional stand-off mounting uses the 150 W panels. As the manufacturer of the world's highest power module at 300 W, the author recommends that we seek to enhance the unique attributes and value-added features of the company's standard product and tailor a new offering with a real difference to maintain diverse options in the residential market.

## 4.4 Benefits to California

The project was started as it supports PIER Program objectives of improving energy cost/value of California's electricity by creating diverse methods of generating electricity. This product, if developed for United States markets in the future, can help reduce California's dependence on fossil fuel power plants and reduce air emissions.

# Glossary

| | |
|---|---|
| AC | Alternating Current. An electric current that reverses direction (sine wave). In the U.S., most household current is single-phase AC at 60 cycles per second. Many businesses in the U.S. that have larger electrical needs use 3-phase AC at 60 cycles per second. |
| Amps or Amperage | The unit of electrical current. Can be thought of as the "flow rate" of electricity. |
| Array (photovoltaic) | A group of modules wired together (in a series and/or in parallel) to form an array of solar modules. |
| BIPV | Building-integrated photovoltaics. |
| Cell (photovoltaic) | The smallest unit of a solar module. A typical a-Si solar cell is rated at 1.5 volts. A typical crystalline solar cell is rated at 0.5 volts. |
| Components | Refers to other devices used and needed when building a solar system. |
| DC | Direct Current. An electric current flowing in one direction only. |
| Grid-Connected (photovoltaic) | A photovoltaic system in which the PV array supplies power directly to a load center (i.e. AC Service Panel) in a home or commercial facility. There is no on-site storage device included with a grid-connected photovoltaic system. Instead, all the kilowatt-hours generated by the PV system are either used by the loads connected to the load center in the building or they are pulled into the utility grid power lines via the utility kilowatt-hour meter attached to the building. |
| ICBO | International Congress of Building Officials (currently ICC) |
| ICC | International Code Council (formerly ICBO) |
| IEC | International Electrotechnical Commission |
| Inverter | An Electronic Device that changes direct current (DC) to alternating current (AC). |
| kW | Kilowatt, 1000 watts; an incandecent light bulb uses 40-100 watts. |
| Module (photovoltaic) | PV modules are manufactured and assembled using solar cells, interconnect wire, bypass |

| | |
|---|---|
| | diodes, encapsulant (which is a top cover over the solar cells) and a protective back sheet behind the solar cells. Most solar modules also include a frame around the edges of the back sheet/top cover assembly. Together, all of these components form the solar PV module. |
| NEC | National Electric Code. |
| Photovoltaic (PV) | Direct conversion of light into electrical energy. |
| PV | Photovoltaic. |
| Photovoltaic Cell | The treated semiconductor material that converts solar irradiance to electricity. |
| RSSI | RWE Schott Solar, Inc. |
| Series Connection | Connection in which the current (amps) stays the same but the voltage multiplies. |
| Solar | Energy from the sun. |
| Solar Collectors | A device designed to capture light or heat energy from the sun. Solar thermal collectors are used in solar hot water systems (often found in homes) and photovoltaic collectors are used in solar electric systems. |
| Solar Panel | Another name for a single module or a group of solar modules that are part of a solar electric PV system. |
| Systems; Balance of Systems | Solar electric systems include the photovoltaic array and the other components that allow these solar panels to be used in homes and commercial facilities where a regulated DC power supply or an AC power supply is required. Components used in solar electric systems include; wire and disconnect devices, charge regulators, inverters, metering, and grounding components. |
| UL | Underwriters Laboratories Inc. |
| Volts (V) | The unit of electromotive force that will force a current of one amp through a resistor or one ohm. |
| Voltage | The measurement of the force of electricity. |
| Watts | A measure of electrical power that is determined by multiplying the voltage by the amperage. |