Application Guidelines for Photovoltaic Laminates

UNI-SOLAR®

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Contact

For further information about United Solar Ovonic products, email USO at info@uni-solar.com.

If you have questions or need support for specific roof PV system applications, contact your local *UNI-SOLAR* office, referring to the contact information above.

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Scope of this Document

This document is a desktop reference for *UNI-SOLAR®* customers to support the development, design, construction, and estimation of rooftop photovoltaic projects involving *UNI-SOLAR* photovoltaic laminates. The design notes and examples, labor case studies for estimations, energy modeling guidelines, and other material in this document are intended to be used as a reference for sales professionals, engineers, estimators, and construction personnel working on *UNI-SOLAR* projects.

The guidelines and information contained herein support, but do not replace or supersede, the specifications of the *UNI-SOLAR* installation guides. The installation guides should be considered the specifications to which a *UNI-SOLAR* installation must adhere for the *UNI-SOLAR* Limited Product and Performance Warranty to apply.

Visit www.uni-solar.com/resource-center for the latest versions of our installation guides.

Additional *UNI-SOLAR* Documentation

Additional *UNI-SOLAR* documentation, including documentation referred to in this document, can be found in our Resource Center at www.uni-solar.com/resource-center. Documents available in the Resource Center include:

- **PVL / PowerTilt™ Installation Manuals:**
  - PVL Installation Guide – Metal Roofs (PVL)
    - Detailed application instructions of PVL to Metal roofs
    - Termination (Wiring) Options for PVL on Metal Roofs
  - PVL Installation Guide – Membrane Roofs (PVL)
    - Detailed application instructions of PVL to Membrane roofs
    - Wire Management System Construction Procedures
  - PowerTilt Installation Guide
    - PowerTilt – Mechanical Assembly
    - Array Assembly
    - System Grounding
- **Enhanced PVL (ePVL) Manuals**
  - Bonding and Installation Manual
    - Site Preparation
    - Safety Procedures
    - Recommended Tools & Equipment
  - Electrical Design Manual
    - Inverter Selection
    - System Wiring
    - Electrical Installation Procedures
  - Operation and Maintenance Manual
    - Maintenance Verifications
    - Cleaning Process
    - Inspection
- **Approved roofing substrates list**
    - List of roofing substrates deemed compatible with PVL and ePVL
- **UNI-SOLAR® Photovoltaic Laminates Limited Product and Power Output Warranty**
    - Detailed description of our 25 year warranty
- **Marketing Collateral**
    - Brochures
    - Product Data Sheets

Definitions and Acronyms

The following definitions are designed to help you understand any unique terminology and acronyms this document may use.

A-Si: An acronym for *amorphous silicon solar technology*.

Approved Substrate: A building material, typically a roofing material, that has been tested by *UNI-SOLAR* personnel and is listed on the *Approved Substrates* list.

Array: A group of modules wired together, in a series and/or in parallel, to form an array of solar modules.

Balance of Systems (BOS): The parts of a photovoltaic (PV) system other than the array. Some examples include switches, controls, meters, power conditioning equipment, supporting structure for the array, and storage components.

BIPV: An acronym for *building integrated photovoltaic*.

EPDM: An acronym for *ethylene propylene diene monomer*.

ETFE: An acronym for *ethylene tetrafluoroethylene*.

ICC: An acronym for *International Codes Council*.

Laminate: A flexible PV module manufactured by encapsulating the cell through a lamination process.

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.

NOA: An acronym for *notice of acceptance*.

NOCT: An acronym for *normal operating cell temperature*.

OSHA: An acronym for *Occupational Safety and Health Association*.

Photovoltaic (PV): The direct conversion of light into electrical energy.

Power Density: The ratio of the power available from a battery to its mass (W/kg) or volume (W/l).

PowerMembrane: A *UNI-SOLAR* solar PV configuration in which multiple PV laminates are adhesively bonded to a large (roughly 10’ x 20’) sheet of single-ply roofing membrane. This assembly is then perimeter-bonded to a single-ply roof membrane. This system provides for solar PV system removal without damaging the primary roofing system.

PVC: An acronym for *polyvinylidene chloride*.

SREC: An acronym for *solar renewable energy credit*.

TPO: An acronym for *thermoplastic olefin*.

Thin Film: A very thin layer of material formed on a substrate.

UL: An acronym for *Underwriters Laboratory*.

UV: An acronym for *ultra-violet*.

WMS: An acronym for *wire management system*.

1 USO Photovoltaic Laminate Description

UNI-SOLAR manufactures photovoltaic (PV) laminates known as PVLs or ePVLS. The *e* in ePVL represents enhanced PVL, which is the latest generation product. The ePVL product line possesses several enhancements including:

- More robust encapsulation
- Decreased width and length, resulting in power density increases
- MC4 electrical connectors with built-in strain relief

UNI-SOLAR's unique amorphous silicon PV technology is comprised of a thin (less than 1 micron thick) layer of silicon deposited on thin stainless steel substrate. This cell structure is encapsulated by durable plastics and is warranted for 25 years.

Figure 1: *UNI-SOLAR* Laminates

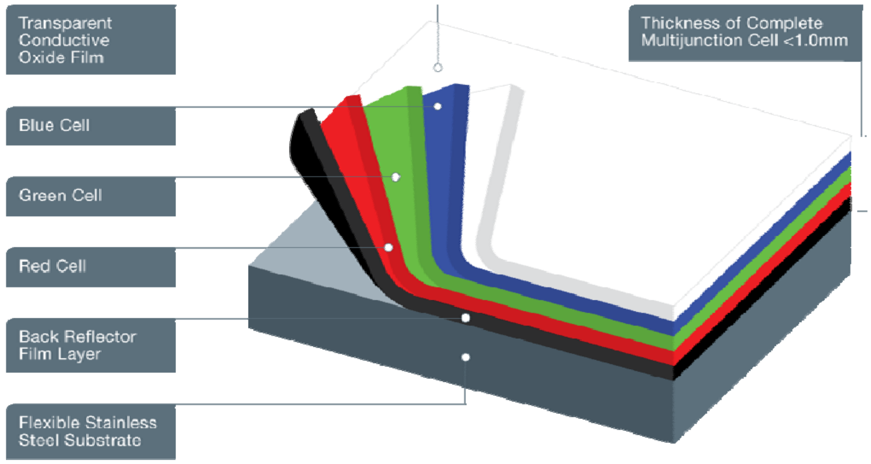


Figure 2: Core Technology

Access the *UNI-SOLAR* Web site at www.uni-solar.com for more information.

2 Application Descriptions

This chapter provides detailed descriptions for the following *UNI-SOLAR* applications:

- Direct bond to single-ply membrane roofs
- Bonding to removable single-ply membranes
- Direct bond to standing seam metal roofs
- Standing seam metal roofs not suitable for direct bond
- Corrugated metal roofs
- Bonding to modified bitumen roofs
- PowerTilt for commercial roofs

Table 1 (on the next page) provides a summary of the application types.

Table 1: Summary of Application Types

	Direct Bond	PowerMembrane	PowerPlate	PowerTilt
Application Description	Apply laminate directly to roof surface. Usually suitable for new or nearly new roofs with warranty of at least 15 years.	Multiple Laminates bonded to large sheets of membrane. These sheets are then attached to the roof. Provides solar PV system removability plus added roof integrity and life extension.	Solar laminates are direct-bonded to metal (usually Galvalume) pans. These pans are affixed to the primary metal roofing system using additional hardware	For flat (< 3 degree slope) roofs. Solar laminates are direct-bonded to metal Galvalume pans. The pans are tilted 15 degrees for increased energy production. Ballast (paving stones) used as required to meet wind rating.
Typical Weight (lbs/ft2)	0.7	1.2	2.1	2.1+ (based on wind rating)
Roof Types				
Single-Ply Membrane Roof	●	●		
Standing Seam Metal Roofs (16 inch on center, flat pans)	●			
Standing Seam Metal Roofs (>/< 16 inch on center, or with non-flat pans)			●	
Corrugated Metal Roofs			●	
Modified Bitumen Roofs	●	●		
Ballasted Roofs (with aggregate or gravel surfaces)				●

2.1 Direct Bond to Single-Ply Membrane Roofs

The *UNI-SOLAR* application **direct bond to single-ply membrane roofs** consists of *UNI-SOLAR* laminates installed directly to a single-ply roof membrane. Laminates are field-applied to an approved membrane using any of the primers specified on the *Approved Substrates* list, in accordance with all specifications of the installation guide.

This section encompasses direct bond to the waterproofing layer of a roof and also applies to bonding to a secondary layer of roofing membrane installed over the existing roof. The secondary layer may be required for roof warranty purposes and is generally installed in large sections, and these application guidelines apply to that installation practice when the laminates are installed to the membrane on the roof. Installing the laminates to membrane before installing the membrane to the roof is covered in the next section.

Applicable *UNI-SOLAR* products include the PVL and ePVL series.

2.1.1 Applicable Roof Types

You can apply the *UNI-SOLAR* PVL product to the following types of single-ply membrane roofs:

- Thermoplastic olefin (TPO)
- Ethylene propylene diene monomer (EPDM)

The roof substrate must be listed on the *UNI-SOLAR Approved Substrates* list.

2.1.2 Design Notes

UNI-SOLAR modules must be located such that all requirements of the installation guide are met, including avoiding areas of ponding water on the roof and not installing *UNI-SOLAR* laminates over seams in the roofing membrane.

2.1.3 Roofing Considerations

Single-ply roofing is typically installed by rolling out the waterproofing membrane over the roof assembly. Roof membrane rolls are 100-150’ long and are most commonly 10’ wide, but can vary between 6’ and 150’ wide. At the seam between two sections of membrane the two edges are sealed with a heat weld or seam tape. *UNI-SOLAR* recommends that you identify and avoid these seams in the design of the *UNI-SOLAR* array.

2.1.4 Array Layout

When installing *UNI-SOLAR* laminates on the roof, you must consider alignment and design the array with some spacing between adjacent laminates to allow for installation alignment tolerance. *UNI-SOLAR* recommends a minimum of 0.25” spacing, with 0.5” providing additional tolerance when space is available.

You must provide spacing for a wire management system (WMS) between the ends of two laminates, where the terminals and wire leads are located. The chapter *Wire Management Systems*, which starts on page 41, provides details on various wire management solutions; however, 5” is the required spacing for the specialty PVC WMS and is a recommended spacing for baseline design purposes. Ensure that final design documentation complies with all requirements of the Installation Manuals, including application of the strain relief pad for the PVL series modules.

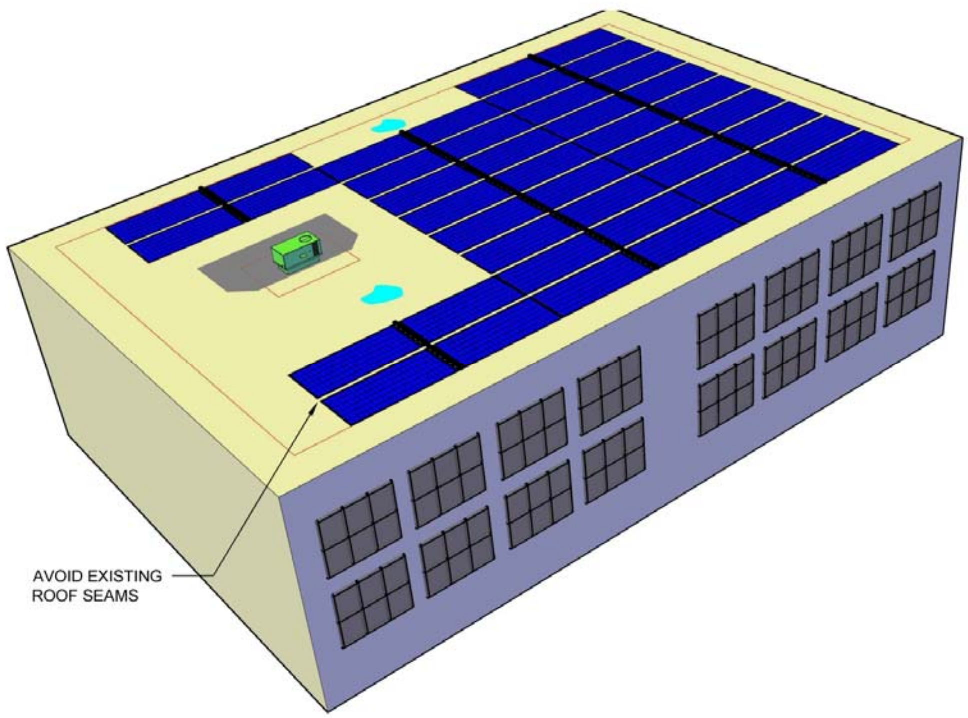


Figure 3: Direct Bond to Membrane Roof Sample Array Layout

2.1.5 Handling and Installation Notes

All specifications and requirements of the *UNI-SOLAR* installation guides apply to the installation of the *UNI-SOLAR* laminates. During installation, be sure to handle and transport the laminates appropriately. Once laminates are installed on the roof, minimize any foot traffic over the array. If personnel must walk on the laminates, wear clean soft soled shoes and walk on the center on the laminate. Do not place tools and material handling equipment (roof carts) on, or allow them to run across, the array.

When planning an installation, loading and sequence of work are critical to ensure that equipment and personnel are not required to access work areas by crossing over installed product. Refer to the chapter *Construction Overview and Scheduling*, which starts on page 48, for more details.

2.1.6 Scheduling and Labor Case Study

Table 2 shows averages only of the PowerBond installation under good conditions with efficient labor performance and is an example of a non-union roofing labor installation of an ~880 kW installation in North America. There is a ramp-up period during the early stages of the project, as well as the optimal rate included in the table. These are strictly roofing installation guidelines only and must not be used for all projects.

Table 2: PowerBond Installation Averages

	kW/Day	Crew	Total Hours	kW per man-hour	kW per man-day	# PVL per man-hour	# PVL per man day
Ramp-up	57	11	88	0.65	5.18	4.50	35.98
Optimal Rate	89	11	88	1.01	8.05	6.99	55.91

Refer to the appendixes for the Power Bond labor case study.

2.1.7 Wind Resistance

The wind uplift rating of a *UNI-SOLAR* laminate directly bonded to a roof is typically driven by the wind uplift resistance of the roof system due to the low profile and high strength of the adhesive. Testing conducted in accordance with FM Standard 4470 and Miami-Dade TAS 114-95 resulted in the failure of the underlying roof system at over 270 psf. While the design pressure applied to a building cladding component varies based on building height, geometry, and location on the roof, 270 psf is sufficient to withstand Class III Hurricane winds of 130 MPH in most cases. Refer to Section 7 of this document for information on certifications and approvals.

2.1.8 Reference Project Photo

Figure 4: Reference Project Photo for Direct Bond to Single-Ply Membrane Roofs

2.2 Bonding to Removable Single-Ply Membranes

The *UNI-SOLAR* application **bonding to removable single-ply membranes** consists of installing *UNI-SOLAR* laminates directly to a secondary layer of single-ply roofing membrane that is attached to the existing roof in such a way that the membrane and *UNI-SOLAR* laminates may be removed, leaving the existing roof intact.

This section covers bonding laminates to the roof membrane before installing the roof membrane to the roof. The application configuration of *UNI-SOLAR* laminates bonded to a sheet of roof membrane will be referred to as the PowerMembrane application for purposes of this document.

Applicable *UNI-SOLAR* products include the PVL and ePVL series. *UNI-SOLAR* does not supply a completed PowerMembrane assembly.

2.2.1 Applicable Roof Types

You can apply the *UNI-SOLAR* PVL product to the following types of single-ply membrane roofing materials in assembly of the PowerMembrane:

- TPO
- EPDM

The roof substrate must be listed on the *UNI-SOLAR Approved Substrates* list.

You can apply the PowerMembrane to TPO, EPDM, cap sheet roofs, some coated roof systems, and other select single-ply roofing systems. However, the PowerMembrane application may not be used over PVC roofs and is incompatible with ballasted roofs and roof with gravel surfacing.

2.2.2 Design Notes

UNI-SOLAR modules must be located such that all requirements of the installation guide are met, including avoiding areas of ponding water on the roof.

2.2.3 PowerMembrane Configuration

You can configure the PowerMembrane assembly in one of several ways, depending on the product configuration (ePVL versus PVL) and other project specific factors. Three typical configurations of the PowerMembrane are shown in Figure 5, Figure 6, and Figure 7.

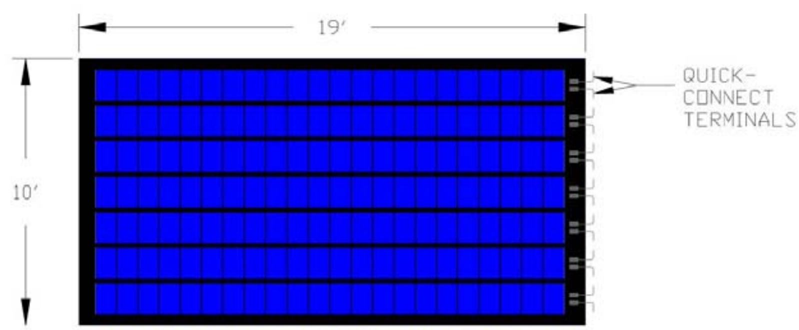


Figure 5: 10' Wide PVL Power Membrane Detail—7 *UNI-SOLAR* PVL

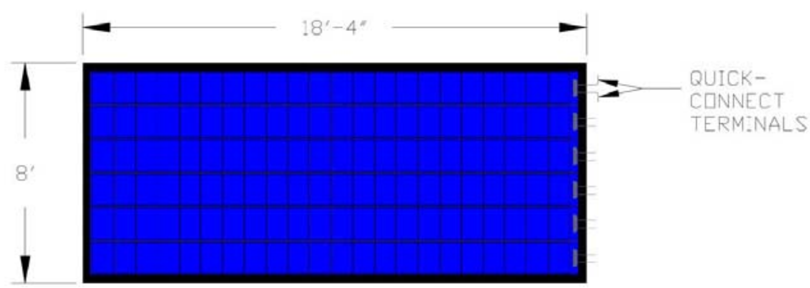


Figure 6: 8' Wide ePVL PowerMembrane Detail—6 *UNI-SOLAR* ePVL

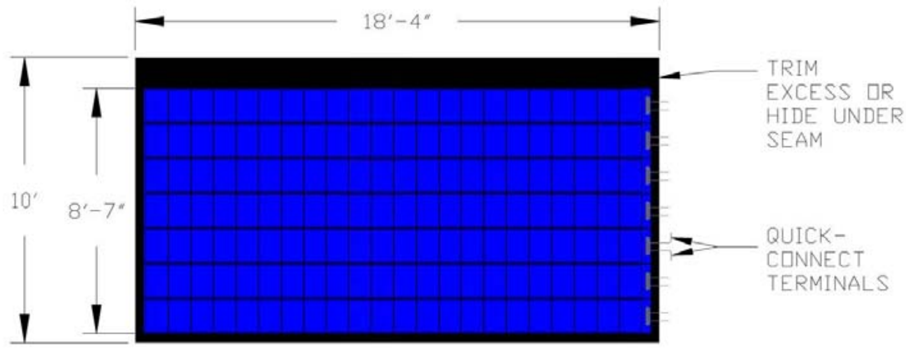


Figure 7: 10' Wide ePVL PowerMembrane Detail—7 *UNI-SOLAR* ePVL

The PowerMembrane assembly attachment to the existing roof will typically utilize standard roofing industry details. The section *Installation and Handling Notes* on page 11 provides attachment details for various roof types; however, all details typically require a 4” perimeter for heat welding and/or taping the perimeter of each PowerMembrane.

2.2.4 Array Layout

Once you have determined the PowerMembrane configuration, you should lay out the array with the PowerMembrane as the building block. Smaller sections of membrane with fewer *UNI-SOLAR* PVL laminates may be required to provide complete strings in a given area of the roof. PowerMembrane panels can typically utilize overlapping seam details between membrane sheets.

You must provide spacing for a WMS between the ends of two laminates where the terminals and wire leads are located. Details on various wire management solutions are provided in the chapter *Wire Management Systems*, which starts on page 41. However, 5” is the required spacing for the specialty PVC WMS and is a recommended spacing for baseline design purposes. Ensure that final design documentation complies with all requirements of the Installation Manuals, including application of the strain relief pad for the PVL series modules.

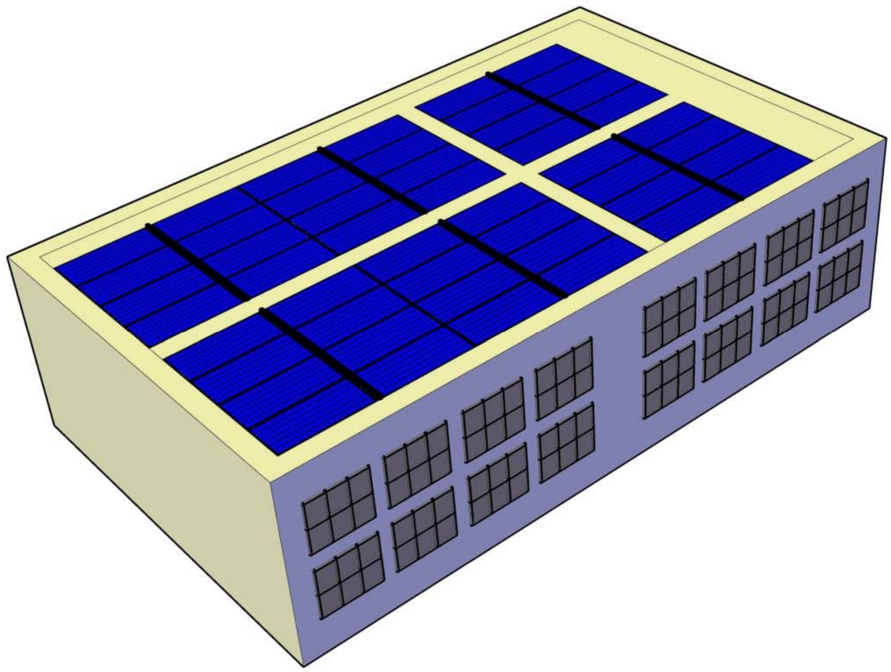


Figure 8: PowerMembrane Sample Array Layout

2.2.5 Installation and Handling Notes

All specifications and requirements of the *UNI-SOLAR* installation guides apply to the installation of the *UNI-SOLAR* laminates.

Attachment of the PowerMembrane to the roof will depend on the existing roof specification. When joining similar materials, the attachment will utilize standard roofing industry methods used to join the seams in a membrane roof (heat welding or priming the area and applying a 4” seam tape). *UNI-SOLAR* recommends that you consult with the existing roof manufacturer to obtain a project specific recommendation when attaching to a dissimilar material such as a coated roof or a built-up roof. In all cases, contact the roofing manufacturer for recommendations on cleaning and preparing the membrane before heat welding or applying seam tape. Table 3 outlines roof types, recommended PowerMembrane material, and a recommended attachment detail.

Table 3: PowerMembrane Attachment Guidelines

Existing Roof Material	PowerMembrane Material	Attachment Specification
TPO	TPO	Heat weld or primer and seam tape
EPDM	EPDM	Primer and seam tape

Existing Roof Material	PowerMembrane Material	Attachment Specification
Built-up	TPO or EPDM	Secondary adhesive primer and seam tape
Coated Roof System	TPO or EPDM	Specialty primer, seam tape, and perimeter coating detail

During installation, be sure to handle and transport the PowerMembrane appropriately. The PowerMembrane should be stored flat and may be stacked as long as no scratching of the laminate or damage to the terminals occurs.

Several methods are employed by Uni-Solar partners to transport the PowerMembrane and lift to the roof. One common method involves placing the PowerMembrane on a flat platform and lift to the roof using a crane. For ease of shipping and lifting with a smaller platform, the PowerMembrane assembly may be folded lengthwise between the laminates such that the roof membrane creases and the Uni-Solar laminates are not bent or creased.

Roll the PowerMembrane on a 20” rigid tube and lifting to the roof with a grade-all has also been employed, but care must be taken not to stress the terminals (especially on the PVL series)and to ensure that the minimum radius of the laminate is not exceeded.

Once laminates are installed on the roof, minimize any foot traffic over the array. Do not place tools and material handling equipment (roof carts) on, or allow them to run across, the array.

2.2.6 Labor Case Study

Table 4 shows averages for a PowerMembrane installation under good conditions with efficient labor performance and is an example of a union roofing labor installation of an ~970 kW installation in North America. Note that the time frames in the table do not include the production of the PowerMembrane mats in a controlled warehouse-like environment. These are strictly roofing installation guidelines only and must not be used for all projects.

Table 4: PowerMembrane Installation Averages

	kW/Day	Crew	Total Hours	kW per man-hour	kW per man-day	# PVL per man-hour	# PVL per man day
Ramp-up and overall project	44.6	16.5	132	0.34	2.73	2.37	18.93

Refer to the appendixes for the PowerMembrane labor case study.

2.2.7 Wind Resistance

The wind uplift rating of a PowerMembrane assembly to a roof is typically driven by the wind uplift resistance of the roof system due to the low profile and high strength of the adhesive. Testing conducted in accordance with FM Standard 4470 and Miami-Dade TAS 114-95 resulted in the failure of the underlying roof system at over 270 psf. While the design pressure applied to a building cladding component varies based on building height, geometry, and location on the roof, 270 psf is sufficient to withstand Class III Hurricane winds of 130 MPH in most cases. Refer to Section 7 of this document for information on certifications and approvals.

2.2.8 Reference Project Photo

Figure 9: Reference Project Photo for Bonding to Removable Single-Ply Membranes

2.3 Direct Bond to Standing Seam Metal Roofs

The *UNI-SOLAR* application **direct bond to standing seam metal roofs** consists of installing the *UNI-SOLAR* laminate directly to a metal roofing pan. Laminates are field-applied to an approved roofing panel in accordance with all specifications of the installation guide.

Applicable *UNI-SOLAR* products include the PVL and ePVL series. *UNI-SOLAR* does not supply a completed PowerMembrane assembly.

2.3.1 Applicable Roof Types

You can apply the *UNI-SOLAR* PVL product to standing seam roofing panels meeting the following requirements:

- Minimum 16” wide space between the seams

- Steel substrate material
- Panel coating approved by *UNI-SOLAR*
- All requirements of the installation guide and *Approved Substrates* list.

2.3.2 Design Notes

UNI-SOLAR modules must be located such that all requirements of the installation guide are met including avoiding areas of ponding water on the roof and avoiding panel lap seams.

2.3.3 Roofing Considerations

Standing seam roofs are typically constructed with vertical seams spaced from 12" to 24" on center. The metal roofing pans are terminated with a ridge cap flashing on the ridge and extend down the slope. On larger buildings, several lengths of roofing panel are commonly used with lap seams joining the sections.

Due to the width of the *UNI-SOLAR* PVL product series (15.5") and ePVL product series (14.5"), narrow standing seam panels are not suitable for direct bond.

2.3.4 Array Layout

UNI-SOLAR laminates are typically installed starting as close to the ridge line as possible, and the design should simply locate the laminates at the same spacing as the roofing panel standing seams.

In the area where one roofing panel ends a lap seam joins that panel to the next. Lap seams should be avoided in the design of the *UNI-SOLAR* system due to the fasteners and thermal movement that occurs at these joints. Any area where a fastener protrudes through the metal panel must be avoided.

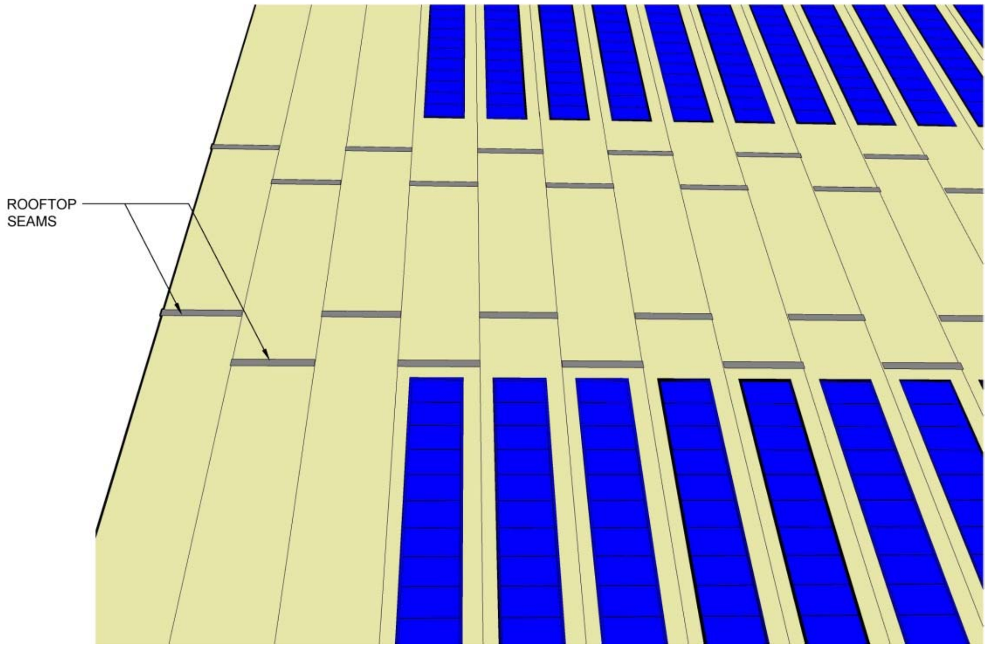


Figure 10: Example of Lap Seams in Metal Roofing

Between the ends of two laminates where the terminals and wire leads are located, spacing must be provided for a WMS. The chapter *Wire Management Systems*, which starts on page 41, provides details on various wire management solutions; however, 5” is the required spacing for the specialty PVC WMS and is a recommended spacing for baseline design purposes. Ensure that final design documentation complies with all requirements of the Installation Manuals, including application of the strain relief pad for the PVL series modules.

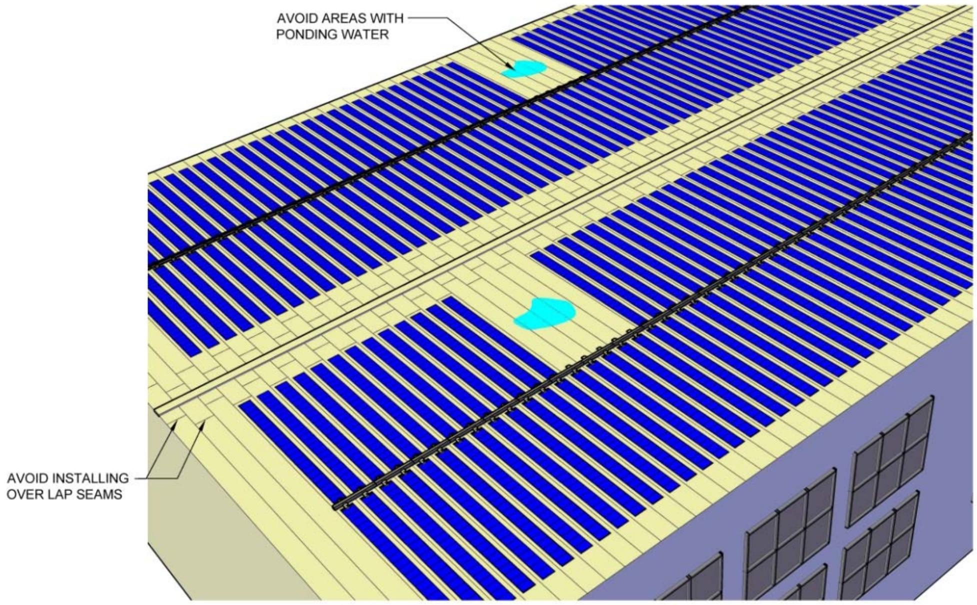


Figure 11: Direct Bond to Standing Seam Metal Roof Sample Array Layout

2.3.5 Installation and Handling Notes

All specifications and requirements of the *UNI-SOLAR* installation guides apply to the installation of the *UNI-SOLAR* laminates.

Once laminates are installed on the roof, minimize any foot traffic over the array. Do not place tools and material handling equipment (roof carts) on, or allow them to run across, the array.

2.3.6 Wind Resistance

The wind uplift rating of a *UNI-SOLAR* laminate directly bonded to a roof is typically driven by the wind uplift resistance of the roof system due to the low profile and high strength of the adhesive. Testing conducted in accordance with FM Standard 4470 and Miami-Dade TAS 114-95 resulted in the failure of the underlying roof system at over 270 psf. While the design pressure applied to a building cladding component varies based on building height, geometry, and location on the roof, 270 psf is sufficient to withstand Class III Hurricane winds of 130 MPH in most cases.

2.3.7 Reference Project Photo

Figure 12: Reference Project Photo for Direct Bond to Standing Seam Metal Roofs

2.4 Standing Seam Metal Roofs Not Suitable for Direct Bond

Some standing seam metal roofs are not suitable for direct bond. The *UNI-SOLAR* application for **standing seam metal roofs not suitable for direct bond** consists of installing the *UNI-SOLAR* laminate to a new metal roofing pan that is secured to the existing roof. Laminates are field or factory-applied to an approved roofing panel in accordance with all specifications of the installation guide.

An alternate solution for an unsuitable standing seam metal roof consists of overlaying the metal roof with an insulation filler and new membrane roof. Refer to the previous sections regarding membrane applications for installation to a new membrane roof.

Applicable *UNI-SOLAR* products include the PVL and ePVL series.

2.4.1 Applicable Roof Types

Roof types suitable for this application are standing seam roofs with seams less than 16” on center, pans with ribbed profiles, or widely spaced seams that excessively reduce power density.

2.4.2 Design Notes

Panel Design

You should size new standing seam metal pans to minimize shading from the standing seams and maximize power density on the roof. *UNI-SOLAR* recommends a configuration with 16” wide panels and 1” vertical seams. A structural engineer must determine the details of material finish, gauge, and profile based on the expected environmental loads and applicable building codes at the project site.

Panel Layout

The array design should position panels parallel to the roof slope at the panel width spacing. Standing seam panels do not require additional space between panels for fastening.

You must provide spacing for a WMS between the ends of two laminates, where the terminals and wire leads are located. Details on various wire management solutions are provided in the chapter *Wire Management Systems*, which starts on page 41. However, 5” is the required spacing for the specialty PVC WMS and is a recommended spacing for baseline design purposes. Ensure that final design documentation complies with all requirements of the Installation Manuals, including application of the strain relief pad for the PVL series modules.

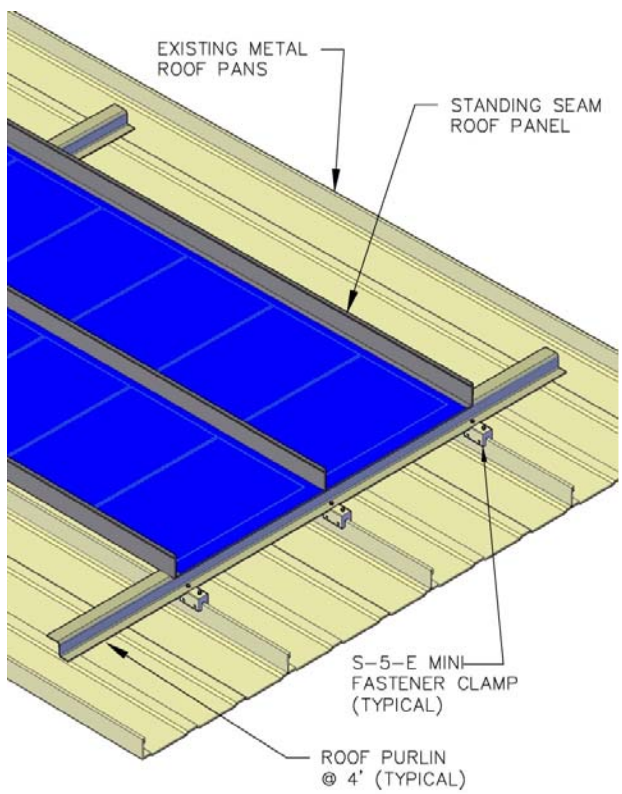


Figure 13: Standing Seam Panels Installed Over Existing Metal Roof

Panel Attachment

The panels are supported by a Z purlin system and attached to the purlins via standing seam clips. The Z purlins are secured to the existing standing seam roof with S-5! Seam clamps. A structural engineer must determine purlin spacing, gauge, profile, and clamp locations based on the expected environmental loads and applicable building codes at the project site.

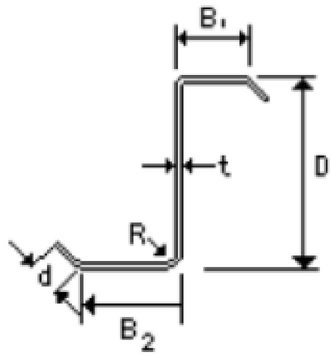


Figure 14: Typical Z Purlin Profile

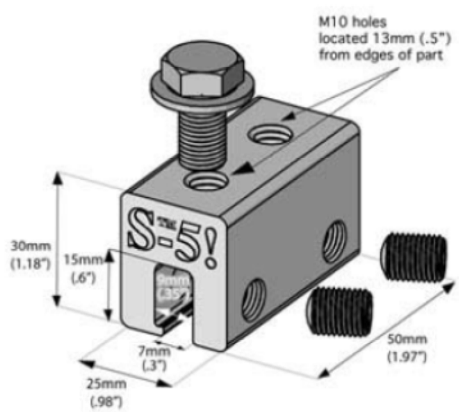


Figure 15: S-5! Seam Clamp Detail

2.4.3 Installation and Handling Notes

All specifications and requirements of the *UNI-SOLAR* installation guides apply to the installation of the *UNI-SOLAR* laminates to the metal pans. Once *UNI-SOLAR* laminates have been installed on metal panels, be sure to take care in the transportation and handling of the panels to avoid damage to the laminate ETFE top sheet and terminals.

Once laminates are installed on the roof, minimize any foot traffic over the array. Do not place tools and material handling equipment (roof carts) on, or allow them to run across, the array.

2.4.4 Wind Resistance

The wind uplift rating of the new metal panel assembly will be determined by the project structural engineer specifying the metal panels, purlins, and clamp details.

2.4.5 Reference Project Photo

Figure 16: Reference Project Photo for Standing Seam Metal Roofs Not Suitable for Direct Bond

2.5 Corrugated Metal Roofs

Corrugated metal roofs are not suitable for direct bond of *UNI-SOLAR* laminates. The *UNI-SOLAR* application for **corrugated metal roofs** consists of installing the *UNI-SOLAR* laminates to a lightweight, new standing seam roofing system that serves as the mounting surface for a solar photovoltaic generation system. Laminates are field or factory-applied to an approved roofing panel in accordance with all specifications of the installation guide.

An alternate solution for a corrugated metal roof consists of overlaying the metal roof with an insulation filler and new membrane roof. Refer to the previous sections regarding membrane applications for installation to a new membrane roof.

Applicable *UNI-SOLAR* products include the PVL and ePVL series.

2.5.1 Applicable Roof Types

Roof types suitable for this application include most lap-seam corrugated metal roofs and standing seam roofs requiring a new waterproofing roof surface.

2.5.2 Design Notes

Panel Design

You should size new standing seam metal pans to minimize shading from the standing seams and maximize power density on the roof. *UNI-SOLAR* recommends a configuration with 16” wide panels and 1” vertical seams. A structural engineer must determine the details of material finish, gauge, and profile based on the expected environmental loads and applicable building codes at the project site.

Panel Layout

This application provides a new standing seam metal roof over the existing roof deck. You must lay out roofing panels to cover the entire roof surface targeted for *UNI-SOLAR* installation from the ridge to the eave. You should locate *UNI-SOLAR* laminates in the most optimal areas of the new proposed standing seam roof.

You must provide spacing for a WMS between the ends of two laminates, where the terminals and wire leads are located. Details on various wire management solutions are provided in the chapter *Wire Management Systems*, which starts on page 41. However, 5” is the required spacing for the specialty PVC WMS and is a recommended spacing for baseline design purposes. Ensure that final design documentation complies with all requirements of the Installation Manuals, including application of the strain relief pad for the PVL series modules.

Panel Attachment

The standing seam panels are supported by a low-profile structural purlin system. Roof Hugger® purlins are fabricated to fit the existing roof profile and tie into the existing roof structure, in many cases adding load bearing capacity to the roof. Standing seam panels are secured to the roof hugger purlins via standing seam clips.

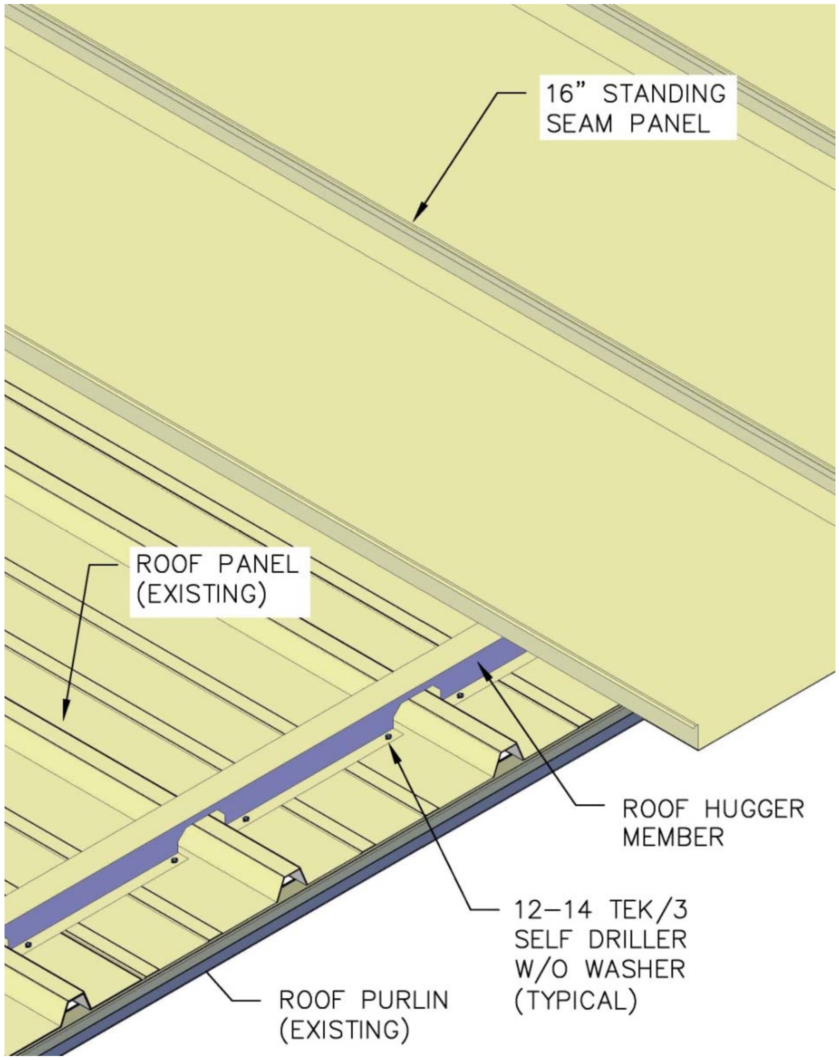


Figure 17: New Standing Seam Roof Over Existing Metal Deck

2.5.3 Installation and Handling Notes

All specifications and requirements of the *UNI-SOLAR* installation guides apply to the installation of the *UNI-SOLAR* laminates to the metal pans. Once *UNI-SOLAR* laminates have been installed on metal panels, be sure to take care in the transportation and handling of the panels (if not already installed as the roof system) to avoid damage to the laminate ETFE top sheet and terminals.

Once laminates are installed on the roof, minimize any foot traffic over the array. Do not place tools and material handling equipment (roof carts) on, or allow them to run across, the array.

2.5.4 Wind Resistance

The wind uplift rating of the new metal panel assembly will be determined by the project structural engineer specifying the metal panels, purlins, and clamp details.

2.5.5 Reference Project Photo

Figure 18: Reference Project Photo for Corrugated Metal Roofs

2.6 Bonding to Modified Bitumen Roofs

The *UNI-SOLAR* application **bonding to modified bitumen roofs** consists of installing *UNI-SOLAR* laminates to a new modified bitumen roof surface. Laminates are field-applied to an approved roof surface using secondary adhesives specified on the *Approved Substrates* list, in accordance with all specifications of the installation guide.

Applicable *UNI-SOLAR* products include the PVL and ePVL series.

2.6.1 Applicable Roof Types

The modified bitumen roof substrate must be listed on the *UNI-SOLAR Approved Substrates* list.

2.6.2 Design Notes

UNI-SOLAR modules must be located such that all requirements of the installation guide are met, including avoiding areas of ponding water on the roof and not installing *UNI-SOLAR* laminates over seams in the roofing membrane.

2.6.3 Roofing Considerations

Modified bitumen roofing is typically installed by rolling out the roofing material over the underlying roof assembly and attaching the material with hot asphalt or an adhesive.

A lap seam with one piece overlaying the adjacent piece is common at the junction between two rolls of material. These joints typically create a difference in height of 0.5" between the two surfaces and must be identified and avoided in the design of the *UNI-SOLAR* array. Similar seams at the end of a roll should be caulked to provide a smooth transition as the laminate crosses the joint.

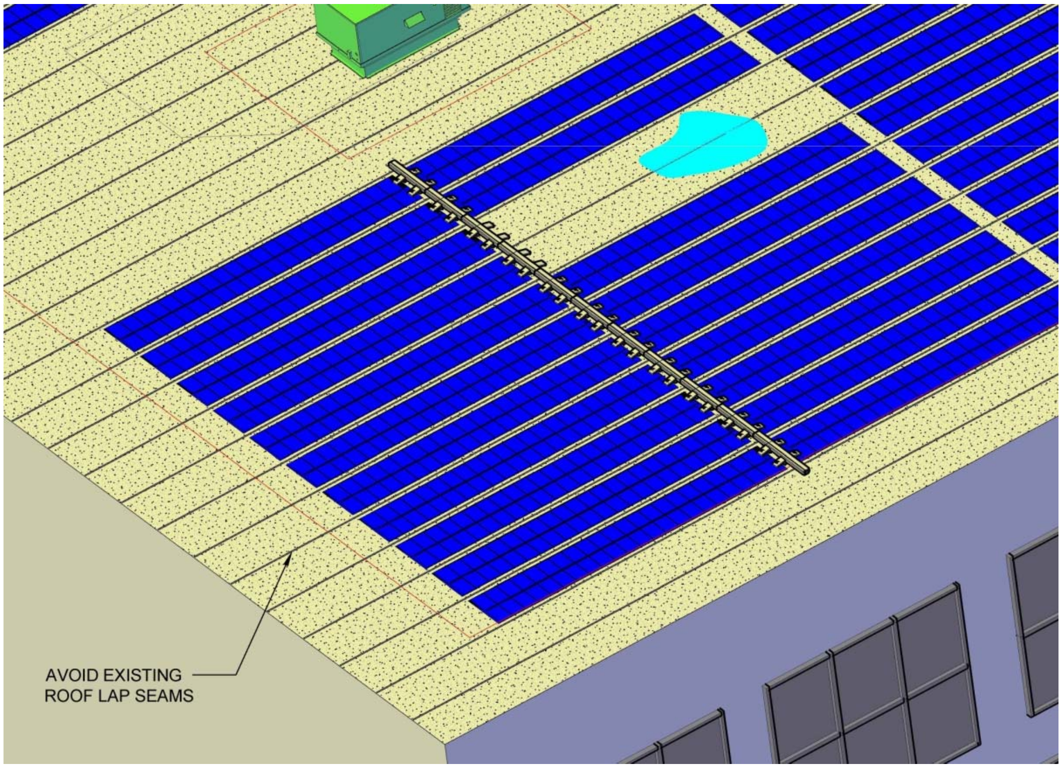


Figure 19: Sample Array Layout on Modified Bitumen Roof

2.6.4 Array Layout

A typical dimension of this type of roofing material allows for the installation of two *UNI-SOLAR* laminates between lap joints.

You must provide spacing for a WMS between the ends of two laminates, where the terminals and wire leads are located. Details on various wire management solutions are provided in the chapter *Wire Management Systems*, which starts on page 41. However, 5" is the required spacing for the specialty PVC WMS and is a recommended spacing for baseline design purposes. Ensure that final design documentation complies with all requirements of the Installation Manuals, including application of the strain relief pad for the PVL series modules.

2.6.5 Installation and Handling Notes

All specifications and requirements of the *UNI-SOLAR* installation guides apply to the installation of the *UNI-SOLAR* laminates. Be sure to handle and transport the laminates appropriately during installation.

Once laminates are installed on the roof, minimize any foot traffic over the array. Do not place tools and material handling equipment (roof carts) on, or allow them to run across, the array.

2.6.6 Reference Project Photo

Figure 20: Reference Project Photo for Bonding to Modified Bitumen Roofs

2.7 PowerTilt for Commercial Roofs

The *UNI-SOLAR* application **PowerTilt for commercial roofs** consists of installing the *UNI-SOLAR* PowerTilt system on a flat commercial roof. Installation must be in accordance with all specifications of the installation guide.

The applicable *UNI-SOLAR* product is the PowerTilt.

2.7.1 Applicable Roof Types

The roof slope must be less than 10 degrees.

2.7.2 Design Notes

The PowerTilt product is supplied as a kit including of 5, 6, or 10 *UNI-SOLAR* PowerTilt modules and includes the supports rails, ballast tray footings, wire management tray, all required hardware, and a grounding kit. You can order modules with terminals and cable leads on either end of the laminate in a left or right configuration.

2.7.3 Array Layout

The PowerTilt system allows adjacent sub-array kits to share base supports between arrays in both the north-south direction and the east-west direction of the array. You can locate 5, 6, or 10-panel kits such that the array is continuous, leaving aisles and clearances as required by local code. You must also provide enough space around the units that require frequent service and maintenance on the roof, even when shading effect is not a concern. It is imperative to run the final layout design and plans by facilities' management to ensure that the system layout does not interfere with regular maintenance operations. You should also provide for clearance from expansion joints, gas lines, and roof edges.

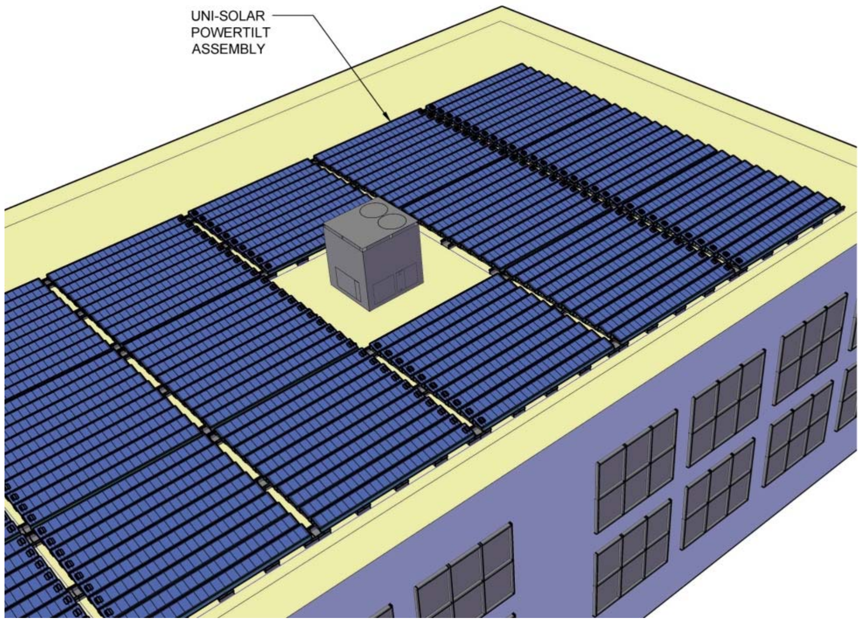


Figure 21: PowerTilt Sample Array Layout

2.7.4 Electrical Design Considerations

You should select a combination of kits (5, 6, and/or 10) that will allow for the optimal array layout on the roof and to accommodate the correct string length (typically 10, 11, or 12 in series).

You should design any areas of the array that are two modules wide (east-west direction) such that one row is specified with left modules and one is specified with right modules and the arrays share a single wire tray between them. *UNI-SOLAR* highly recommends joining as many PowerTilt sub-arrays as possible to reduce ballasting and the amount of hardware required.

2.7.5 Ballasting Guidelines

The PowerTilt system has undergone wind tunnel testing and snow accumulation analysis. For details on ballasting a PowerTilt array, consult the RWDI report *Wind Pressure and Snow Accumulation UNI-SOLAR Tilt Pan System* and the *UNI-SOLAR* document *PowerTilt Ballasting Guidelines: Using the RWDI Report*.

UNI-SOLAR Applications Engineering provides layouts and complete ballasting plans for PowerTilt projects for review by the customer's local structural engineer.

2.7.6 Project Logistical Planning

Following the design phase, the execution sequence of the installation must be determined in conjunction with the project timeline to plan the transfer of material to the construction site. Depending on truck loads, number of trucks that could be received at once and site space constraints, the system layout could be divided in sections and consequently the hardware bill of material (BOM) for each could be determined. Typically, a flat bed truckload consists of 12 crates (360 total pans). This number could be used as a base to determine roof sections. Based on the productivity of the installation crew and site space constraints, the schedule for transferring material and the frequency could be set. Figure 22 and Figure 23 contain examples to illustrate this process.

Figure 22: Sample PowerTilt Installation Sequencing Plan

				kW / day		USO loads 12 crates (Batch #1) on Friday 9/16 to arrive on day1	
Week1	Mon	9/19/2011	Day1	1	Truck 1	Truck leaves (USO) at **6 a.m** to arrive by **NOON**/Installers unload Truck 1 - Crates Batch #1	Empty truck goes back empty
	Tue	9/20/2011	Day2	16			
	Wed	9/21/2011	Day3	17		USO loads 12 crates (Batch #2) to arrive on day 4	
	Thu	9/22/2011	Day4	17	Truck 2	Truck to arrvie by **NOON**/Installers unload Truck 2 - Crates Batch #2	Installers load 12 empty crates (Batch #1) on truck 2 back to USO
	Fri	9/23/2011	Day5	17			Truck 2 (loaded w/empty crates) arrives at USO @ 8 a.m.
Week2	Mon	9/26/2011	Day6	17		USO loads 12 crates (Batch #3) on Truck 3 to arrive on day 7	
	Tue	9/27/2011	Day7	17	Truck 3	Truck to arrive to the site by **NOON**/Installers unload Truck 3 - Crates Batch #3	Installers load 12 empty crates (Batch #2) on truck 3 to go back to USO
	Wed	9/28/2011	Day8	17			Truck 3 (loaded w/empty crates) arrives at USO @ 8 a.m.
	Thu	9/29/2011	Day9	17		USO loads 12 crates (Batch #4) on truck 4 to arrive on day 10	
	Fri	9/30/2011	Day10	17	Truck 4	Truck to arrive to the site by **NOON**/Installers unload Truck 4 - Crates Batch #4	Installers load 12 empty crates (Batch #3) on truck 4 to go back to USO
Week3	Mon	10/3/2011	Day11	17			Truck 4 (loaded w/empty crates) arrives at USO @ 8 a.m.
	Tue	10/4/2011	Day12	17		USO loads 12 crates (Batch #5) on truck 5 to arrive on day 13	
	Wed	10/5/2011	Day13	17	Truck 5	Truck to arrive to the site by **NOON**/Installers unload Truck 5 - Crates Batch #5	Installers load 12 empty crates (Batch #4) on truck 5 to go back to USO
	Thu	10/6/2011	Day14	17			Truck 5 (loaded w/empty crates) arrives at USO @ 8 a.m.
	Fri	10/7/2011	Day15	17		USO loads 12 crates (Batch #1) on Truck 6 to arrive on day 16	
Week4	Mon	10/10/2011	Day16	17	Truck 6	Truck to arrive to the site by **NOON**/Installers unload Truck 6 - Crates Batch #1	Installers load 12 empty crates (Batch #5) on truck 6 to go back to USO
	Tue	10/11/2011	Day17	17			Truck 6 (loaded w/empty crates) arrives at USO @ 8 a.m.
	Wed	10/12/2011	Day18	17		USO loads 12 crates (Batch #2) on Truck 7 to arrive on day 19	
	Thu	10/13/2011	Day19	17	Truck 7	Truck to arrive to the site by **NOON**/Installers unload Truck 7 - Crates Batch #2	Installers load 12 empty crates (Batch #1) on truck 7 to go back to USO
	Fri	10/14/2011	Day20	17			Truck 7 (loaded w/empty crates) arrives at USO @ 8 a.m.
Week5	Mon	10/17/2011	Day21	17		USO loads 12 crates (Batch #3) on Truck 8 to arrive on day 22	
	Tue	10/18/2011	Day22	17	Truck 8	Truck to arrive to the site by **NOON**/Installers unload Truck 8 - Crates Batch #3	Installers load 12 empty crates (Batch #2) on truck 8 to go back to USO
	Wed	10/19/2011	Day23	17			Truck 8 (loaded w/empty crates) arrives at USO @ 8 a.m.
	Thu	10/20/2011	Day24		Truck 9	Empty Truck arrives on site	Installers load 12 empty crates (Batch #3) on truck 9 to go back to USO
	Fri	10/21/2011	Day25				Truck 9 (loaded w/empty crates) arrives at USO @ 8 a.m.
		Total		374		**End of installation**	

Figure 23: Sample PowerTilt Logistics Sequencing Plan

2.7.7 Installation and Handling Notes

All specifications and requirements of the *UNI-SOLAR* installation guides apply to the installation of the *UNI-SOLAR* PowerTilt system. Be sure to handle and transport the PowerTilt modules appropriately during installation.

Laminates of the PowerTilt system are factory-applied to the pans and loaded to wooden crates that can hold 30 pans in each. Once unloaded off the truck, loaded crates can be taken up to the roof installation areas with equipment that can handle the weight in an effort to minimize handling of pans on the ground, and to increase productivity and efficiency. However, fully loaded crates weigh more than 1200 pounds. *UNI-SOLAR* highly recommends, based on the roof condition, not to lay the crate down on the roof surface, and to make sure that the crate stays above the roof surface. All roof loading of panels must be approved by a professional structural engineer.

2.7.8 Labor Case Study

The following productivity data is based on a rooftop non-union labor of a ~440 kW DC with (3,040) *UNI-SOLAR* PT-144 PV modules in North America. Installation training was provided to the installer's superintendent before the project began, but the installation crews had no prior training or experience with the PowerTilt system. On-site personnel completed daily reports that detail the crew size, work completed, weather, and other data about the conditions on site. The crew size, hours worked, and number of PowerTilt pans installed in a day are important metrics that were captured and are used in this analysis to determine the PV capacity (kW) installed per labor hour.

The scope of work of this labor study is strictly for the mechanical installation of the PowerTilt system. Specific activities of this scope include:

- Unloading flatbeds
- Shipping PowerTilt crates to the jobsite (assumes no onsite storage)
- Transporting material to the roof (assumes adequate access and staging for the crane and materials)
- Layout and locating the array
- Assembly of the PowerTilt ballasted framing system
- Ballasting the array with paver blocks
- Installation of integrated wire trays
- Installation of the PowerTilt pans
- Ground testing

Activities not included in this scope include:

- Interconnection of the PowerTilt module leads
- Wiring from the panels to combiner boxes
- Combiner box installation

- Inverter installation
- Any other electrical, site work, or structural work

In this case study, weather (including rain and high winds) was an important factor during construction. When safe, the crews performed work through rain and wind; however, when the crew did not work due to weather, only the hours worked were included in the total hours for the day. This guide is based on a sample project that was installed from April to June in North America. Productivity may be adversely affected during winter months and should be taken into consideration.

This crew is based on an eight-man crew that had never installed the PowerTilt system. As a result, there was a learning curve to overcome in the beginning of the installation. Once the crew became familiar with the PowerTilt system, the installation rate increased. Installation hours provided below are inclusive of all phases of the installation including ramp-up. The labor hours presented below are inclusive of reasonable minor array relocation work due to misinterpretation of drawings. Significant array relocation labor and the associated structural evaluation are not within the scope of this case study, but the developer should be aware of the structural engineering evaluation required to design any ballasted PV array or modify the array design in the field. Productivity data was as follows:

- **Total labor hours:** 2126
- **Total installed kW:** 437.76
- **kW per labor hour:** 0.206

This data will be different in the case of removing a section or several sections of the array. Activities such as disconnecting the fuses and strings, removing cables and conduit for the sections to be disassembled have to be planned. Based on the roof space and the distances to be traveled in order to stage the disconnected sub-arrays material, the productivity data above is expected to change and improve since activities such as loading/unloading trucks, transferring material to the roof and to the installation areas are unlikely to be required again. However, times that will be shown in these cases will have to be doubled since the same amount of time to disassemble the sub-array will be required to assemble it again. Based on time studies conducted during installation trials strictly for mechanically assembling the frame of a 10 PT-144 sub-array system, productivity data was as follows:

- **Total labor hours:** 3.2
- **Total installed kW:** 1.440
- **kW per labor hour:** 0.450

Another installation trail was conducted for assembling a 40 PT-144 system on a ballasted roof. The productivity data collected includes the assembly times of the frames, the labor time that was required for transferring material from the edge (the off loading area) of the roof to the installation area, and the time that was required to markup the roof and ballast the system. Productivity data for that activity was as follows:

- **Total labor hours:** 19.20
- **Total installed kW:** 5.760

- **kW per labor hour:** 0.300

It is important to point out that the above data will vary from one construction site to another based on weather, storage and staging areas allocated, the size of the roof and the installation area, and roof loading accessibility and feasibility. Moreover, the data will also depend on the productivity of the installation crews, compliance with the certification processes, familiarity with the installation of the product, and the accuracy and the clarity of the design drawings.

Refer to the appendixes for the PowerTilt labor case study.

2.7.9 Wind Resistance

The PowerTilt system can be engineered for wind speeds up to 125 mph. Refer to *PowerTilt Array Ballast Guidelines* for additional details on determining the required ballast for a PowerTilt array. A locally licensed structural engineer should review and approve any ballast calculations.

2.7.10 Reference Project Photo

Figure 24: Reference Project Photo for PowerTilt for Commercial Roofs

3 Rooftop Array Design Considerations

This chapter discusses the following solar design parameters that the designer should consider when designing a rooftop PV system for any *UNI-SOLAR* application:

- Setbacks
- Shading
- Fire code requirements

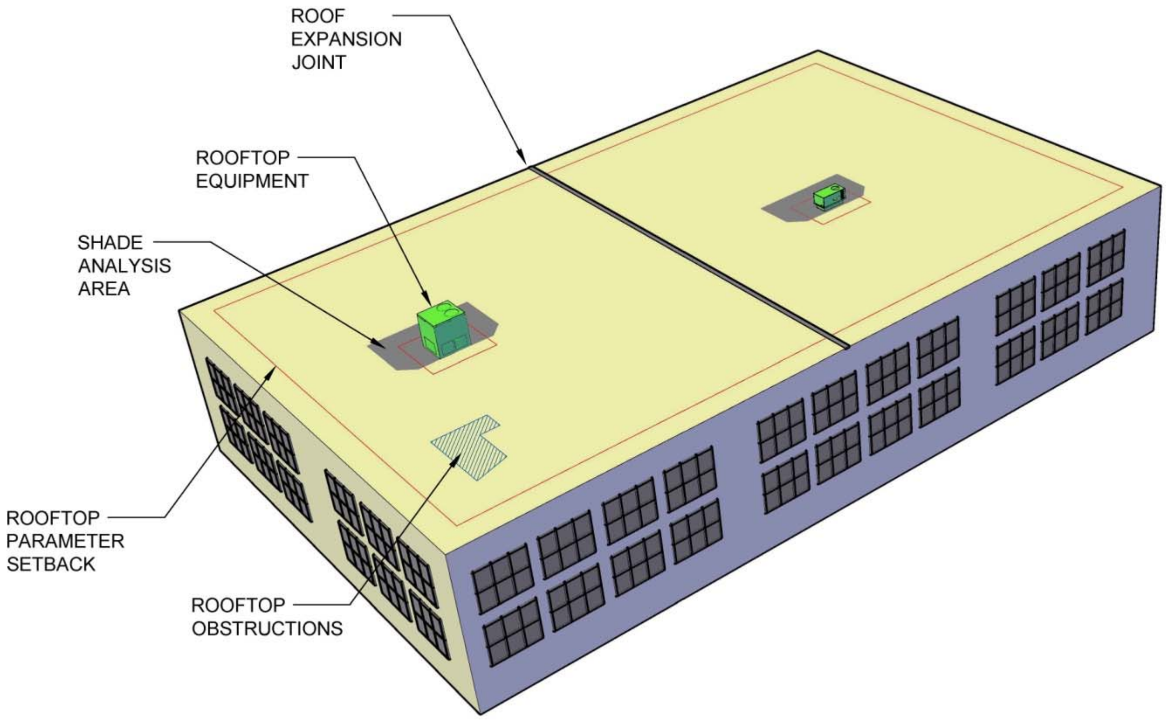


Figure 25: Building Rendering with Solar Design Considerations Identified

3.1 Setbacks

The U.S. OSHA requires a six-foot setback from the roof perimeter, or else the installers and maintenance personnel working on the array must have complete fall restraint if sufficient parapets are not present. OSHA also requires the use of hard hats during loading and unloading. As a general practice, *UNI-SOLAR* recommends a six-foot setback from all roof edges. You should also provide an additional setback for mechanical equipment requiring service. *UNI-SOLAR* recommends a four-foot setback for mechanical equipment.

3.2 Shading

Avoid shading from rooftop equipment, structural elements of a building, and nearby trees or other buildings to minimize the impact on production of the *UNI-SOLAR* array. An on-site analysis using a Solar Pathfinder or other shading analysis tool can provide the designer valuable information on the impact of shading on solar resource.

CAD-based design tools provide another method of evaluating a rooftop for areas with less than ideal solar resource. The *UNI-SOLAR* Design Engineering team performs shading analyses using an internally developed AutoCAD script. Since the sun's path varies throughout the year, shade lines are drawn for the summer solstice, winter solstice, and the equinox. The positions of the shade points at each hour between 8:00 am and 4:00 pm are calculated based on an input site latitude and obstruction height. The output displays shade lines from a "pole" shading object; for rectangular units this object is copied to all four corners of the obstruction.

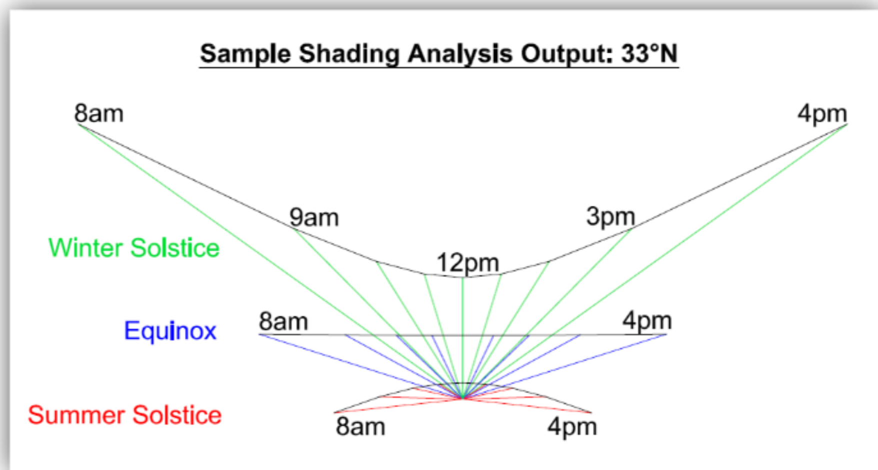


Figure 26: Sample Shading Analysis Tool Output

The output of the shading tool is then used to create hatched grey shade splashes on the roof. The shade splash typically covers 8:00 am to 4:00 pm in the summer, 8:00 am to 4:00 pm at the equinox, and 9:00 am to 3:00 pm at the winter solstice. During the winter, the 8:00 am to 9:00 am hour and the 3:00 pm to 4:00 pm hour typically cast very long shadows. Because very little energy is captured during that time, these hours are typically excluded from the shade splash.

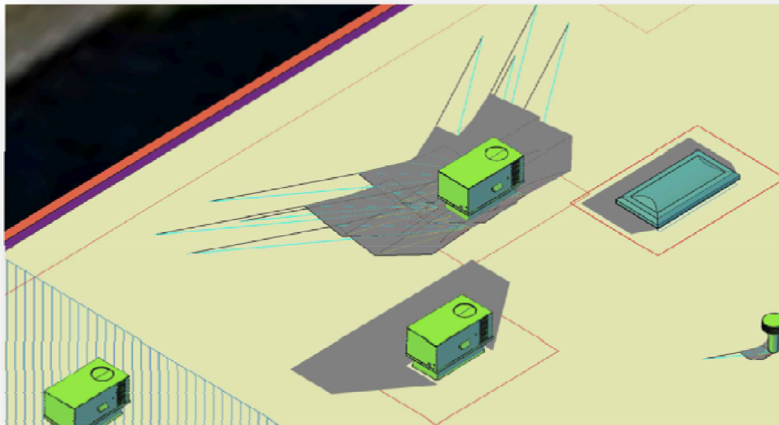


Figure 27: Shading Analysis Inserted on Roof Plan

3.3 Fire Code Requirements

Local codes vary and should be consulted in the design of a particular PV system. However, many jurisdictions and codes are adopting guidelines published by the California Office of the State Fire Marshall (CAL FIRE). The CAL FIRE guidelines are available at:

`http://gov.ca.gov/docs/ec/CalFIRE_Solar_PV_guideline.pdf`

You should review this document; however, in general, a commercial array must be limited to a 150' x 150' sub-array with access and ventilation paths between sub-arrays. No formal guidance or exclusions exist for *UNI-SOLAR* applications directly to the roof, although on a case-by-case basis the local fire marshal may review and provide exceptions to certain roof access requirements since the *UNI-SOLAR* array will not prevent roof ingress or egress for emergency personnel.

4 Energy Modeling

This chapter discusses the following factors for energy modeling:

- Energy yield
- Performance modeling
- PV modeling software
- PVSyst (software) modeling guidelines

4.1 Energy Yield

Comparative test sites and performance history of *UNI-SOLAR* PV laminates have a significant history of high energy yields. Numerous third-party test sites have reported excellent kWh/kW yields throughout the world. The *UNI-SOLAR* publication *Comprehensive Overview of Technical Information and Product Performance Data* contains many project references and third-party test sites.

4.2 Performance Modeling

Energy modeling, or forecasting when and how much energy will be delivered by a PV system, is critical to in the development and structuring of any PV project. Because of the differences between *UNI-SOLAR* amorphous silicon technology and crystalline PV, *UNI-SOLAR* makes particular recommendations about how to model energy performance.

4.3 PV Modeling Software

A number of publicly and commercially available energy-modeling software platforms are available, some better suited to modeling *UNI-SOLAR* performance than others. Performance modeling tools can be divided onto two categories: those that model performance on an hourly basis throughout a year of typical environmental data and consider the characteristics of the particular system being analyzed and those that do not. Since *UNI-SOLAR* laminate temperature dependence and spectral sensitivity differ from the characteristics of crystalline PV panels, *UNI-SOLAR* recommends that the modeling tool you use accounts for those factors. *UNI-SOLAR* does not recommend PVWATTS or RET Screen since those tools do not consider A-Si temperature dependence and spectral sensitivity.

UNI-SOLAR recommends PVSyst, a modeling software package based on research conducted by the University of Geneva, as a preferred platform for modeling *UNI-SOLAR* PV systems for three reasons:

- *UNI-SOLAR* laminates were studied and the software adjusts for the spectral sensitivity of A-Si.
- The software can use environmental data from the best available sources.
- The software is known throughout the industry and recognized as a bankable performance modeling package.

PVSyst steps through 8,760 hourly data points and at each hour uses the input environmental data to calculate effective energy at the PV array based on direct irradiance, diffuse irradiance, ambient temperature, and wind speed. That array energy is then derated for system losses, including inverter efficiency curves. The output is an hourly file and summary report for a typical year based on the input environmental data.

4.4 PVSyst Modeling Guidelines

This section provides standardized PVSyst input guidelines for modeling *UNI-SOLAR* PVL laminates.

4.4.1 Meteorological Data

Meteorological data for PVSyst comes from National Renewable Energy Laboratory (NREL) as well as several other data sources.

National Renewable Energy Laboratory (NREL)

PVSyst comes with synthetic weather data from many locations but also allows you to provide weather data from an outside source. An ideal choice is Typical Meteorological Year (TMY) data from NREL, which is now in its third revision (TMY3). TMY3 data represents an average year of solar irradiance (both global and diffuse), ambient temperature, wind speed, and many other parameters in over 1,000 locations across the United States. NREL compiled these sets of data from hourly data taken between 1991 and 2005 in the National Solar Radiation Database (NSRDB), and it can be accessed at:

`http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html`

Other Data Sources

RetScreen, NASA, Meteonorm, and other meteo data providers can be used as data sources for PVSyst simulation. The most accurate data sources will be ground-based measurements located close to the project site. Monthly averages of daily insolation are the least accurate type of meteo input.

4.4.2 Orientation

PVSyst includes orientation settings, where you can set parameters for BIPV and metal roof installations as well as for PowerTilt.

BIPV and Metal Roof Installations

When the *UNI-SOLAR* laminates will be applied directly to a metal or membrane roof, use the **Fixed Tilted Plane** field type in the **Orientation** parameter, and enter the plane tilt and azimuth of the array. For a "flat roof" BIPV installation, the roof is not perfectly flat due to drainage; however, you can assume an average 0 degree slope for simulation purposes. For a sloped roof installation, enter the roof slope and azimuth. PVSyst allows for two different tilt and azimuth entries. Use the **Double Orientation** field type if you have two different slopes on a roof and the array will be tied to a single inverter.

PowerTilt

For PowerTilt applications, select the **Unlimited Sheds** field type, and use the parameters shown in Figure 28 (azimuth is site-specific).

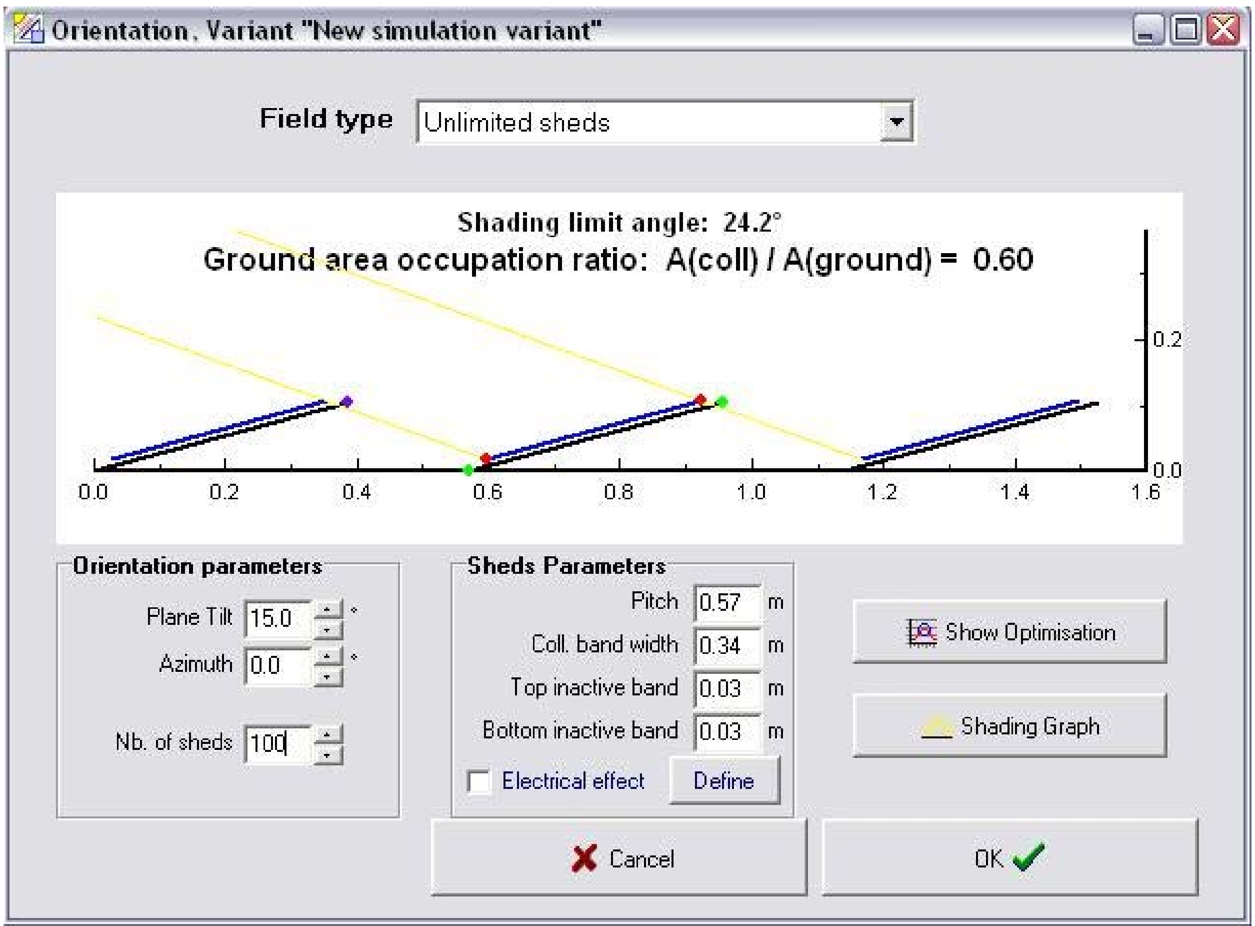


Figure 28: PowerTilt "Unlimited Sheds" Configuration in PVSyst

4.4.3 Model Parameters

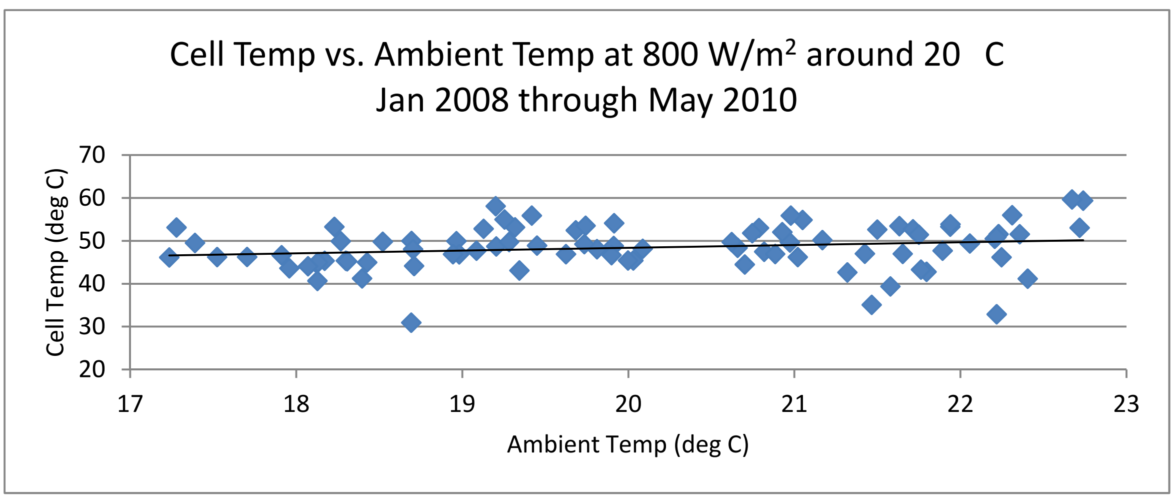
PVSyst allows for customization of its loss parameters. You can access this feature by clicking the **Detailed Losses** button when configuring the inverter and modules in the **System** page.

4.4.4 Thermal Loss Factor

Thermal loss strongly influences the outcome of the simulation. The array's thermal behavior depends on changes in ambient temperature and how the cell temperature responds. The thermal loss factor k characterizes this loss and is determined by observing panel temperature under standardized conditions. This parameter is referred to as the normal operating cell temperature (NOCT). The conditions are 800 W/m^2 of solar irradiance and an ambient temperature of 20° C (68° F).

4.4.5 Derivation of NOCT

The value for NOCT given in the PVL-144 datasheet is for metal-mounted installations and thus does not apply to a building-integrated case, where insulation backing affects the cell temperature behavior. To determine the appropriate NOCT, a study was conducted on a *UNI-SOLAR* installation on the east coast. Two and a half years of performance and weather data that was taken every 15 minutes since 2008 was compiled and analyzed. The data set includes solar irradiance, ambient temperature, kW of AC production, wind speed, and other system data. The first step was to reduce this data down to only those points where solar irradiance fell within 10 W/m^2 of 800 W/m^2. Then it was further sorted to only include points where the ambient temperature was within 3° of 20° C. In this way, those variables were set to be rough constants, fulfilling the required conditions for finding NOCT. The cell temperature under these conditions averaged around 48° C (118° F).



Calculation of k from NOCT

Thermal loss is defined by the equation:

$$k * (T_{cell} - T_{ambient}) = \alpha * G_{inc} * (1 - \eta)$$

Where:

$$k = Thermal\ Loss\ Peramter$$

$$T_{cell} = PV\ Laminate\ Cell\ Temperature$$

$$T_{ambient} = Ambient\ Temperature$$

$$\alpha = Absorbtion\ Coefficient$$

$$G_{inc} = Total\ Incident\ Irridation$$

$$\eta = PV\ cell\ efficiency$$

The factor k can be split into two terms, k_c, a constant, and k_v, a factor proportional to wind speed (v).

$$k = k_c + k_v * v$$

For simplicity, it is acceptable to discard k_v and in turn not take wind velocity into account in the thermal loss calculation.

To find k for *UNI-SOLAR* panels, simply plug values into the first equation. PVSyst suggests a value of 0.9 for α. A value of 6% is used for the PV efficiency. For T_{cell}, T_{amb}, and G_{inc}, use the values from the above study: NOCT of 48° C for T_{cell}, an ambient temperature of 20° C, and 800 W/m^2 of solar irradiance.

Plugging all these terms into the thermal loss parameter equation, k is found to be 23.7 W/$m^2 \cdot k$.

This k value was found using data from an insulation-backed, roof integrated installation, which yields a different NOCT than an installation mounted directly to free standing metal. In the latter case, such as on a PowerTilt system, the NOCT value of 46° C from the PVL-144 datasheet is used, resulting in a k of 25.5 W/$m^2 \cdot k$.

Table 1: PVSyst Thermal Loss Parameter

Installation Type	NOCT	*k*
Free standing (metal)	46° C	25.5 W/$m^2 \cdot$k
BIPV	48° C	23.7 W/$m^2 \cdot$k

> **Note:** When a new k value is entered in PVSyst, the software performs a quick calculation and displays an associated NOCT value in the box to the right for checking. This displayed NOCT value is **not** accurate for *UNI-SOLAR* modules because it is assuming an efficiency of 10%. Disregard this displayed value of NOCT and enter the k factor per Table 5.

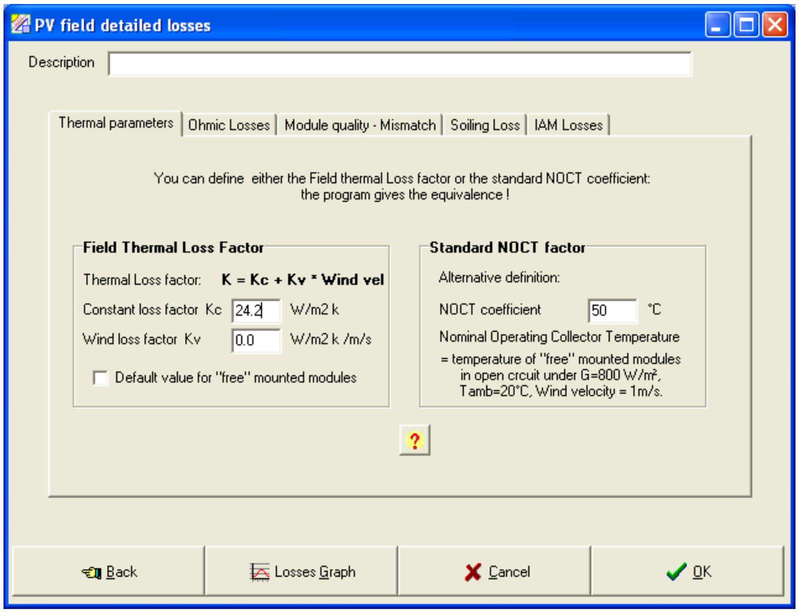


Figure 29: PVSyst Thermal Loss Parameter Input Screenshot

4.4.6 Soiling Loss

PVSyst allows you to enter a soiling loss term, which further improves simulation accuracy by modeling dust and dirt buildup on the array panels.

4.4.7 Geographic Factors

UNI-SOLAR recommends a soiling factor of 1-2% in areas with regular rainfall and 5-7% in a high soiling area and arid climate. Rainfall will clean the panels; however, in dry climates dust and grime will build up on the array and decrease performance. Cleaning the array will reduce the impact of soiling on energy production, and energy models can be customized to reflect cleaning schedules. Refer to *Operations and Maintenance Manual for the UNI-SOLAR PowerBond ePVL* for cleaning procedures and field testing procedures for estimating the impact of soiling.

4.4.8 Snowfall Losses

When covered by snow, a solar PV system produces little or no energy. Solar photovoltaic energy yield modeling packages do not account for the impact of snowfall on the system output, and a post-simulation correction must be made to account for the impact of snow on annual production. *UNI-SOLAR* conducted research and analysis on sites in snowfall areas and documented the results in *Impact of Snowfall on UNI-SOLAR PV System Yield*. The research results in loss factors (a percentage drop in Normalized Performance Index), which is applied to the monthly energy production values from PVSyst. Two sets of loss recommendations are presented for sites with flat roof installations and sites with sloped installations of 15 degrees or more.

Table 6: Snowfall Losses for Flat Roof *UNI-SOLAR* Installations

Inches of Snow	Drop in NPI
0-5"	10%
5-10"	20%
10-15"	30%
>15"	40%

Table 7: Snowfall Losses for Sloped *UNI-SOLAR* Installations ≥ 15°

Inches of Snow	Drop in NPI
0-5"	5%
5-10"	10%
10-15"	20%
>15"	30%

4.4.9 Model Outputs

Sample PVSyst reports and snowfall correction reports are included in the appendixes.

5 Wire Management Systems

UNI-SOLAR laminates require a wire management system (WMS) to manage the cable leads between modules and the cable runs back to rooftop combiner boxes or inverters. Several options for wire management are available that you can evaluate for cost, appearance, wind resistance, and snow loading.

Balance of system requirements are different for the *UNI-SOLAR* PVL and ePVL product lines. The PVL products require a secondary strain relief and a cover for the terminals to avoid direct prolonged UV exposure. Those requirements do not apply to the ePVL products. Consult the installation guides for complete installation specifications.

5.1 PVC WMS

UNI-SOLAR developed the PVC WMS for flat commercial roof applications. The material is UV-stabilized and PVC-rated for outdoor exposure.

5.1.1 Components

The PVC WMS features three components: the base, the tray, and the cover. The base of the WMS is secured to the roof, and the tray and cover snap-lock into the base.

Figure 30: PVC WMS Installation

5.1.2 Roof Attachment

The base of the PVC WMS secures the assembly to the roof. The base may be adhered to the roof with a roofing tape or held down with a strap of membrane heat welded to the roof.

5.1.3 Wind and Snow Loading

This assembly has been tested for 130 psf wind uplift resistance, exceeding hurricane wind speed design requirements. The assembly is designed for flat commercial roofs and is not rated to support snow loads on sloped roofs.

5.1.4 Availability

Two manufacturers currently supply PVC WMS systems. Table 8 provides information on the available PVC WMS systems.

Table 8: PVC Wire Management System Suppliers

Manufacturer	Product Line	Website
Advanced Green Technologies	AGT WMS	www.agt.com
Soprema	Soprema WMS	www.soprema.us/solar-energy.aspx

UNI-SOLAR is currently working to supply our customers with PVC tray style wire management systems. Visit the *UNI-SOLAR* Web site at www.uni-solar.com, or contact your sales representative for the latest sourcing options.

5.2 Wire Mesh Cable Tray

Wire mesh baskets are a common and effective method of managing cable on a rooftop solar array. The mesh basket easily allows cables to be fed into the tray at each *UNI-SOLAR* laminate.

Figure 31: Uncovered Wire Mesh Cable Tray – Installation in Progress

5.2.1 Components

The basic component is an outdoor rated steel wire mesh cable tray. This type of tray is available in a variety of dimensions depending on the needs of the project and number of cables that must be run through a particular section of tray. *UNI-SOLAR* recommends a steel cover that clips to the tray for protection of the cables from prolonged UV exposure.

5.2.2 Roof Attachment

A wire mesh cable tray requires some support and attachment to the roof. On flat commercial roof installations, rooftop conduit blocking is commonly used to support the tray. However, other low-profile attachment methods, as shown in Figure 32, may be used with this WMS.

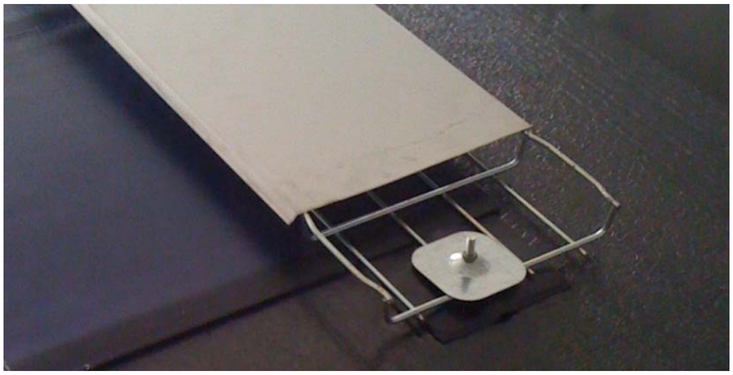


Figure 32: Covered Wire Mesh Cable Tray with Roof Attachment Detail

On standing seam roofs, a wire mesh cable tray may be secured to the roof with S-5! Standing seam clamps.

5.2.3 Wind and Snow Loading

Consult the cable tray manufacturer for details on the testing of wire mesh cable trays with respect to environmental loading. If applying the WMS to a standing seam metal roof, you may use the uplift resistance of the S-5! Clamps to determine the wind and snow loading forces that the tray may withstand.

5.2.4 Availability

Wire mesh cable trays are available from many electrical contractors and distributors. Table 9 provides a list of manufacturers of some common mesh cable tray systems used with *UNI-SOLAR* products.

Table 9: Wire Mesh Cable Tray Manufacturers

Manufacturer	Product Line	Website
Cooper B-Line	Wire Basket	www.cooperbline.com
Cabofil	Wire Cable Tray	www.cabofil.com
Snake Tray	Solar Snake	www.snaketray.com

5.3 Custom Wireways

You can use a custom roll-formed or break-formed steel section as a WMS for *UNI-SOLAR* installations. Custom wire channels can be designed to match existing architecture or meet other specific project requirements.

Figure 33: Custom Wireway Installation Matching Existing Metal Roof

5.3.1 Components

You can construct a custom wireway with two sheet metal parts. A one part wire cover for module interconnection wiring may utilize a hat channel profile, as shown in Figure 34.

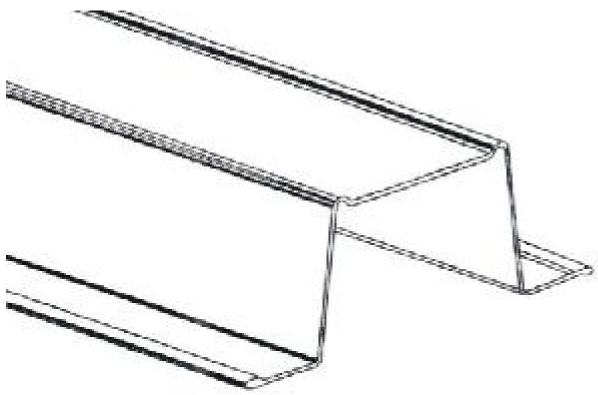


Figure 34: Hat Channel Profile Wire Cover

A two part wire channel will provide a raceway for running multiple conductors. Figure 35 and Figure 36 show examples of wireway profiles and an installation assembly detail.

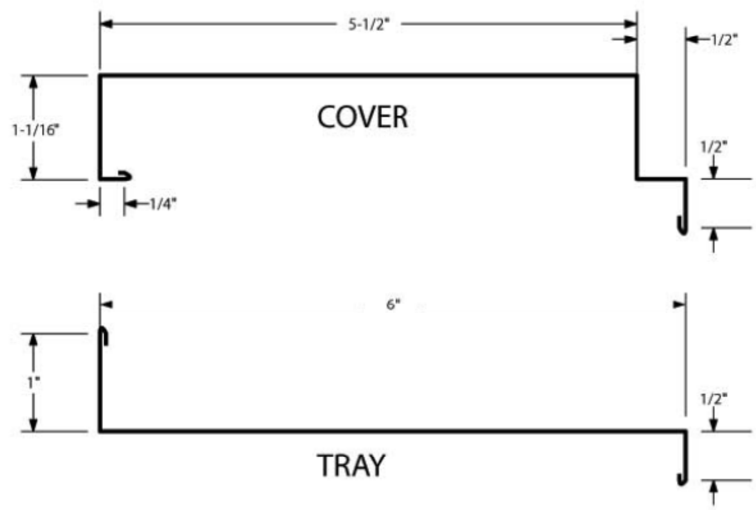


Figure 35: Custom Wire Channel Profiles

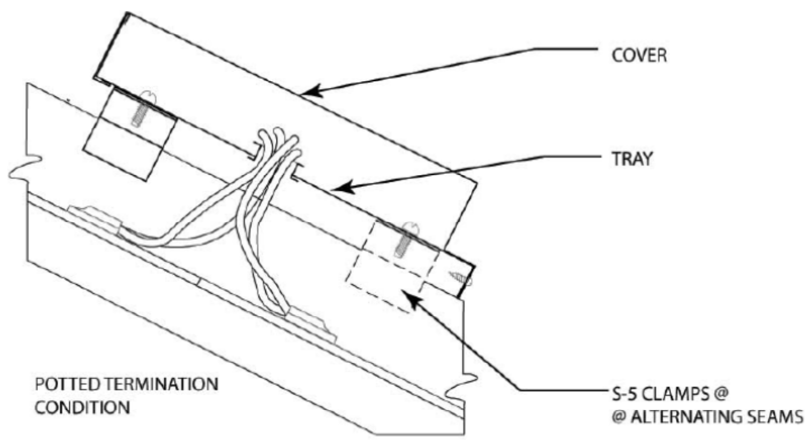


Figure 36: Custom Wire Channel Installation Detail

5.3.2 Roof Attachment

You can use Standing seam clamps to attach a custom metal gutter to a metal roof. Other roof types will require attachment to the roof designed to withstand all expected environmental loading.

5.3.3 Wind and Snow Loading

S-5! Standing seam clamp pull test results are available from the manufacturer and can be used to determine the strength of the wire tray attachment to the roof.

5.3.4 Availability

Metal shops and many roofing contractors have sheet metal forming equipment that can produce the custom wireway required for a *UNI-SOLAR* project.

6 Construction Overview and Scheduling

This chapter provides best practices, recommendations, and guidelines for planning a successful *UNI-SOLAR* project. The *UNI-SOLAR* installation guides contain the installation specifications and should be consulted for all installation requirements.

6.1 Handling and Storage

All specifications and requirements of the *UNI-SOLAR* installation guides apply to the installation the *UNI-SOLAR* laminates. Contractors should carefully consider the storage of the laminates prior to the site installation. The laminates are shipped in 4' x 4' x 17" boxes. PVL series boxes must not be stacked more than three boxes high, while ePVL series boxes may be stacked 4 high. Laminates must be kept in a dry, clean warehouse-type facility prior to installation, with ambient temperatures between 15° C (59° F) and 30° C (86° F). Contractors should choose a storage location close to the job site if available to avoid excess transportation costs and excessive handling.

6.2 Logistics

You should discuss the following items and finalize them during the logistics period:

- Loading areas
- Construction access
- Dumpster locations
- Access to roof (any special requirements from the owner)
- Parking areas for construction vehicles
- Noise levels
- Daily cleanup
- Working hours
- Supervision
- Power source
- Water source
- Building access, if required
- On-site storage, if required

Figure 37 shows an example of a logistics plan that was utilized at a North American project of ~880 kW installation.

Figure 37: Sample Site Logistics Plan

6.3 Loading and Sequencing

Before any personnel are allowed on site, you must install a 10’ safety line around the perimeter of the roof. If any work must be performed outside of the 10’ perimeter, the personnel must be tied off according to OSHA requirements. Prior to loading the roof, contractors must pay special attention to the structural parameters of the roof to avoid excess weight on the roof and also determine the overall size and placement of the laminates to avoid loading over installation areas. A professional structural engineer must approve all roof loading. Carefully coordinate proper sequencing and loading with the structural engineer of record to avoid any structural issues. Figure 38 shows an example of a sequencing plan. The laminate boxes must not be directly loaded on to roof, and bracing must be installed before loading occurs. Depending on the size of the project, contractors are not advised to load the roof all at one time.

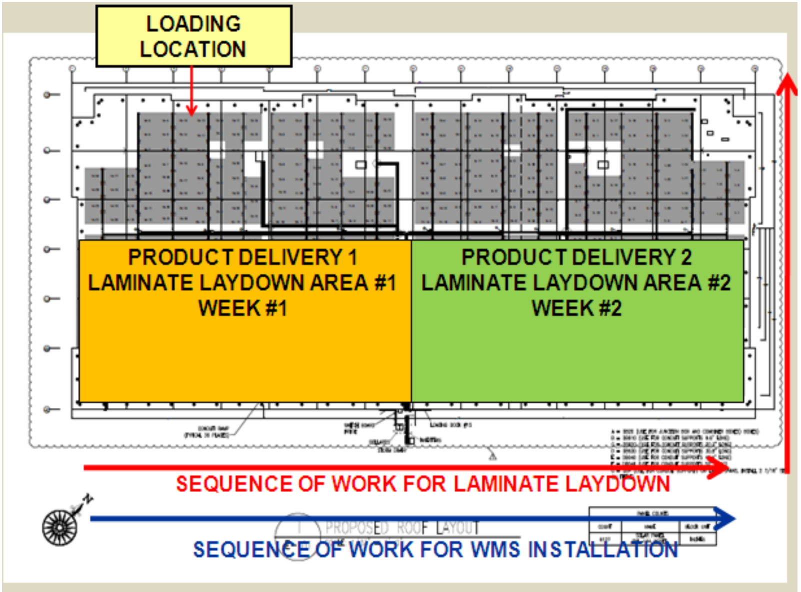


Figure 38: Sample Work Sequencing Plan

UNI-SOLAR recommends that you coordinate and schedule the roofing and electrical contractors to work in conjunction on site. Carefully manage roof work so that the roofing and laying down of laminates and electrical activities can be performed with overlap.

6.4 Procurement

Contractors should consider long lead items and materials specified on job including, but not limited to:

- PVC conduit, if applicable
- IMC conduit, if applicable
- Inverters
- Switchgear
- Laminates
- WMS
- Combiner/junction boxes
- Wire (varying sizes)

6.5 Installation of Laminates

Do not install direct bond laminates during the following conditions:

- Excessively hot roof temperatures above 85° C (185° F)
- Roof temperatures below 10° C (50° F)
- Extreme wind
- Rainy or snowy weather

You should also consider the following additional items during the laminate installation on the roof:

- Walkways, if required
- Flagging (for WMS/combiner box identification), if required
- Ramps (to avoid breaking WMS), if required

6.6 Electrical Activities

If available, there should be two electrical crews working the following activities to accelerate the schedule (ground work and rooftop work):

- **Ground-level electrical work** includes trenching at inverters, installation of conduit, backfilling, setting of pads and inverters, installation of the switchgear and metering, installation of the monitoring equipment, and tapping into existing switchboard.
- **Roof-level electrical work** includes installation of vertical conduit, loading of electrical material, installation of horizontal conduit, installation of WMS, connection of PV panels, pulling of horizontal wire, pulling of down leads, installation of wire harness, wiring of combiner boxes, and termination and splicing of cables.

6.7 Commissioning

Commissioning a *UNI-SOLAR* array is critical to the success of the project. Personnel on site must be trained to commission the system properly to verify functionality and performance expectations. You must establish commissioning and performance parameters at the onset of each project.

6.8 Scheduling

Compile a detailed schedule prior to the start of the project, and include the following important scheduling items:

- Permitting
- Utility inspections
- SREC submissions, if applicable
- State permits, if applicable
- Zoning permit
- Procurement
- Mobilization
- Re-roofing, if applicable
- Roof delivery
- Installation of *UNI-SOLAR* laminates
- Rooftop electrical (WMS, combiner boxes, junction boxes, conduits, etc.)
- Interconnection electrical work

- Utility shut-down, if required
- Final cleanup
- Final inspections (utility, state, SREC, etc.)

In general, schedule activities should be specific, measurable, achievable, realistic, and clearly timed (SMART).

Be sure to consider weather and union vs. non-union labor depending on the section of the country, as cost and labor productivity will be impacted by it.

Refer to *Appendix D: Sample Schedule* for a sample schedule.

7 Application Certifications

UNI-SOLAR products have been certified by nationally recognized testing laboratories to many standards worldwide pertaining to photovoltaic equipment safety and reliability. The following is a list of standards to which *UNI-SOLAR* products have been tested, the testing agency, and status of the listing.

7.1 UL 1703 Flat-Plate PV Modules and Panels

Products tested by Underwriters Laboratories:

- PVL and ePVL products are certified to UL 1703.
- *UNI-SOLAR* PVL and ePVL products are listed by UL and marked with Underwriters Laboratories (UL) and Canadian Underwriters Laboratories (cUL) marks

Products tested by Intertek ETL:

- PowerTilt products are certified by Intertek ETL to UL 1703.

7.2 UL 790 Fire Tests of Roof Coverings

Products tested by Underwriters Laboratories:

- PVL and ePVL products are certified with particular roof materials and assemblies to UL 790
- Fire classification depends on slope and roof assembly. Class A rated assemblies are available, with other assemblies categorized as Class B and C.
- *UNI-SOLAR* PVL and ePVL products are listed by UL and marked with Underwriters Laboratories (UL) and Canadian Underwriters Laboratories (cUL) marks

7.3 ICC AC-365 Acceptance Criteria for BIPV Roof Modules and Panels

Product tested by International Code Council Evaluation Service:

- Testing to AC-365 has been completed and certification is in progress.

7.4 CEC SB1 Guidelines for California's Solar Electric Incentive Programs

Products tested by KEMA:

- PVL, ePVL, and PowerTilt products are listed on the CEC eligible modules list.

7.5 Miami-Dade Notice of Acceptance

Products tested by Trinity ERD

- Factory assembled Solar-Mat (PowerMembrane Application – see Section 2.2) has a current Miami-Dade NOA
- Direct bond to metal roofs (see Section 2.3) is under review by Miami-Dade and NOA is expected to be issued
- Direct bond to membrane (see section 2.1) and bonding to a removable secondary membrane in the field (see Section 2.2) is under review by Miami-Dade and NOA is expected to be issued

7.6 IEC 61646 Thin-film Terrestrial PV Modules and IEC 61730 and PV Module Safety Qualification

Products tested by TUV Rheinland:

- *UNI-SOLAR* PVL and ePVL products are marked with the TUV mark.

7.7 Korea: KEMCO Korean Energy Management Corporation

Products tested by KTL/KEMCO:

- The PVL product is currently approved.
- ePVL approval testing is in progress.

7.8 Brazil: IEE-USP

Product tested by INMETRO:

- The PVL product is currently approved.

7.9 Puerto Rico: AEE

Products tested by AEE:

- The PVL product is currently approved.
- ePVL approval testing is in progress.

7.10 United Kingdom: MCS Microgeneration Certification Scheme

Products tested by BRE Global:

- The PVL and ePVL products are currently approved.

Appendix A: PowerBond Estimating Reference

UNI-SOLAR PowerBond PV laminates may be applied directly to a new roof membrane or newly installed layer of roofing membrane, provided that you comply with all substrate material and installation specifications documented in the *UNI-SOLAR* installation guides.

This appendix provides project developers and construction estimators with a case study for a commercial scale PowerBond installation and reference material to support building a project estimate.

A.1 Project Description

This case study examines rooftop PV system construction at the PowerBond Project 1 property in North America. The PV system capacity is ~880 kW DC and features (6,127) *UNI-SOLAR* PVL-144 PowerBond laminates. *UNI-SOLAR* laminates were installed on a new Carlisle EPDM membrane roof.

A.2 Estimating Data

The estimating data in Table 10 is taken from daily reports submitted by *UNI-SOLAR* field personnel. The scope of work encompasses installation of the *UNI-SOLAR* PVL-144 laminates and installation of the wire management tray bases by a labor crew.

Early in the project, a slower installation rate typical of a local labor installation with experienced supervision and training was observed. As the installation progressed, the crew ran more efficiently and hit a better run-rate.

Table 10: Typical Installation Rates for *UNI-SOLAR* PVL on Membrane

	kW/Day	Crew	Total Hours	kW per man-hour	kW per man-day	# PVL per man-hour	# PVL per man day
Ramp-up	57	11	88	0.65	5.18	4.50	35.98
Optimal Rate	89	11	88	1.01	8.05	6.99	55.91

Appendix B: PowerMembrane Estimating Reference

UNI-SOLAR PowerMembrane PV laminates may be applied directly to a secondary layer of single-ply roofing membrane which is attached to the existing roof in such a way that the membrane and *UNI-SOLAR* laminates may be removed, leaving the existing roof intact.

This appendix provides project developers and construction estimators with a case study for a commercial scale PowerMembrane installation and reference material to support building a project estimate.

B.1 Project Description

This case study examines rooftop PV system construction at the PowerMembrane Project 1 property in North America. The PV system capacity is ~80 kW DC and features (6,754) *UNI-SOLAR* PVL-144 laminates. *UNI-SOLAR* laminates were installed on a new Carlisle EPDM membrane.

B.2 Estimating Data

The estimating data in Table 11 is taken from daily reports submitted by *UNI-SOLAR* field personnel. The scope of work encompasses installation of the *UNI-SOLAR* PVL-144 laminates. Figure 39 shows installed modules and the pallets of *UNI-SOLAR* laminates handled/staged for installation. Note that there is additional time associated with the mat installation (typically seven laminates per mat) performed inside a control warehouse-type environment. This document does not include the mat production.

Early in the project, a slower installation rate typical of a local labor installation with experienced supervision and training was observed. As the installation progressed, the crew ran more efficiently and hit a better run-rate.

Table 11: Typical Installation Rates for *UNI-SOLAR* PVL on Mats

	kW/Day	Crew	Total Hours	kW per man-hour	kW per man-day	# PVL per man-hour	# PVL per man day
Ramp-up and Overall project	44.6	16.5	132	0.34	2.73	2.37	18.93

Figure 39: Installed *UNI-SOLAR* PowerMembrane Array

Figure 40: Installation of PowerMembrane in Progress

Appendix C: PowerTilt Estimating Reference Guide

The *UNI-SOLAR* PowerTilt modules and ballasted racking system arrive kitted to the jobsite with modules, racking, and fasteners. The PowerTilt system assembles quickly and integrates material and labor, saving electrical features including integrated wire management and integrated module and racking grounding.

This appendix provides project developers and construction estimators with a case study for a commercial scale PowerTilt installation and reference material to build a project estimate. Important qualifications regarding this data are provided in the section *C.2 Estimating Data* on page 60.

C.1 Project Description

The case study examines the rooftop PV system construction for the PowerTilt Project 1 facility located in North America. The PV system capacity is ~440 kW DC with (3,040) *UNI-SOLAR* PT-144 PV modules. The system is interconnected to the Enersource utility grid at the point where power enters the facility.

Installation training was provided to the installer's superintendent before the project began, but the installation crews had no prior training or experience with the PowerTilt system. *UNI-SOLAR* provided installation Technical Specialists who oversaw the installation.

Figure 41: Installed PowerTilt Array

C.2 Estimating Data

On-site personnel created daily reports that detail the crew size, work completed, weather, and other data about the conditions on site. The crew size, hours worked, and number of PowerTilt pans installed in a day are important metrics that were captured and are used in this analysis to determine the PV capacity (kW) installed per labor hour.

C.3 Estimating Assumptions, Exclusions, and Clarifications

The scope of work of this labor study is strictly for the mechanical installation of the PowerTilt system. Specific activities of this scope include:

- Unloading flatbeds
- Shipping PowerTilt crates to the jobsite (assumes no onsite storage)
- Transporting material to the roof (assumes adequate access and staging for the crane and materials)
- Laying out and locating the array
- Assembling the PowerTilt ballasted framing system
- Ballasting the array with paver blocks
- Installation integrated wire trays
- Installing the PowerTilt pans

- Performing ground testing

Activities not included in this scope include:

- Interconnection of the PowerTilt module leads
- Wiring from the panels to combiner boxes
- Combiner box installation
- Inverter installation
- Any other electrical, site work, or structural work

During construction, weather (rain and high winds) was an issue on several occasions. When safe, the crews worked through rain and wind; however, when the crew did not work due to weather, only the hours worked are included in the total hours for the day. This guide is based on a sample project that was installed from April to June in North America. Productivity may be adversely affected during winter months and should be taken into consideration.

This study is based on an eight-man crew that had never installed the PowerTilt system, and there was a learning curve to overcome in the beginning of the installation. Once the crew was familiar with the PowerTilt system, the installation rate increased. Installation hours provided in Table 12 are inclusive of all phases of the installation, including ramp-up. The labor hours presented in the table are inclusive of reasonable minor array relocation work due to misinterpretation of drawings. Significant array relocation labor and the associated structural evaluation are not within the scope of this case study; however, the developer should be aware of the structural engineering evaluation required to design any ballasted PV array or modify the array design in the field.

Table 12: Summary of Installation Rate for PowerTilt Project 1 Installation

Total Labor Hours	Total Installed kW	kW per Labor Hour
2126.	437.76	0.206

Appendix D: Sample Schedule

The content in this appendix shows an example of a schedule. The example begins on the next page

POWER MEMBRANE INSTALLATION SCHEDULE

ID		Task Name	% Complete	Duration	Start	Finish
0		**Solar installation**	**90%**	**297.94 days**	**Fri 6/4/10**	**Mon 7/25/11**
1		**Weekly Field Production Meeting**	**87%**	**262.94 days**	**Wed 6/30/10**	**Wed 6/29/11**
55		**Building (973 kW Sacrificial Sheet; 6732 laminates)**	**90%**	**297.94 days**	**Fri 6/4/10**	**Mon 7/25/11**
56		**General Conditions**	**96%**	**283.94 days**	**Fri 6/4/10**	**Tue 7/5/11**
57	✓	Receive notice to proceed and sign contract	100%	20 days	Fri 6/4/10	Thu 7/1/10
58	✓	Prepare preliminary construction drawings	100%	5 days	Fri 7/2/10	Thu 7/8/10
59	✓	Drawing review	100%	5 days	Fri 7/9/10	Thu 7/15/10
60	✓	Prepare and submit project schedule	100%	3 days	Fri 7/9/10	Tue 7/13/10
61	✓	Finalize and Stamp drawings	100%	7 days	Mon 7/19/10	Tue 7/27/10
62	✓	Labor Union versus Prevailing Wage CO#1	100%	63 days	Fri 7/2/10	Tue 9/28/10
63	✓	Authorization to proceed	100%	1 day	Wed 3/16/11	Wed 3/16/11
64	✓	Authorization to proceed to EPC	100%	1 day	Thu 4/7/11	Thu 4/7/11
65	✓	Complete PPA	100%	0 days	Thu 5/26/11	Thu 5/26/11
66		Finalize and Stamp As Built Drawings	0%	4 days	Wed 6/29/11	Tue 7/5/11
67	✓	**Permit Office approval**	**100%**	**68 days**	**Wed 7/28/10**	**Fri 10/29/10**
68	✓	Building permit	100%	2 wks	Wed 7/28/10	Tue 8/10/10
69	✓	Electrical permit	100%	68 days	Wed 7/28/10	Fri 10/29/10
70	✓	Zoning permit	100%	2 wks	Wed 7/28/10	Tue 8/10/10
71	✓	**Utility Approval**	**100%**	**23 days**	**Fri 7/9/10**	**Tue 8/10/10**
72	✓	Interconnection Application for Netmetering	100%	8 days	Fri 7/9/10	Tue 7/20/10
73	✓	Interconnection Review for Netmetering	100%	2 wks	Wed 7/21/10	Tue 8/3/10
74	✓	Interconnection approval for Netmetering	100%	1 wk	Wed 8/4/10	Tue 8/10/10
75	✓	**Procurement**	**100%**	**74 days**	**Wed 7/28/10**	**Mon 11/8/10**
76	✓	Sacrificial Sheet	100%	2 wks	Wed 7/28/10	Tue 8/10/10
77	✓	Wire Management	100%	2 wks	Wed 7/28/10	Tue 8/10/10
78	✓	Conduit	100%	2 wks	Wed 7/28/10	Tue 8/10/10
79	✓	Combiner Boxes	100%	2 wks	Wed 7/28/10	Tue 8/10/10
80	✓	MC Connectors	100%	2 wks	Wed 7/28/10	Tue 8/10/10
81	✓	MC Connectors tools	100%	2 wks	Wed 7/28/10	Tue 8/10/10
82	✓	Wires & Cables	100%	2 wks	Wed 7/28/10	Tue 8/10/10
83	✓	Bonding Material	100%	2 wks	Wed 7/28/10	Tue 8/10/10
84	✓	Site Equipment	100%	2 wks	Wed 7/28/10	Tue 8/10/10
85	✓	300MCM wire	100%	2.8 wks	Wed 10/20/10	Mon 11/8/10
86	✓	**Long Lead Items**	**100%**	**45 days**	**Fri 7/2/10**	**Thu 9/2/10**
87	✓	Submit drawings and order long lead items - Laminates	100%	4 wks	Fri 7/2/10	Thu 7/29/10
88	✓	Submit drawings and order long lead items - Inverters	100%	3 wks	Fri 7/9/10	Thu 7/29/10
89	✓	Submit drawings and order long lead items - Data Acquisition System	100%	3 wks	Fri 7/2/10	Thu 7/22/10
90	✓	Submit drawings and order long lead items - Switchgear	100%	8 wks	Fri 7/9/10	Thu 9/2/10
91	✓	**Mobilize on Site**	**100%**	**6 days**	**Wed 4/6/11**	**Tue 4/12/11**
92	✓	Notify tenant prior to start	100%	2 days	Wed 4/6/11	Thu 4/7/11
93	✓	Prepare site and schedule labor	100%	4 days	Fri 4/8/11	Tue 4/12/11
94		**Installation**	**88%**	**208.94 days**	**Mon 9/20/10**	**Wed 7/6/11**
95	✓	**Mechanical Installation**	**100%**	**193.32 days**	**Mon 9/20/10**	**Tue 6/14/11**
96	✓	Bonding of Laminates to sacrificial sheets (initial)	100%	27.69 wks	Mon 9/20/10	Tue 6/14/11
97	✓	**Bonding sheets to the roof (960 mats in total)**	**100%**	**40.06 days**	**Mon 4/11/11**	**Fri 6/3/11**
98	✓	Membrane Delivery	100%	1 wk	Mon 4/11/11	Fri 4/15/11
99	✓	Product delivery 1 and install 1	100%	1 wk	Mon 4/11/11	Fri 4/15/11
100	✓	Product delivery 2 and install 2	100%	1 wk	Sun 4/24/11	Thu 4/28/11
101	✓	Product delivery 3 and install 3	100%	1 wk	Mon 5/16/11	Fri 5/20/11
102	✓	Product delivery 4 and install 4	100%	1 wk	Mon 5/23/11	Fri 6/3/11
103	✓	Clean Installation areas	100%	1 day	Wed 6/8/11	Wed 6/8/11
104		**Electrical Installation**	**76%**	**62.06 days**	**Mon 4/11/11**	**Wed 7/6/11**
105		**Rooftop Electrical**	**82%**	**59.06 days**	**Mon 4/11/11**	**Thu 6/30/11**
106	✓	Electrical Product Delivery	100%	1 day	Mon 4/11/11	Mon 4/11/11
107	✓	Install WMS base and connections	100%	2.1 wks	Mon 4/25/11	Fri 5/27/11
108		Install WMS wire harness & caps	70%	27 days	Mon 5/23/11	Wed 6/29/11
109	✓	Install Lower Roof over electrical room	100%	2 days	Thu 4/14/11	Fri 4/15/11
110	✓	Install vertical conduit per conduit plan (crew 2)	100%	10 days	Mon 4/18/11	Fri 4/29/11
111	✓	Install horizontal conduit per conduit plan (crew 2)	100%	13.2 days	Mon 5/2/11	Fri 5/27/11
112	✓	Install combiner boxes, junction boxes and dura block (crew 2)	100%	16.5 days	Mon 5/9/11	Fri 6/10/11
113		Install horizontal cable, cable testing and termination at combiner boxes (26 pulls)	90%	19 days	Tue 5/31/11	Fri 6/24/11
114		Commission Combiner Boxes	0%	5 days	Mon 6/20/11	Fri 6/24/11
115		Install Data Acquisition weather station (crew 2)	0%	2 days	Mon 6/27/11	Tue 6/28/11
116		Comissioning of Draker System	0%	2 days	Wed 6/29/11	Thu 6/30/11
117		**Interconnection Electrical**	**56%**	**53 days**	**Thu 4/21/11**	**Wed 7/6/11**
118		**Laydown Inverter Per Conduit Plan and Code**	**56%**	**53 days**	**Thu 4/21/11**	**Wed 7/6/11**
119	✓	Excavation	100%	2 days	Thu 4/21/11	Sun 4/24/11
120	✓	Install conduit/inspection	100%	6 days	Mon 4/25/11	Mon 5/2/11
121	✓	Backfill/compaction	100%	2 days	Tue 5/3/11	Wed 5/4/11
122	✓	Concrete pads	100%	1 day	Mon 4/25/11	Mon 4/25/11
123	✓	Install inverters and switchgear	100%	3 days	Tue 4/26/11	Thu 4/28/11
124		Cable pull inverters and switchgear	44%	8 days	Wed 6/8/11	Fri 6/17/11

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POWER MEMBRANE INSTALLATION SCHEDULE

ID	Task Name	% Complete	Duration	Start	Finish
125	Termination at inverters and switchgear	90%	5 days	Mon 6/20/11	Fri 6/24/11
126	Cable Testing at Inverter and Switchgear	0%	2 days	Mon 6/27/11	Tue 6/28/11
127	CT cabinet and metering	0%	3 days	Wed 6/22/11	Fri 6/24/11
128	Shutdown (data pending due to PSE&G issue)	0%	0 days	Sat 6/25/11	Sat 6/25/11
129	Commissioning of System (PV Power)	0%	7 days	Mon 6/27/11	Wed 7/6/11
130	Mechanical Completion	0%	0 days	Wed 7/6/11	Wed 7/6/11
131	**Substantial Completion**	**0%**	**15 days**	**Thu 6/30/11**	**Thu 7/21/11**
132	Milestone completion contract date	0%	1 day	Thu 6/30/11	Thu 6/30/11
133	Substantial completion date	0%	1 day	Thu 7/21/11	Thu 7/21/11
134	**Final Clean-up**	**0%**	**5 days**	**Thu 7/7/11**	**Wed 7/13/11**
135	Clean Installation areas	0%	1 wk	Thu 7/7/11	Wed 7/13/11
136	**Complete Final Inspections**	**0%**	**13 days**	**Thu 7/7/11**	**Mon 7/25/11**
137	Architect/System designer inspection	0%	1 day	Thu 7/7/11	Thu 7/7/11
138	PE inspection/stamp As-built	0%	1 day	Fri 7/8/11	Mon 7/11/11
139	Perform local building agency inspection	0%	1 day	Thu 7/7/11	Fri 7/8/11
140	Perform local electrical inspection	0%	2 days	Thu 7/7/11	Fri 7/8/11
141	Utility inspection / approval (PSEG)	0%	3 days	Mon 7/11/11	Wed 7/13/11
142	Performance Testing	0%	8 days	Thu 7/14/11	Mon 7/25/11
143	SREC approval	0%	1 wk	Thu 7/14/11	Wed 7/20/11
144	Complete punch list items from all inspections	0%	3 days	Mon 7/11/11	Thu 7/14/11
145	Issue final completion documents including warranties	0%	1 day	Thu 7/14/11	Fri 7/15/11
146	Issue final request for payment	0%	1 day	Fri 7/22/11	Fri 7/22/11

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DIRECT BOND INSTALLATION
SAMPLE SCHEDULE

ID	Task Name	% Complete	Duration	Start	Finish
0	**Solar Commercial Construction**	**97%**	**293 days**	**Fri 6/4/10**	**Thu 7/21/11**
1	**Weekly Field Production Meeting**	**86%**	**264 days**	**Wed 6/30/10**	**Wed 7/6/11**
56	**Building (882 kW Direct Bond; 6125 panels)**	**97%**	**293 days**	**Fri 6/4/10**	**Thu 7/21/11**
57	**General Conditions**	**100%**	**287.75 days**	**Fri 6/4/10**	**Thu 7/14/11**
58	Receive notice to proceed and sign contract	100%	20 days	Fri 6/4/10	Thu 7/1/10
59	Prepare and submit project schedule	100%	3 days	Fri 7/2/10	Tue 7/6/10
60	Prepare preliminary construction drawings to client	100%	5 days	Wed 8/11/10	Tue 8/17/10
61	Drawing review	100%	1.67 days	Wed 8/18/10	Thu 8/19/10
62	Drawing revisions	100%	44 days	Thu 8/19/10	Wed 10/20/10
63	Drawing approval	100%	13 days	Wed 10/20/10	Mon 11/8/10
64	Finalize and Stamp Construction drawings	100%	54 days	Mon 11/8/10	Fri 1/21/11
65	Finalize and Stamp As-built Drawings	100%	7 days	Tue 7/5/11	Thu 7/14/11
66	CO#1	100%	63 days	Fri 7/2/10	Tue 9/28/10
67	Complete PPA	100%	178 days	Fri 7/2/10	Wed 3/9/11
68	Change Order #002 finalized	100%	0 days	Thu 4/21/11	Thu 4/21/11
69	**Permit Office approval**	**100%**	**166 days**	**Wed 8/18/10**	**Thu 4/7/11**
70	Roof Permit	100%	161 days	Wed 8/18/10	Thu 3/31/11
71	State Permit	100%	56 days	Wed 1/19/11	Thu 4/7/11
72	Building/Construction permit	100%	0 days	Thu 4/7/11	Thu 4/7/11
73	Town Electrical permit	100%	116 days	Wed 10/27/10	Thu 4/7/11
74	Zoning permit	100%	10.8 wks	Fri 1/21/11	Thu 4/7/11
75	**Utility Approval**	**100%**	**166 days**	**Wed 8/18/10**	**Thu 4/7/11**
76	Net Metering Interconnection Application	100%	3 wks	Wed 8/18/10	Tue 9/7/10
77	PSE&G Tariff	100%	140 days	Wed 8/18/10	Wed 3/2/11
78	Wholesale Service Approval	100%	5 wks	Fri 11/5/10	Thu 4/7/11
79	**Procurement**	**100%**	**219 days**	**Wed 8/18/10**	**Wed 6/22/11**
80	Wire Management	100%	2 wks	Wed 8/18/10	Tue 8/31/10
81	Wire Mesh	100%	2 wks	Wed 8/18/10	Tue 8/31/10
82	Conduit	100%	2 wks	Wed 8/18/10	Tue 8/31/10
83	Combiner Boxes	100%	2 wks	Wed 8/18/10	Tue 8/31/10
84	MC Connectors	100%	2 wks	Wed 8/18/10	Tue 8/31/10
85	MC Connectors tools	100%	2 wks	Wed 8/18/10	Tue 8/31/10
86	Wires & Cables	100%	2 wks	Wed 8/18/10	Tue 8/31/10
87	Bonding Material	100%	2 wks	Wed 8/18/10	Tue 8/31/10
88	Site Equipment	100%	2 wks	Wed 8/18/10	Tue 8/31/10
89	300 MCM wire	100%	3 wks	Wed 10/20/10	Tue 11/9/10
90	CT Can and Disconnect	100%	4.4 wks	Thu 4/21/11	Wed 6/22/11
91	**Long Lead Items**	**100%**	**58 days**	**Wed 8/18/10**	**Fri 11/5/10**
92	Submit drawings and order long lead items - Laminates	100%	4 wks	Wed 8/18/10	Tue 9/14/10
93	Submit drawings and order long lead items - Inverters	100%	3 wks	Wed 8/18/10	Tue 9/7/10
94	Submit drawings and order long lead items - Data Acquisition System	100%	3 wks	Wed 8/18/10	Tue 9/7/10
95	Submit drawings and order long lead items - Switchgear	100%	8 wks	Mon 9/13/10	Fri 11/5/10
96	Submit drawings and produce wire harnesses	100%	2 wks	Wed 8/18/10	Tue 8/31/10
97	**Mobilize on Site**	**100%**	**8 days**	**Wed 3/30/11**	**Fri 4/8/11**
98	Prepare site (roofing) - lay down temporary fencing & Clear	100%	3 days	Wed 3/30/11	Fri 4/1/11
99	Prepare site (solar); organize labor	100%	2 days	Thu 4/7/11	Fri 4/8/11
100	**Reroof**	**100%**	**49 days**	**Mon 8/23/10**	**Thu 10/28/10**
101	Stone removal	100%	1 wk	Mon 8/23/10	Fri 8/27/10
102	Apply membrane	100%	5 wks	Mon 8/30/10	Fri 10/1/10
103	Gravel stop	100%	18 days	Mon 10/4/10	Wed 10/27/10
104	Roof inspection	100%	1 day	Thu 10/28/10	Thu 10/28/10
105	**Installation**	**98%**	**67 days**	**Fri 4/8/11**	**Tue 7/12/11**
106	**Mechanical Installation**	**100%**	**17 days**	**Fri 4/8/11**	**Tue 5/3/11**
107	**Bonding laminates to the roof**	**100%**	**15 days**	**Fri 4/8/11**	**Fri 4/29/11**
108	Product delivery 1	100%	1 wk	Fri 4/8/11	Thu 4/14/11
109	Product delivery 2	100%	1 wk	Mon 4/18/11	Mon 4/25/11
110	Product delivery 3	100%	1 wk	Mon 4/25/11	Fri 4/29/11
111	Clean Installation areas	100%	2 days	Mon 5/2/11	Tue 5/3/11
112	**Electrical Installation**	**97%**	**50 days**	**Wed 5/4/11**	**Tue 7/12/11**
113	**Rooftop Electrical**	**100%**	**42 days**	**Wed 5/4/11**	**Wed 6/29/11**
114	Electrical Product Delivery	100%	1 day	Wed 5/4/11	Thu 6/23/11
115	Install dura blocks and junction boxes	100%	0.72 days	Tue 5/24/11	Fri 5/27/11
116	Install WMS (base and connections) (crew 1)	100%	3 days	Thu 5/5/11	Fri 5/13/11
117	Install WMS wire harnesses and caps	100%	15 days	Wed 6/8/11	Mon 6/27/11
118	Install vertical conduit & wire per conduit plan (crew 2)	100%	1.52 wks	Fri 5/27/11	Fri 6/24/11
119	Install horizontal conduit per conduit plan (crew 2)	100%	19.4 days	Wed 5/11/11	Wed 6/22/11
120	Install combiner boxes	100%	4 days	Mon 5/23/11	Fri 6/3/11
121	Completion of horizontal, cable testing and terminate combiner boxes	100%	12 days	Mon 5/30/11	Tue 6/21/11
122	Commission combiner boxes	100%	4 days	Tue 6/14/11	Fri 6/17/11
123	Install Data Acquisition weather station	100%	2 days	Tue 6/28/11	Wed 6/29/11

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DIRECT BOND INSTALLATION
SAMPLE SCHEDULE

ID	Task Name	% Complete	Duration	Start	Finish
124	Commissioning of Draker System	100%	2 days	Tue 6/28/11	Wed 6/29/11
125	**Interconnection Electrical**	**91%**	**50 days**	**Wed 5/4/11**	**Tue 7/12/11**
126	**Laydown Inverter Per Conduit Plan and Code**	**91%**	**50 days**	**Wed 5/4/11**	**Tue 7/12/11**
127	Sawcutting	100%	3 days	Wed 5/4/11	Fri 5/6/11
128	Excavation	100%	3 days	Fri 5/6/11	Tue 5/10/11
129	Layout and Install conduit	100%	0.8 days	Mon 5/23/11	Fri 5/27/11
130	Underground Inspection	100%	1 day	Tue 5/31/11	Tue 5/31/11
131	Backfill/compaction	100%	2 days	Wed 6/1/11	Thu 6/2/11
132	Concrete Fill	100%	1 day	Mon 6/13/11	Mon 6/13/11
133	Concrete Pads	0%	1 day	Fri 7/8/11	Fri 7/8/11
134	Install inverters and switchgear	100%	2 days	Thu 6/16/11	Fri 6/17/11
135	Cable pull for inverters and switchgear	100%	5 days	Mon 6/20/11	Fri 6/24/11
136	Terminates at inverters and switchgear	100%	5 days	Mon 6/20/11	Fri 6/24/11
137	Cable Testing of Inverter and Switchgear	100%	5 days	Mon 6/20/11	Fri 6/24/11
138	CT cabinet and metering	0%	2 days	Mon 7/11/11	Tue 7/12/11
139	PSE&G Shutdown #1	100%	0 days	Sat 6/25/11	Sat 6/25/11
140	Commissioning of system (PV Power)	100%	3 days	Tue 6/28/11	Thu 6/30/11
141	**Completion Dates**	**0%**	**6 days**	**Tue 7/12/11**	**Wed 7/20/11**
142	**Mechanical completion**	0%	0 days	Tue 7/12/11	Tue 7/12/11
143	**Substantial completion date**	0%	0 days	Wed 7/20/11	Wed 7/20/11
144	**Complete Final Inspections**	**8%**	**12 days**	**Wed 7/6/11**	**Thu 7/21/11**
145	Final Clean-Up	0%	3 days	Wed 7/6/11	Fri 7/8/11
146	Architect/System designer inspection	100%	1 day	Wed 7/6/11	Wed 7/6/11
147	PE inspection/stamp As-built	100%	1 day	Wed 7/6/11	Thu 7/7/11
148	Perform local building agency inspection	0%	1 day	Wed 7/6/11	Thu 7/7/11
149	Perform local electrical inspection	0%	1 day	Wed 7/6/11	Wed 7/6/11
150	Utility inspection / approval (PSE&G)	0%	1 wk	Thu 7/7/11	Wed 7/13/11
151	Draker Inspection	100%	1 day	Wed 7/6/11	Wed 7/6/11
152	Performance Testing	0%	7 days	Mon 7/11/11	Tue 7/19/11
153	SREC inspection / approval	0%	1 wk	Thu 7/14/11	Wed 7/20/11
154	Complete punch list items from all inspections	0%	1 wk	Thu 7/7/11	Thu 7/14/11
155	Issue final completion documents including warranties	0%	7 days	Thu 7/7/11	Fri 7/15/11
156	Issue final request for payment	0%	1 day	Thu 7/21/11	Thu 7/21/11

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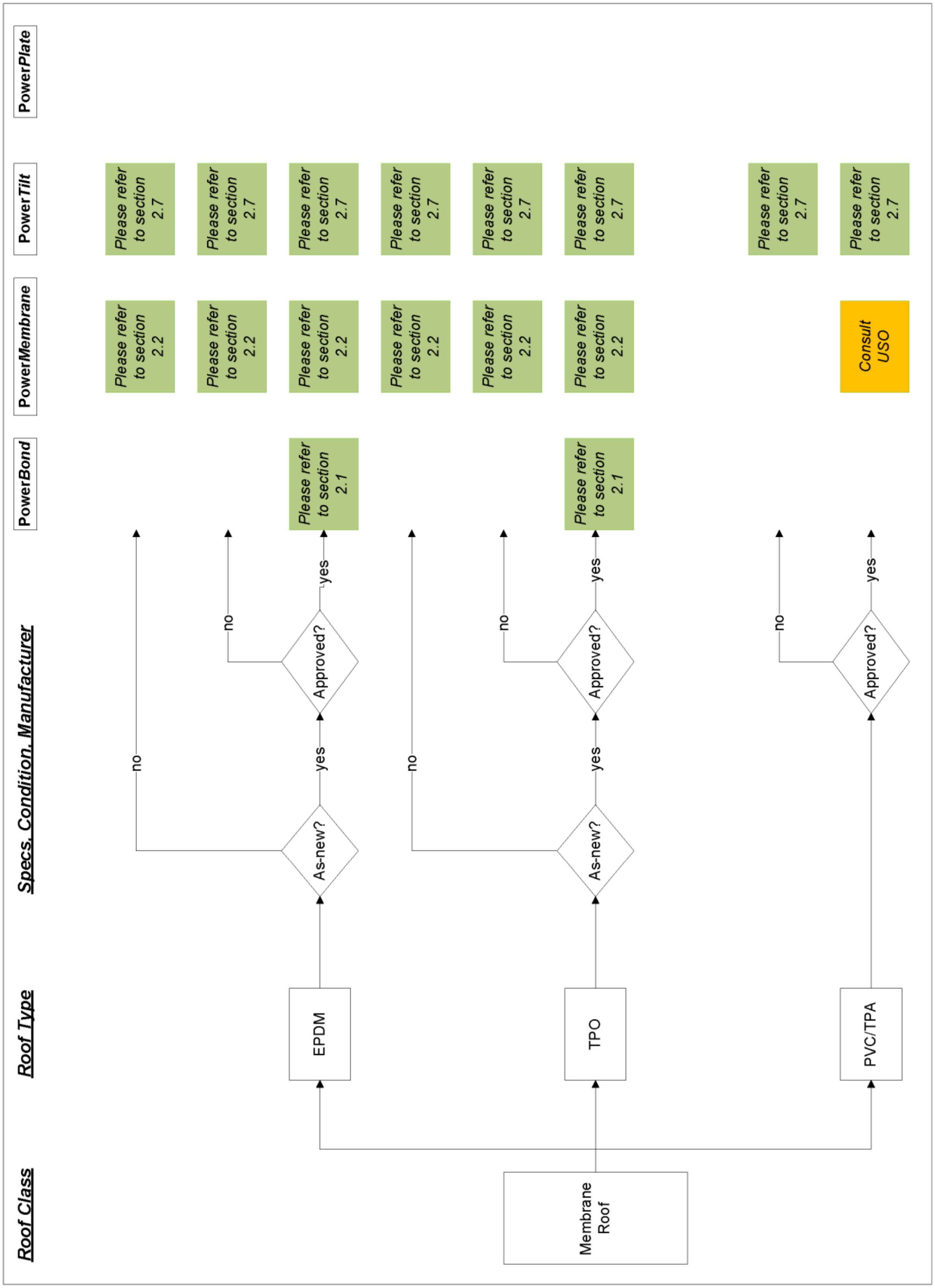
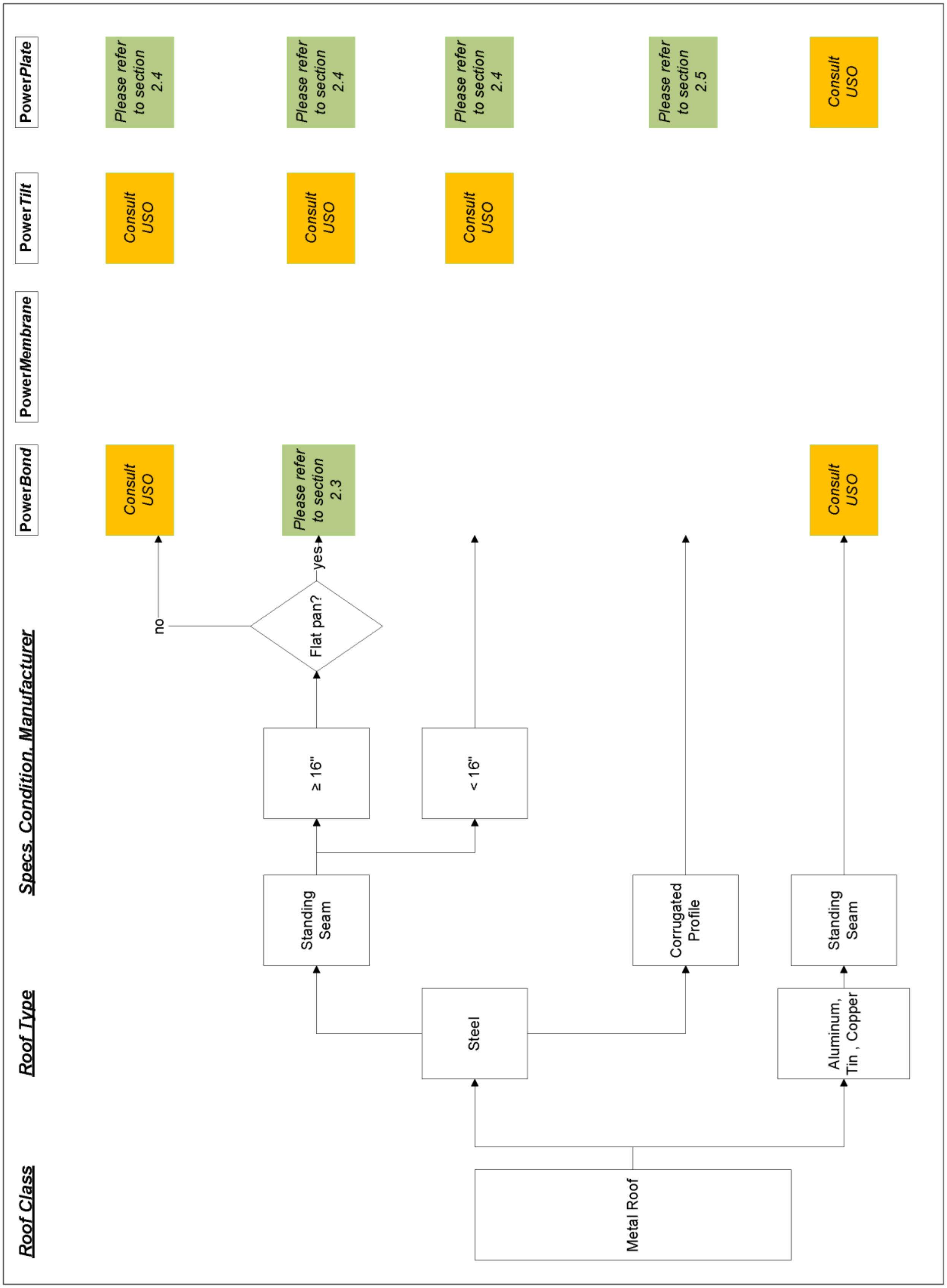
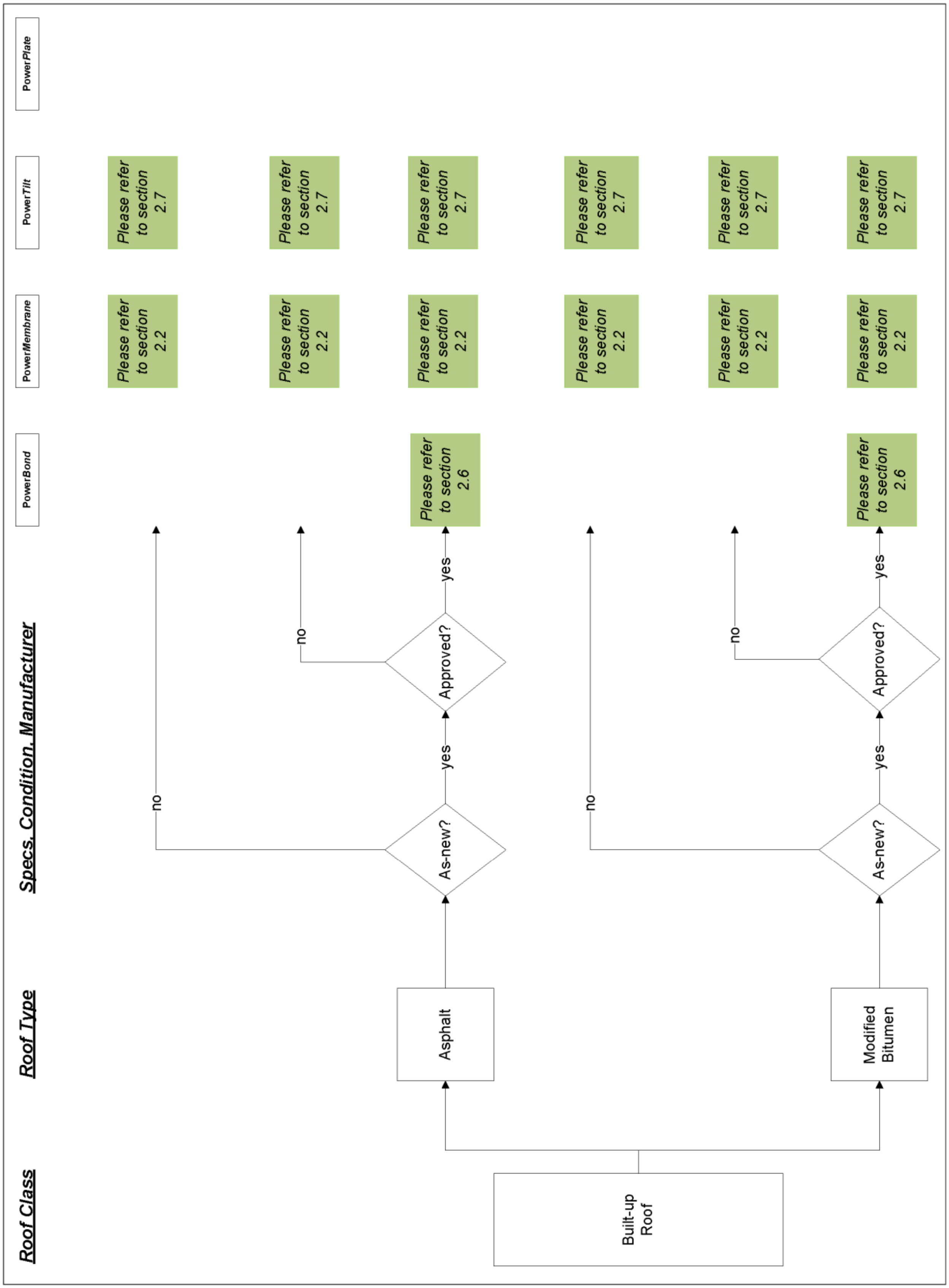
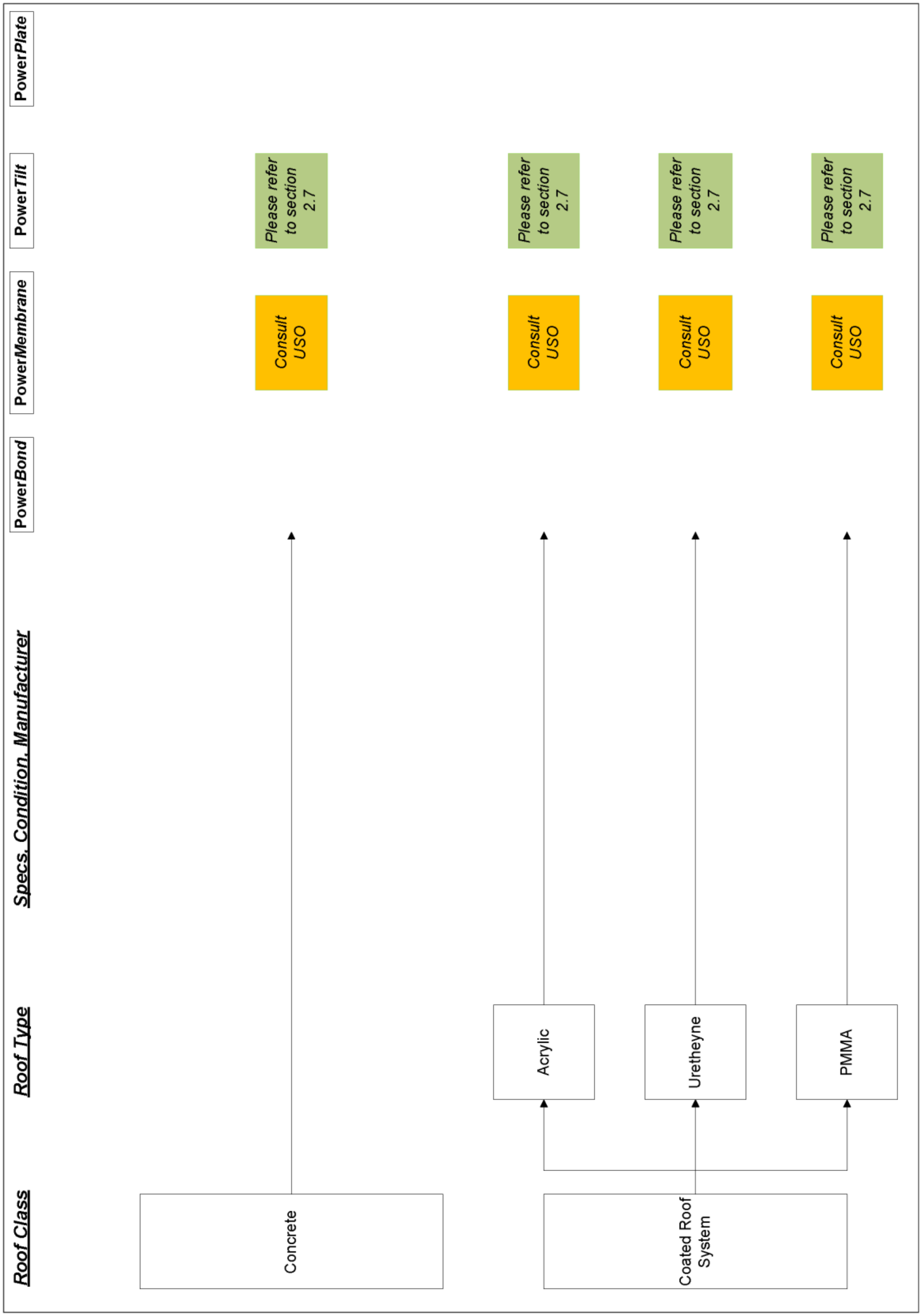
Appendix E: Application Selection Flowchart

This appendix contains an application selection flowchart. The flowchart begins on the next page.


Roof Class
Roof Type
Specs, Condition, Manufacturer
PowerBond
PowerMembrane
PowerTilt
PowerPlate
Membrane Roof
EPDM
TPO
PVC/TPA
As-new?
Approved?
yes
no
Please refer to section 2.1
Please refer to section 2.2
Please refer to section 2.7
Consult USO


Roof Class
Roof Type
Specs. Condition. Manufacturer
PowerBond
PowerMembrane
PowerTilt
PowerPlate
Metal Roof
Steel
Aluminum, Tin , Copper
Standing Seam
Corrugated Profile
Standing Seam
≥ 16"
< 16"
Flat pan?
no
yes
Consult USO
Please refer to section 2.3
Consult USO
Consult USO
Consult USO
Consult USO
Please refer to section 2.4
Please refer to section 2.4
Please refer to section 2.4
Please refer to section 2.5
Consult USO


Roof Class
Roof Type
Specs, Condition, Manufacturer
PowerBond
PowerMembrane
PowerTilt
PowerPlate
Built-up Roof
Asphalt
Modified Bitumen
As-new?
Approved?
yes
no
Please refer to section 2.6
Please refer to section 2.2
Please refer to section 2.7


Roof Class
Roof Type
Specs, Condition, Manufacturer
PowerBond
PowerMembrane
PowerTilt
PowerPlate
Concrete
Coated Roof System
Acrylic
Uretheyne
PMMA
Consult USO
Consult USO
Consult USO
Consult USO
Please refer to section 2.7
Please refer to section 2.7
Please refer to section 2.7
Please refer to section 2.7

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