



**BUILDING  
INNOVATION 2019**

National Institute of  
BUILDING SCIENCES

CONFERENCE & EXPO

## National Institute of Building Sciences

Provider Number: G168

### Photovoltaics and Their Impact on Roofing Assemblies

**WE3A**

Steven J Bohlen, P.E., RRC, RWC, BECxP

**January 9th, 2019**





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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.





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## Course Description

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As the demand for renewable energy sources is increasing and more energy programs are available, photovoltaic (PV) arrays are being installed on roof areas more frequently. Proper planning when considering installing PV arrays can greatly reduce the potential for roof leaks, voided roof warranties, structural damage and unnecessary expenses. These considerations should include evaluation of the existing roof system and planning for the installation of a roof-top PV system; selection of the appropriate PV system for the building; design of the PV system attachment to the building and roof; design of roof repairs or roof replacement in conjunction with the PV installation; maintenance of the roof and PV arrays; and evaluation of the costs associated with each phase. Specifically, the owner and designer should review the condition and warranty duration of the existing roof system, the available capacity of the existing structure; options for PV systems and attachments; roof manufacturer limitations; life safety for maintenance; fire safety; and the appropriate coordination of the various tradesmen before, during and after construction.





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# Learning Objectives

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At the end of the this course, participants will be able to:

1. Understand how proper planning when considering installing PV arrays can greatly reduce the potential for roof leaks, voided roof warranties, structural damage, and unnecessary expenses.
2. Understand the available options for PV systems and attachments, and roof manufacturer limitations.
3. Overview of the condition and warranty duration of the existing roof system, the available capacity of the existing structure.
4. Understand life safety for maintenance, fire safety, and the appropriate coordination of the various tradesmen before, during, and after construction.



**Introduction to Roof-Mounted Photovoltaics (PV)**

**Design Criteria Related to Roof-Mounted PVs**

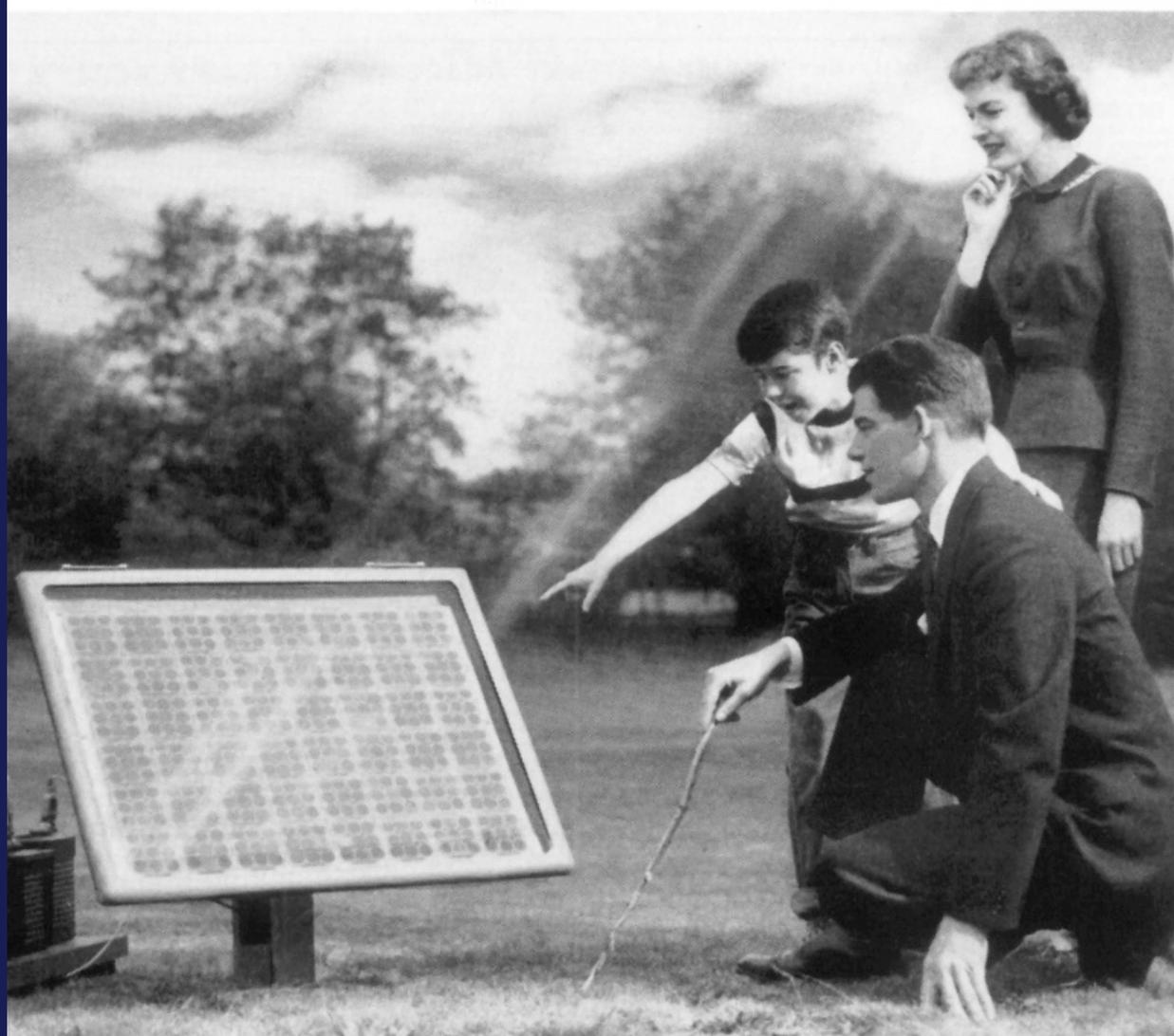
**Installation Coordination**





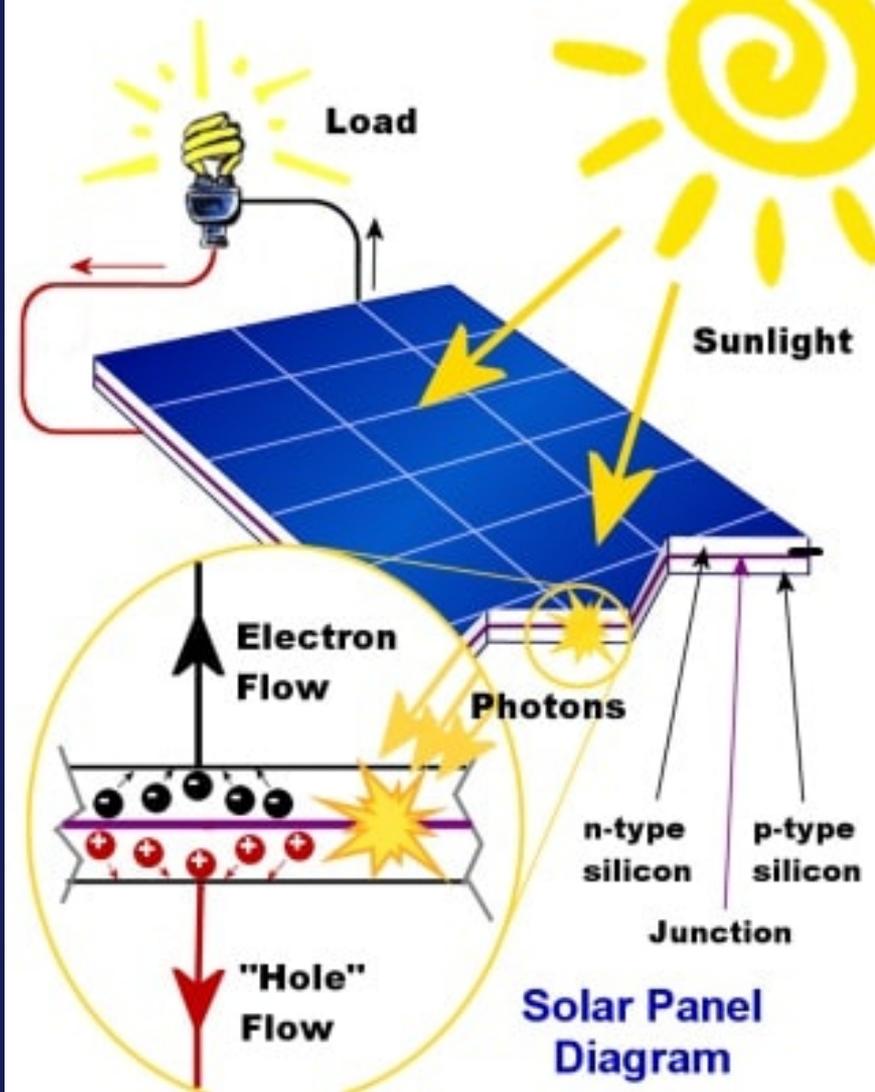
# A Brief History of Photovoltaic Technology

- **1839 - French physicist, Edmond Becquerel, observed a physical phenomenon allowing light-electricity conversion**
- **1954 - Bell Labs exhibits first high-power silicon PV cell**
- **1990 - Progressive Governments Use Subsidies to Speed Adoption**
- **1997 - Kyoto Protocol**

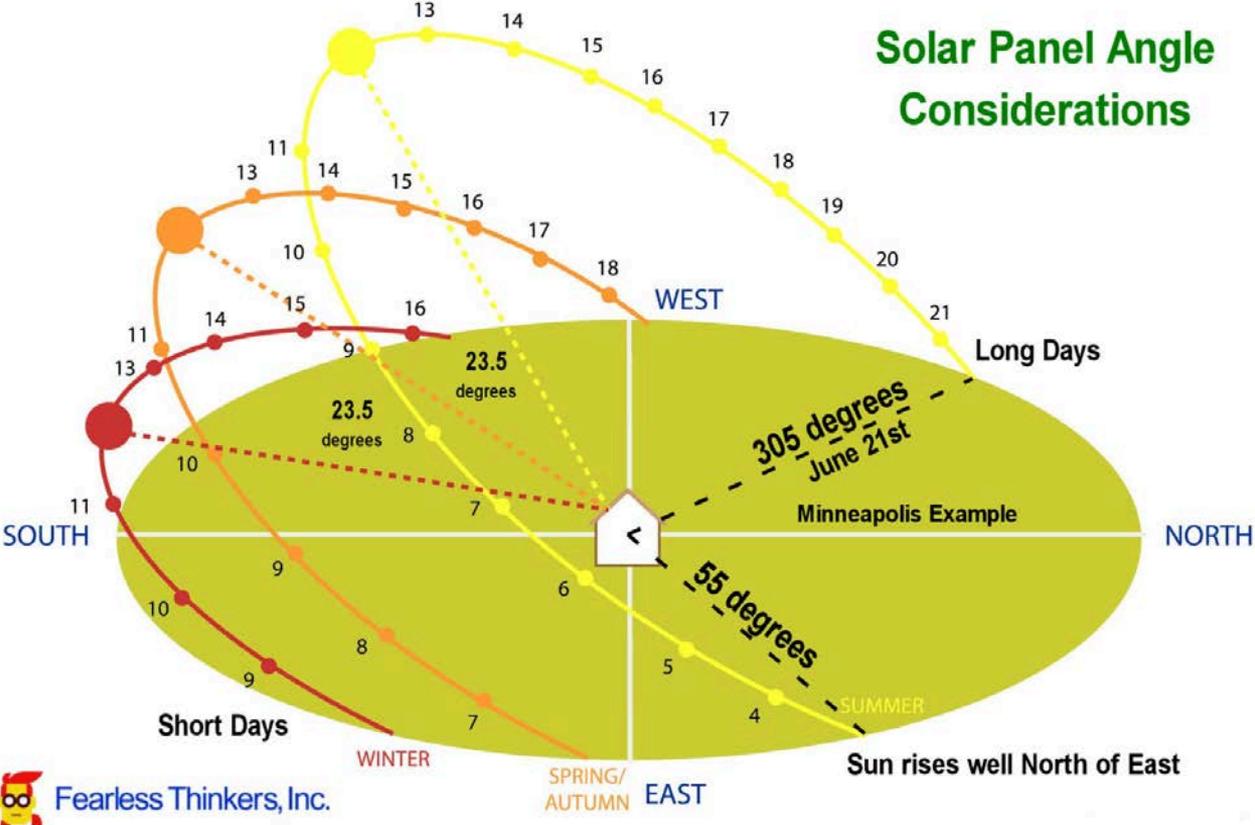


# Photovoltaic Technology: How it Works

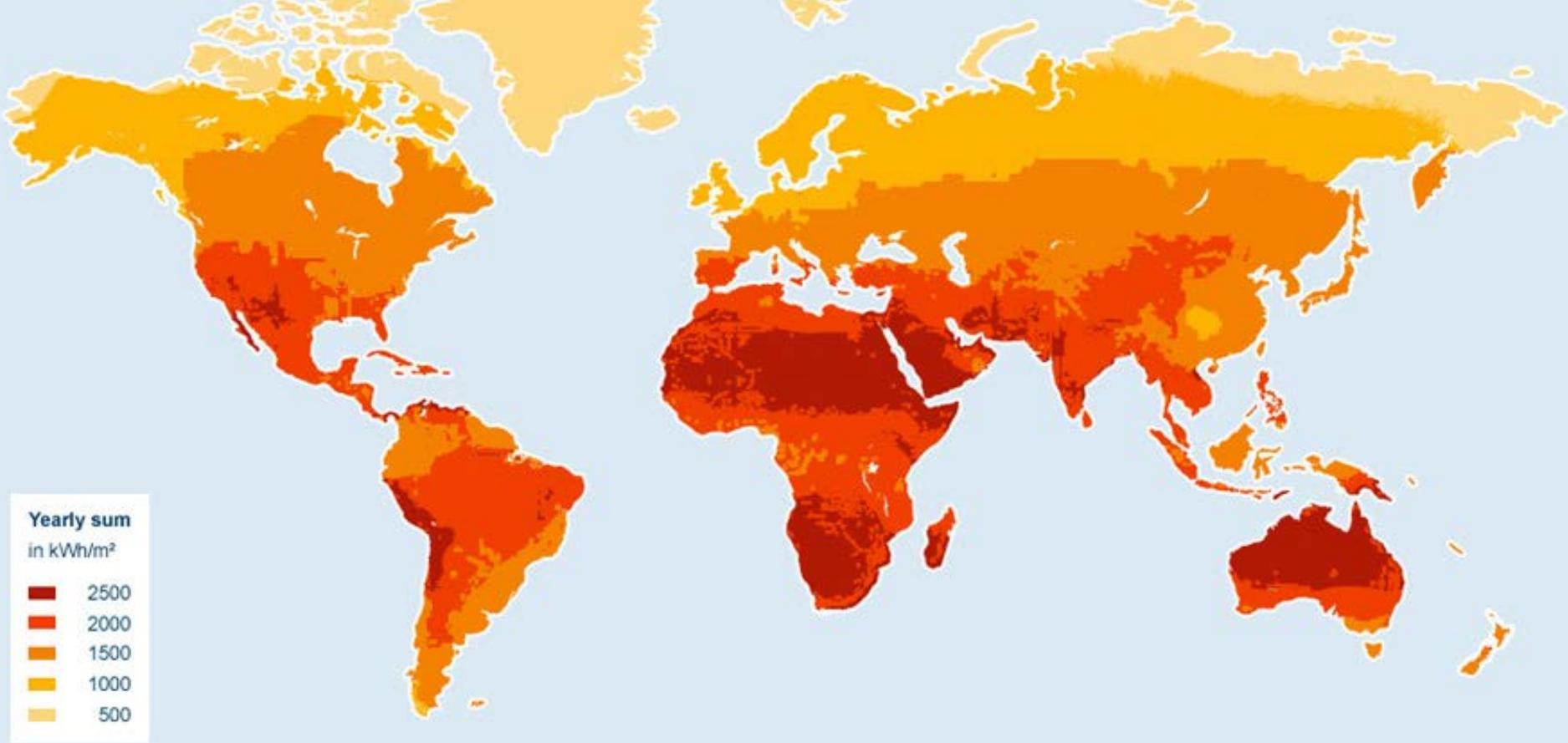
- Positively and negatively charged silicon semi-conductors are arranged in PV cells, creating an electric field at the junction
- Photons from the sun knock electrons free, generating an electric current
- Metallic conductor plates collect electrons and transfer the current to electrical wires



# Solar Panel Angle Considerations

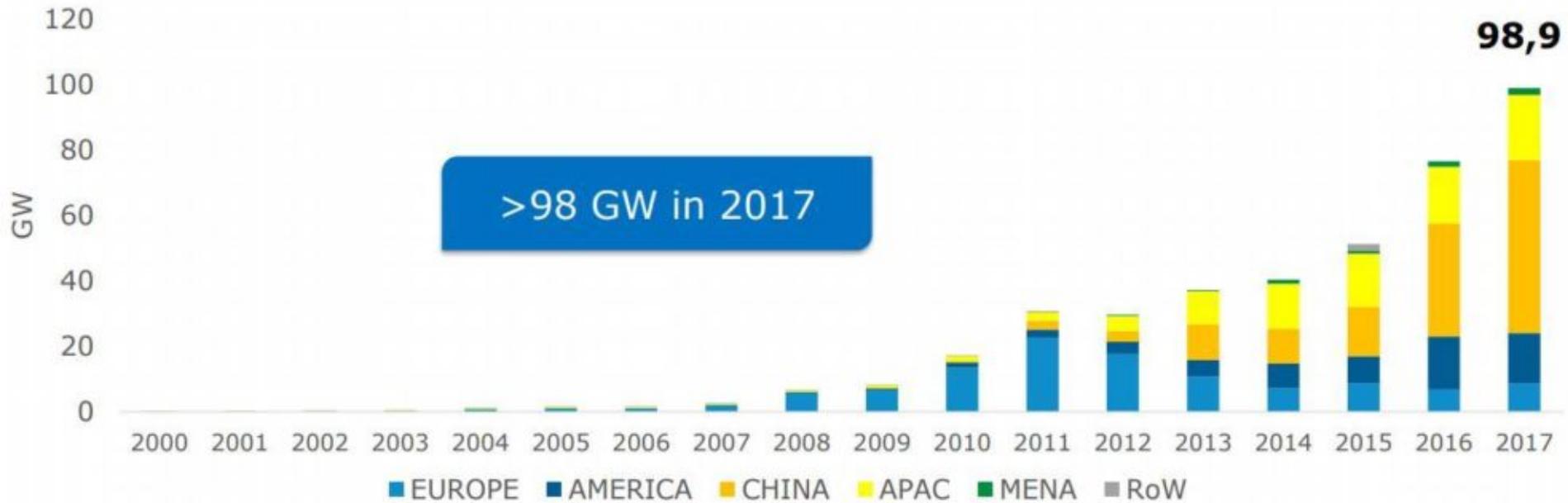


## Seasonal Effects on Quality of Solar Energy



## Geographic Effects on Quality of Solar Energy

# EVOLUTION OF GLOBAL ANNUAL SOLAR PV INSTALLED CAPACITY 2000 - 2017

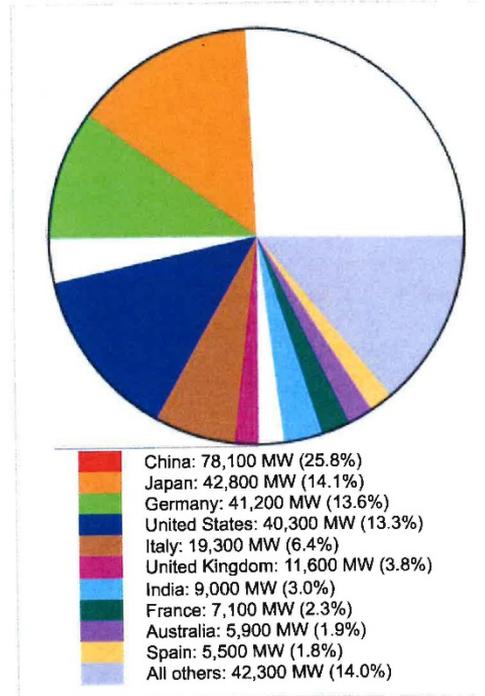


**Global annual PV installed capacity increased by over 29% YoY in 2017**

**World Solar Power Generation**



2016 based on total PV installed capacity (MW)<sup>[2]</sup>



- 
- A globe is positioned in the upper left, and several solar panels are arranged in a row on the right side of the slide. The background is a dark blue gradient.
- Annual Power Demand = 22,000 Terawatt-hours | Equivalent to 2,500 GW running 24/7
  - 98.9 GW of solar generated electricity added in 2017
    - ✓ 0.7% of World Power Demand
    - ✓ Pound for pound: Solar capacity > Nuclear Power Capacity

## Current State of Power Worldwide

# Solar-Ready Buildings

- 2015 IBC
- Solar-ready zones required for most low-rise commercial buildings
- Requirements for solar-ready area, including structural, electrical, and fire protection
- Design criteria must be included in the construction documents



# Types of Photovoltaic Panels

- **Monocrystalline**
- **Polycrystalline**
- **Thin film**

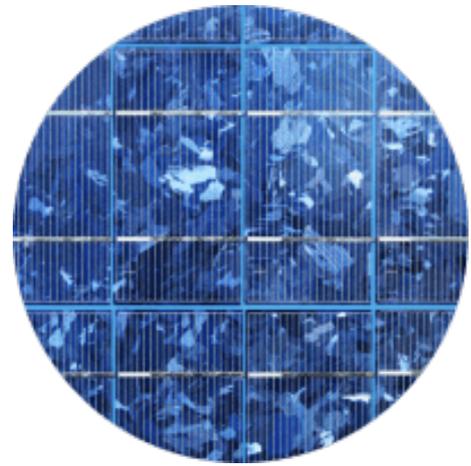
# Monocrystalline PV

- Oldest technology on the market
- Crystalline Silicon based
- Created from a single, continuous crystal structure
- Highest efficiency
- Long life span (typical 25 year warranty)
- Most expensive



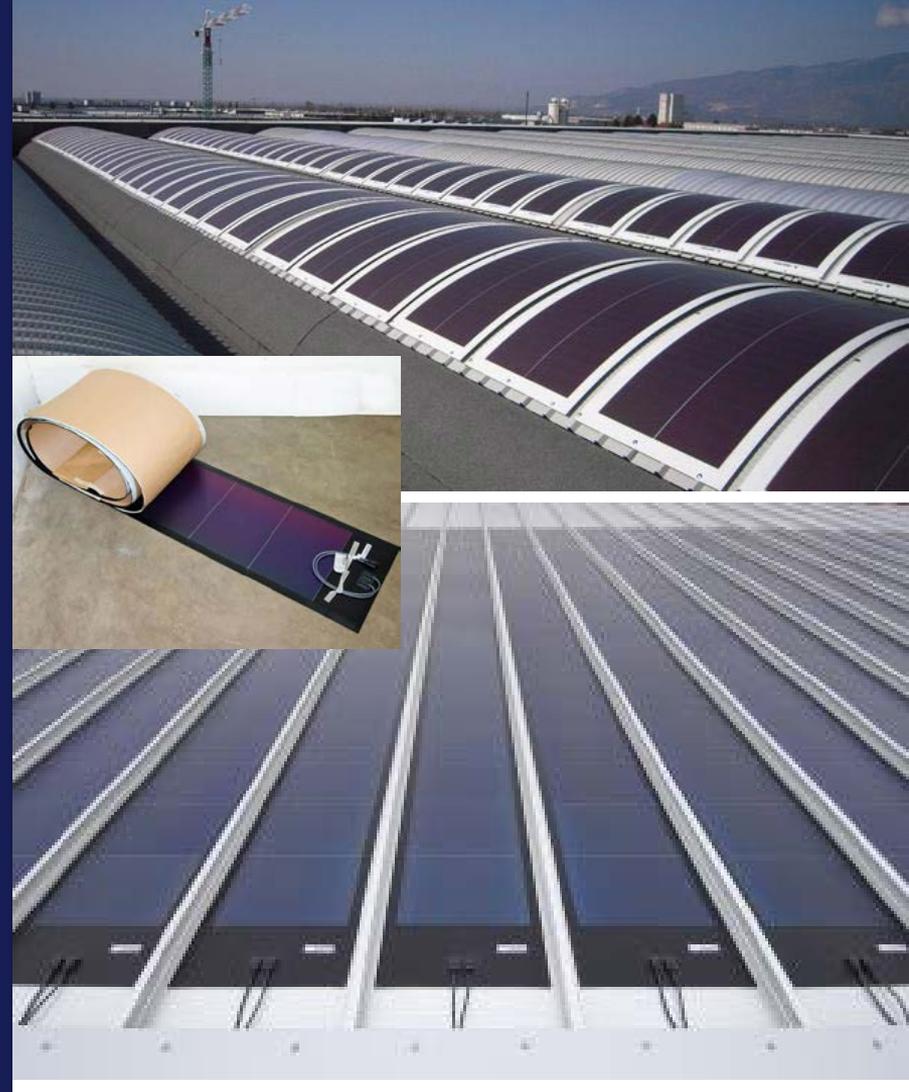
# Polycrystalline PV

- Crystalline Silicon based
- Multicrystalline – made of multiple crystals of Silicon
- Simpler manufacturing process
- Less expensive than monocrystalline panels
- Less efficient than monocrystalline panels
- Recent improvements in efficiency are making these panels more common in residential applications



# Thin Film Amorphous PV

- Thin, flexible panels
- Higher temperature resistance
- Better resistance to shading
- Flexible installation options
- Lower efficiency than polycrystalline panels = more panels are required to generate equivalent power
- Potential issues with differential thermal expansion when laminated to roofing materials





# Financing Options

# Solar Leases/Power Purchase Agreements (PPA)

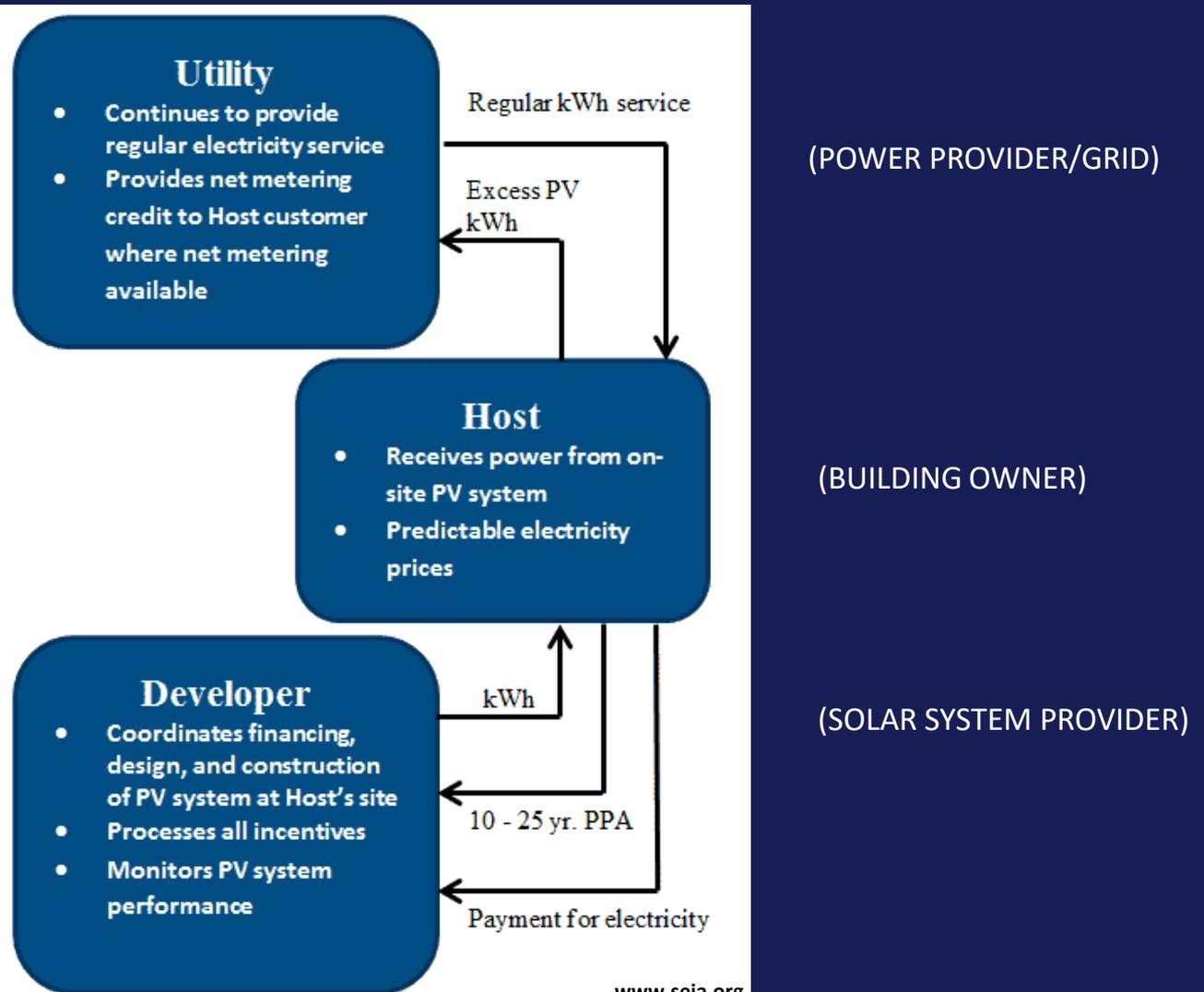
A third party owner installs the solar panels on your building

The third-party owner is responsible for maintenance and operation of the photovoltaic panels

Building owners agree to pay a negotiated price to use the solar electricity (typically below market price)

PPA's terms vary in duration but are typically around 20 years

# Power Purchase Agreements (PPA)



# Power Purchase Agreements (PPA)

## Advantages

- **Low upfront costs for building owners**
- **Low risk for building owners**
- **Consistent power cost for owners**

## Disadvantages

- **Building owner does not own the panels**
- **Additional cost to the owner if panels need to be removed**

# Solar Loans / Net Metering

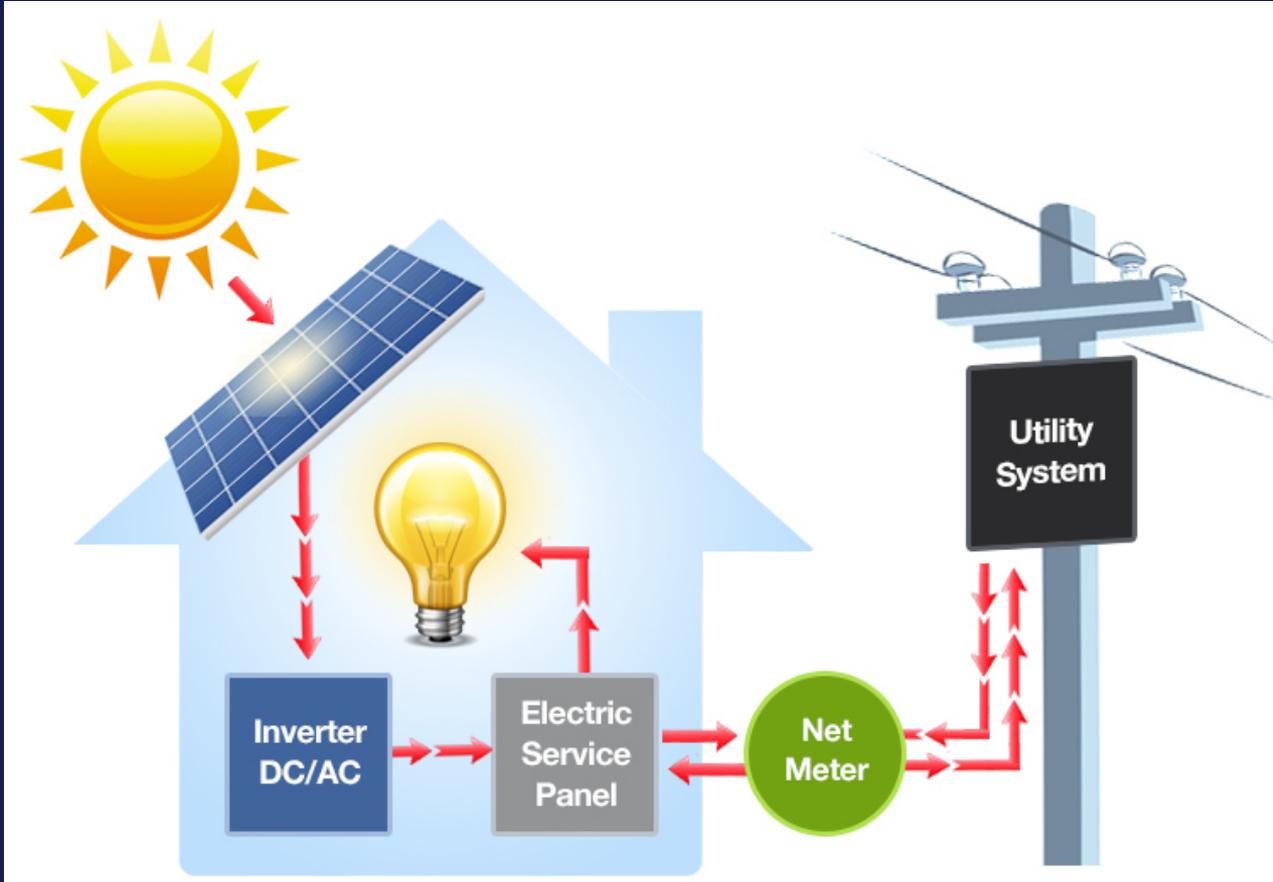
Building owner buys the solar system outright (typically a loan is taken out)

The solar electricity is used by the building to supplement electricity demand at no cost

Building owner is responsible for installing and maintaining photovoltaic system

Excess power is sold back to the utility at the same rate the customer pays for utility generated power (net metering)

# Solar Loans / Net Metering



# Storing / Direct Use

Building owner installs PV panels and uses the energy produced

The power that is produced when there is no demand is stored on site in batteries

Storing power is not efficient and requires multiple batteries

Typically the power produced is not sufficient to fully power a large commercial building



# Photovoltaic Systems and Attachments

# Low Slope Roof Curb Systems



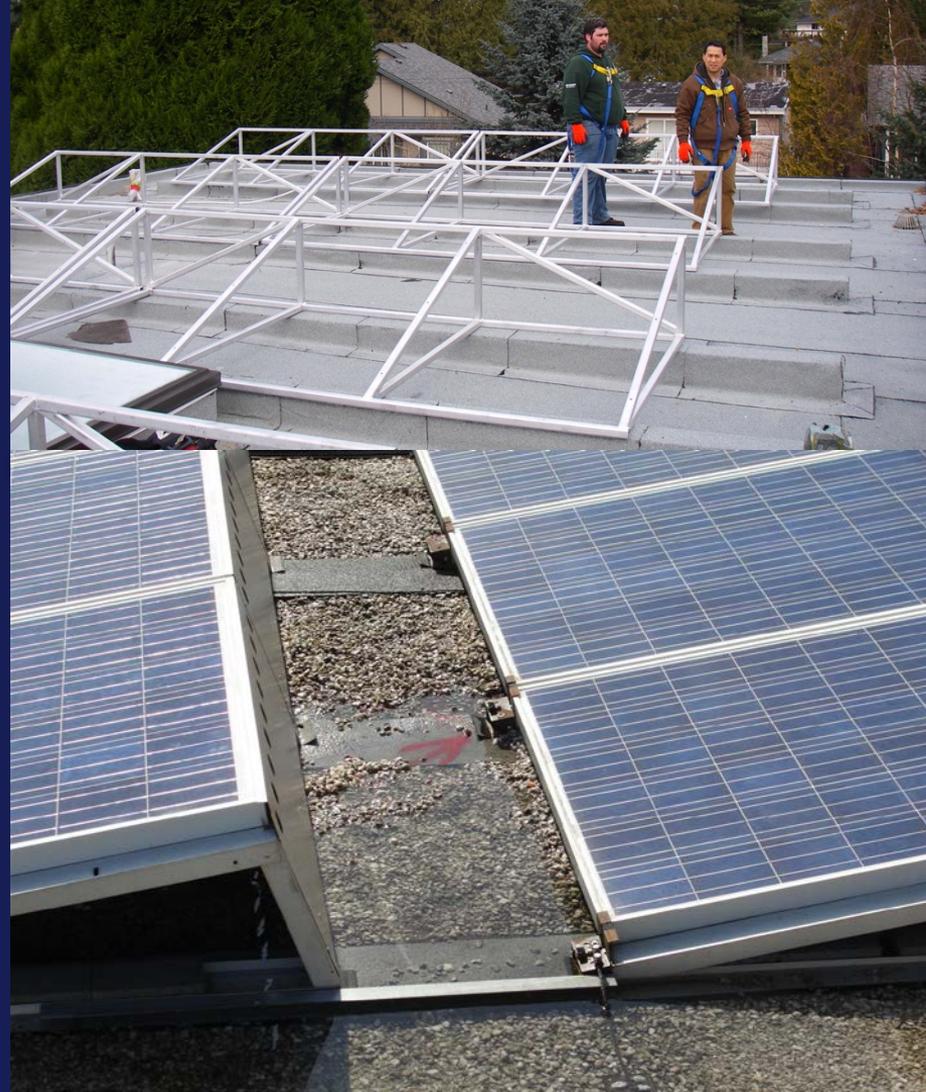
# Curb Systems

## Pros:

- Attachment to building structure
- Greater angles = more efficient panels

## Cons:

- Additional roof penetrations
- Curbs can disrupt drainage path on roof
- Potential for additional wind loading on structure



# Low Sloped Roof Post Systems



# Post Systems

## Pros:

- Attachment to building structure
- Greater angles = more efficient panels
- Does not affect drainage

## Cons:

- Additional roof penetrations = more potential leak locations
- May require additional structure or steel dunnage
- Potential for additional wind loading on structure and snow drifting



# Low Sloped Roof Ballasted Systems



# Ballasted Systems

## Pros:

- Easy to install
- No roof penetrations

## Cons:

- Heavier system, but less snow drifting
- Lower angle = less efficient
- Can displace in high wind or seismic events
- Direct contact with the roof system
- For low slope roofs only



# Low Sloped Roof – Roofing Manufacturer Integrated Systems



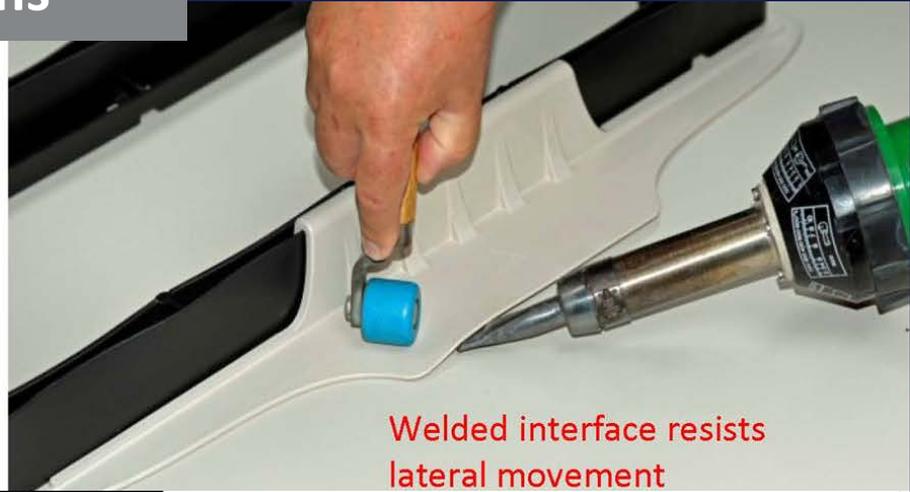
## New Industry Concepts:

- Solar and roof are 1 system (solar-roof system)
  - Developed in partnership between roof and solar companies
- Single-source warranty for both roof and PV mounting system

(SIKA  
CORPORATION)

# Low Sloped Roof – Roofing Manufacturer Integrated Systems

- Innovative heat-welded mount/roof attachment
- Loads distributed throughout
- Material: same formulation as roof membrane



# Steep Sloped Roof Standing Seam Systems



# Standing Seam Roofs

## Pros:

- Direct attachment to the metal seams
- No roof penetrations
- Panels installed parallel to the roof slope will have the same, or reduced wind uplift loads

## Cons:

- Difficult to access panels for maintenance and repairs
- Additional fall protection may be required



# Steep Sloped Roof Shingle Systems



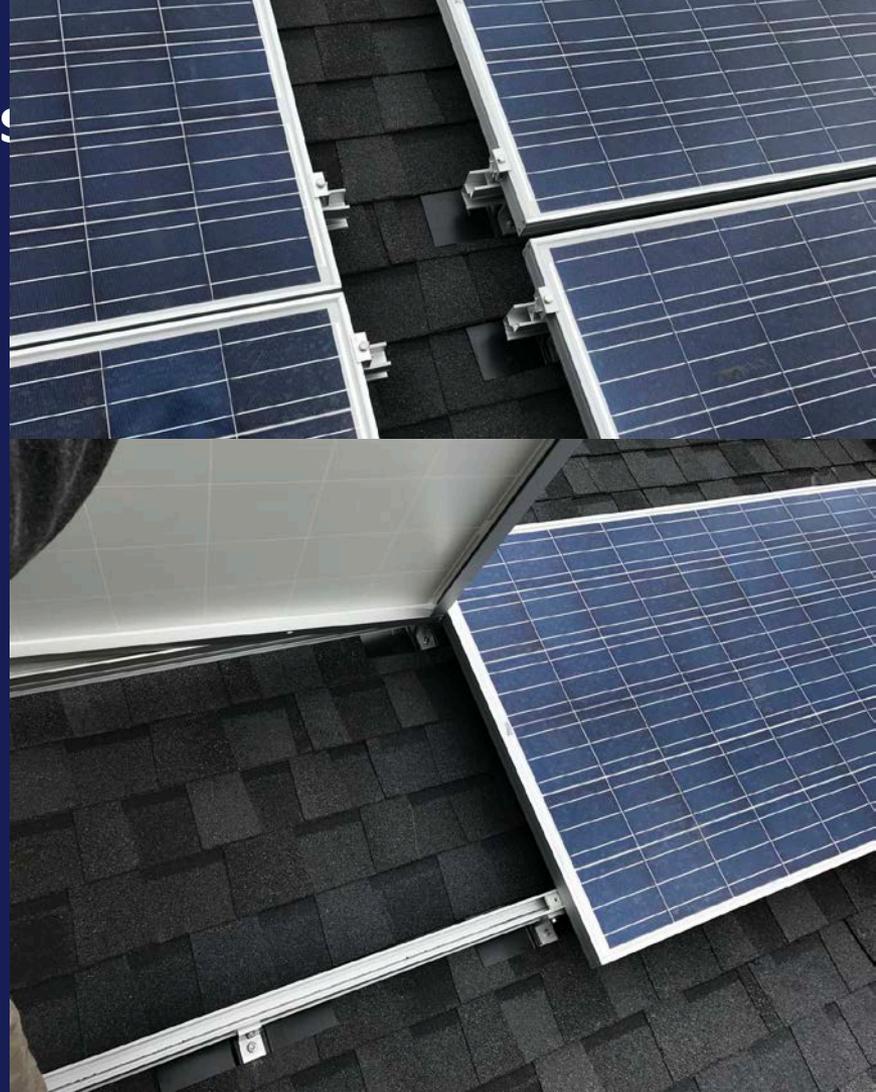
# Steep Sloped Roof Shingle Systems

## Pros:

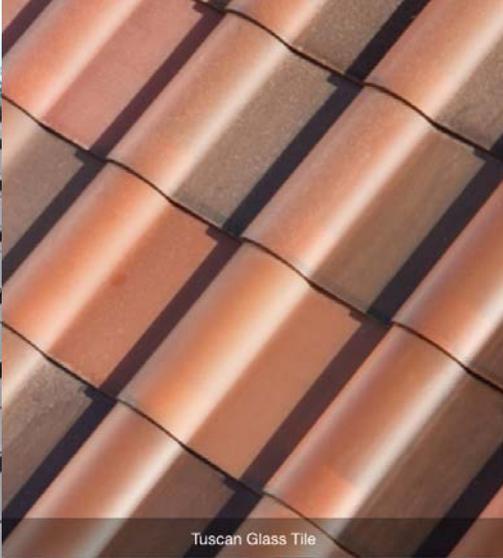
- Direct attachment into structure
- Easy to install

## Cons:

- Connection typically through roof
- Difficult to access panels for maintenance and repairs
- Additional fall protection may be required
- Snow/ice sliding off roof



# Emerging Technology



Tuscan Glass Tile



Slate Glass Tile

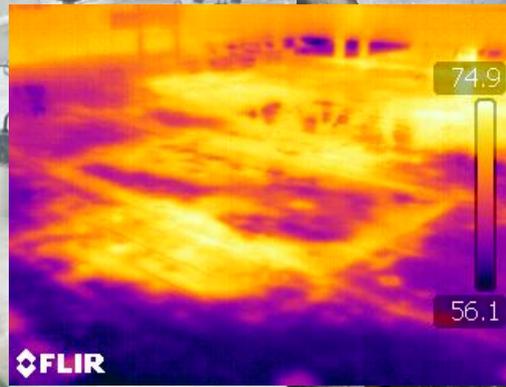




**You've Decided to Install Rooftop PV Panels:  
Now What?**



**Evaluate the Existing Roof System: Repair or Replace**



**Destructive and Non-Destructive Testing**  
(visual evaluation, leak audit, roof core/test cuts, infrared survey, electric Field Vector Mapping [EFVM])

# Review Existing Roof System Warranty

- Warranties could be partially or fully voided if a PV system is installed
- Each manufacturer has specific requirements to maintain or obtain a roof system warranty with a PV system
- Roof manufacturer PV installation requirements
- Roof Manufacturer's warranty exclusions/ requirements

## Terms, Conditions and Limitations

1. The SOPREMA® roofing materials covered by this warranty (this "Warranty") are the roofing and flashing materials specifically identified by number or other description on the face of this Warranty (referred to as the "roofing").
2. The authorized contractor who installed the roofing is not an agent of SOPREMA. Any future work impacting the roofing must be performed by a contractor selected and hired by Owner and authorized by SOPREMA. Contact SOPREMA if you would like to receive a list of authorized contractors in your area.
3. The design and installation of the roof assembly must be in accordance with applicable instructions, details, specifications, approvals, codes, laws, and regulations. All services by SOPREMA related to design, construction, review of project documents or conditions and site visits are limited in scope and do not expand the provisions of this Warranty. These services were not offered, and should not be considered, as a substitute for fulltime quality assurance, project management or professional design services.
4. Owner is responsible for ensuring that the roofing is maintained in accordance with SOPREMA's Care and Maintenance Guide (see Form 901) and for promptly notifying SOPREMA of any change in occupancy, usage or any other condition adversely affecting the roofing.
5. During the entire term of the Warranty, upon request, SOPREMA and anyone it hires shall have full and free rooftop access. Access shall be provided during regular business hours, and, if requested in advance, any other times.
6. This Warranty covers SOPREMA roofing products included in a properly designed and installed roof assembly that develops a roofing leak due to workmanship or a product manufacturing defect. The Warranty will provide Owner with a remedy when Owner follows the Warranty Claim Procedure (see Form 900) and the claim is validated by SOPREMA.
7. The Warranty also covers roofing leaks caused by wind with a speed less than 74 m.p.h. The wind speed warranty excludes damage where the cause includes any of the following: (a) primary or secondary structural components, (b) wood nailers or blocking and edge system components, (c) deck and deck fastening; (d) walls, doors, windows, openings and other building envelope components; (e) substrates that are deteriorated, rusted, rotted, deformed, weakened, crushed, compressed, or otherwise failed; (f) rooftop structures and/or equipment connected to, or supported by, the roofing or waterproofing system; (g) windborne debris; or (h) neglect or physical abuse.
8. Following are some examples of conditions and types of damage not covered by this Warranty:
  - a. The effects of lightning, fire, flood, acid rain, thermal shock, explosion, hail, seismic event, hurricane, tornado, or microburst.
  - b. Improper use, order, sequencing, storage or handling of materials or systems.
  - c. The lack of positive slope or inadequate drainage.
  - d. Inaccessible leaks concealed below rooftop equipment, overburden, and all other products applied to the roofing or flashing materials.
  - e. Failure to apply the roofing to a suitable substrate, or subsequent substrate failure.
  - f. Failure of roofing substrates or attachments.
  - g. A deficient pre-existing condition or any sources of water entry other than the roofing.
  - h. Building or substrate settlement, deflection, movement, vibration, or displacement.
  - i. The accumulation of moisture from condensation in or below the roofing.
  - j. Exposure to extreme temperatures or humidity, for example, from equipment, exhaust, steam, hot water, freezers, or cold storage.
  - k. Plants, animals, insects, or other living organisms.
  - l. Incompatible materials or substances.
  - m. Deliberate or negligent acts such as excessive traffic, rooftop storage, vandalism, misuse, or abuse.
  - n. Falling, flying, dropped, discharged or blown materials, objects or debris.
  - o. Change in building occupancy or rooftop usage.
  - p. Unauthorized or improper repairs or modifications.
9. This Warranty becomes a binding contract once it has been signed by both parties and all fees and expenses associated with the roofing project have been paid in full.
10. Temporary, emergency repairs to stop a leak may be made at Owner expense and will not void this Warranty, however it is Owner's responsibility to pay the cost of removing any excessive repairs. Promptly after making emergency repairs, Owner is responsible for following the Warranty Claim Procedure (see Form 900).
11. SOPREMA's failure to exercise or enforce any of its rights under this Warranty is not a waiver and does not preclude SOPREMA from exercising the same or any other right in the future. Owner's failure to comply with any of the provisions of this Warranty applicable to it relieves SOPREMA of its obligations under this Warranty.
12. This Warranty is governed by and shall be construed and enforced in accordance with the internal laws of Ohio, without giving effect to any choice of law rules that may require the application of the laws of another jurisdiction. Any lawsuit by Owner that is related to the roofing or this Warranty, including the alleged breach of this Warranty, must be filed in either the Medina County, Ohio Court of Common Pleas or the U.S. District Court for the Northern District of Ohio. Owner irrevocably consents to the jurisdiction and venue of these courts.
13. In order for Owner to bring a lawsuit against SOPREMA, Owner must, as a condition precedent thereto, (a) have complied with all of the terms and conditions of this Warranty applicable to it, and (b) the lawsuit must be commenced within one (1) year after the cause of action accrues. Time is of the essence. The failure to satisfy either of these conditions precedent shall result in Owner's claims being forever barred.
14. The terms of this Warranty are severable so that any illegal, invalid or unenforceable provision, if feasible, shall be modified so that it becomes legal, valid and enforceable, or if not so feasible, stricken, in either case without affecting the validity or enforceability of the remaining provisions.
15. This Warranty document (and the documents referred to herein) sets forth the entire agreement between SOPREMA and Owner with respect to the roofing. SOPREMA disclaims, and Owner waives, any affirmation of fact or promise not expressly stated in this Warranty that may have been made by SOPREMA or any of its employees, agents, representatives, or distributors.
16. The damages excluded by the terms of this Warranty include, but are not limited to, loss or reduction of profits, interruption of business, injury to or illness or death of people, animals or other living organisms, damage or loss caused by or attributable to indoor air quality (including, but not limited to, the presence or growth of mold, mildew or other similar substance in, on or about the roof assembly), or damage to or destruction of property, including the building or any of its contents, even if SOPREMA has been advised of the possibility, or even the likelihood, of any of these types of damages.
17. This Warranty may be transferred to a subsequent building owner upon compliance with the following requirements: (a) a transfer request is made in writing to SOPREMA's Warranty Department, (b) at the time the request is made, SOPREMA is paid its then current transfer fee, and (c) you complete any repairs to the roof assembly or other building components that SOPREMA believes are necessary to preserve the watertight integrity of the roofing for the remaining term of this Warranty.



**Evaluate the Existing Roof Deck and Structure**

# Design Criteria

- **Structural Code Review – dead load, wind load, seismic load analysis**
- **Roof System Selection and Detailing**
- **Fire Protection (NFPA 285)**
- **Access and Safety Considerations**
- **Electrical Design (NFPA 70)**
- **FM Global Design Requirements (Data Sheet 1-15)**





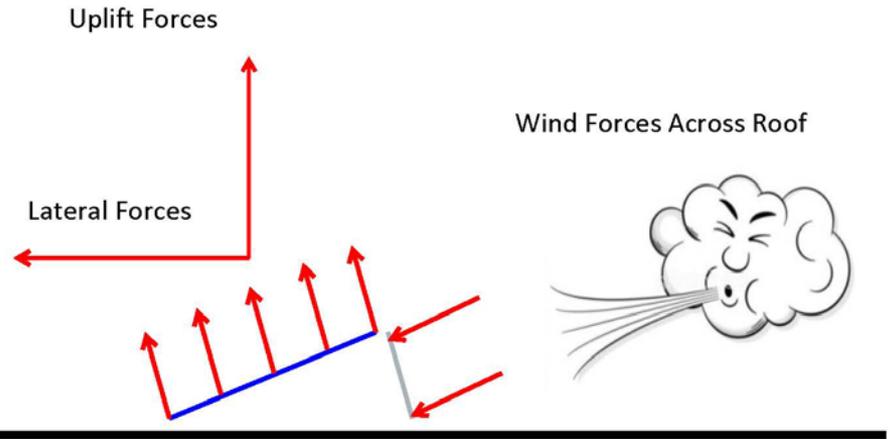
## WIND DESIGN FOR SOLAR ARRAYS



by

SEAO Solar Photovoltaic Systems Committee

Report *SEAO PV2-2017*  
July 2017





## STRUCTURAL SEISMIC REQUIREMENTS AND COMMENTARY FOR ROOFTOP SOLAR PHOTOVOLTAIC ARRAYS



By

SEAOC Solar Photovoltaic Systems Committee

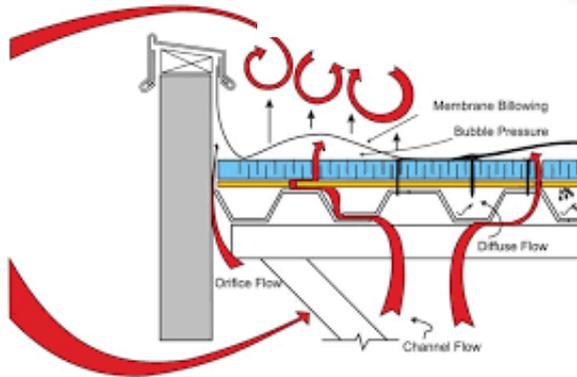
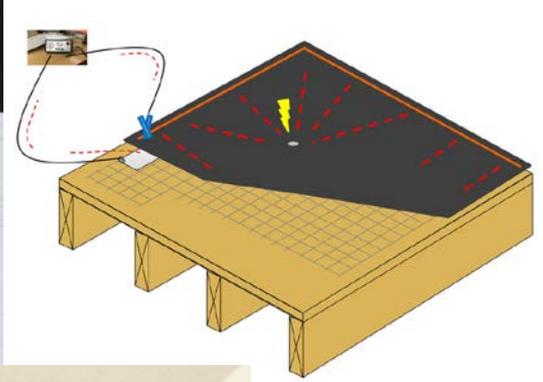
Report *SEAOC PV1-2012*  
August 2012



# Seismic Analysis

# Roof Selection and Detailing

- Reflective Roof Membrane
- Fully Adhered Roof System
- High Compressive Strength Insulation Boards and Rigid Cover Board
- EFVM Grid
- Increased Membrane Thickness
- Walkway Protection Pads and Slip Sheets





## Fall Protection and Access

# Existing Electrical Equipment Design Coordination

- Review existing equipment to be removed, stored, and reinstalled to perform rising wall repairs
- Raise wall penetrations to provide 8" minimum height above roof to wall flashing
- Raise conduit trays for new insulation system thickness
- Modify conduit to accommodate new cable tray height





## Electrical Details



**Fire protection – review panel fire ratings for compatibility with A, B, or C Class rated systems**

# Solar-Ready Requirements for New Buildings

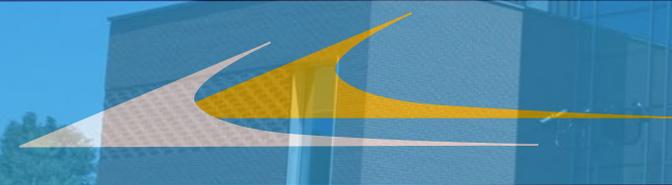
- Solar-ready zones required for most low-rise commercial buildings
- Criteria for solar-ready area, including structural, electrical, fire safety



# Pre-Construction

- **Coordination meeting with all trades – PV installer, roofer, electrician, facility personnel, roof manufacturer, designer, Owner’s representative**
- **Submittals – review materials for conformance with ASTM standards, such as CMU ballast for freeze-thaw durability**





# Issues to Avoid with Rooftop Solar

BRISTOL COMMUN

# Fire Protection

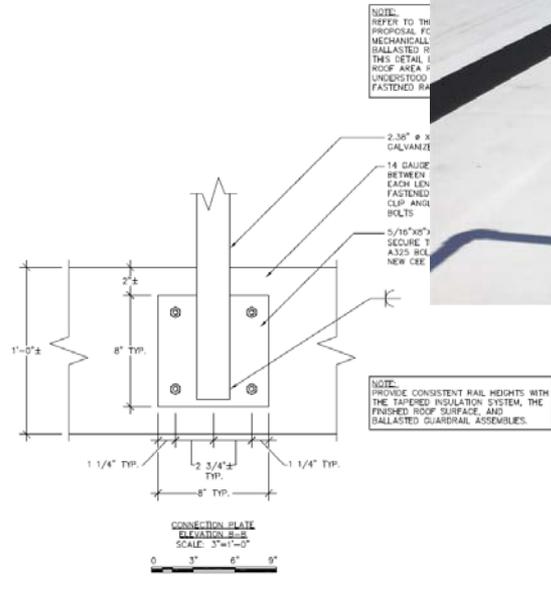
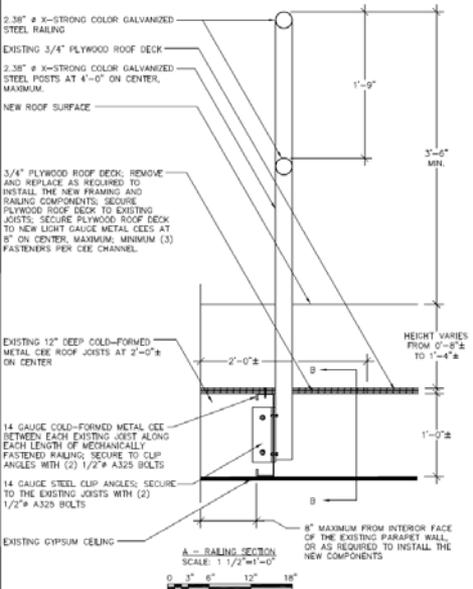


**Fire in New Jersey – Dietz & Watson, 2013**



**Fire in Arizona – GT Advanced Technologies, 2015**

# Fall Protection

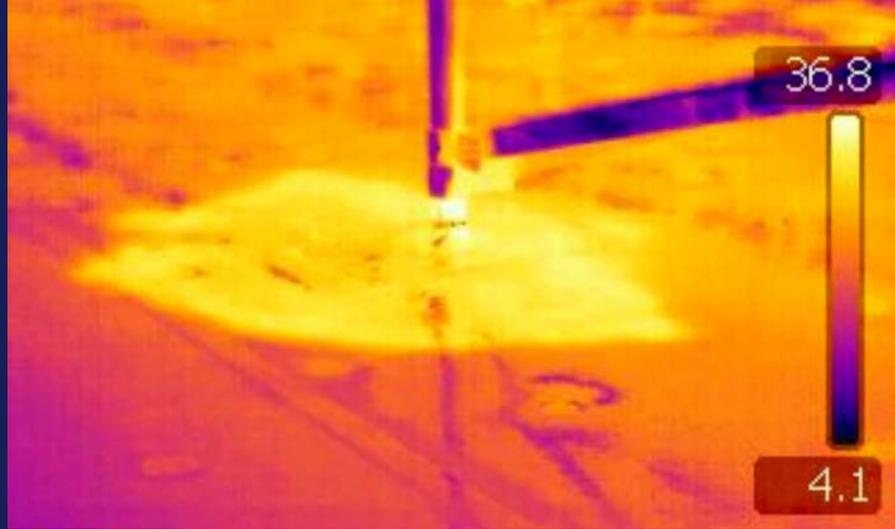
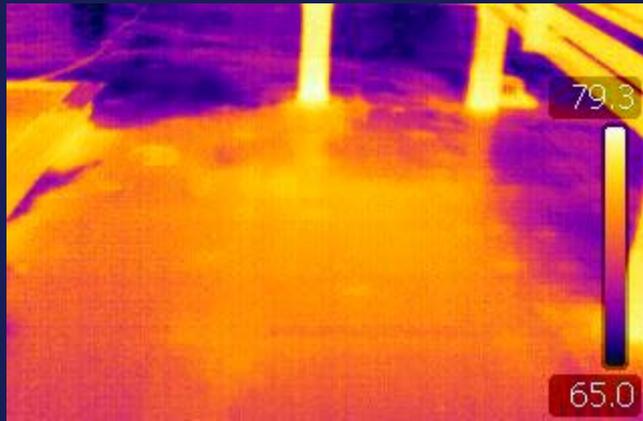


# Steep Sloped Roof Solar Installation Issues



# Roof Detailing

- Proper Detailing and Installation - have a roofing contractor install any PV system roof penetrations
- Flashing Heights - minimum of 8"
- Manufacturer Approval – use a certified installer to avoid potential warranty issues



# Additional Costs

- PV material and installation, combined with additional roof recommendations
- PV manufacturer claims of return on investment may be exaggerated
- Disconnecting, removing, storing, and reinstalling the PV system if roof needs to be repaired/replaced
- Added costs of \$500,000 to remove, reinstall a 300kW PV system





**Don't Forget the Maintenance!**

# Snow Removal

- Snow can affect output of PV system
- Snow removal is recommended for highest output during the winter months



# Servicing PV Panels and Roof System

- PV panel maintenance should be performed annually
- Annual roof maintenance should be coordinated with the PV panel maintenance to address any potential damage caused by PV maintenance staff
- The owner could consider additional annual maintenance for the roof system through the roof system manufacturer





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Thank you!



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