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Mastering the Design Issues of Solar Photovoltaic Installations on An Existing Roof

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Allana Buick & Bers, Inc.

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Karim P. Allana, PE, RRC, RWC

Education: B.S., Civil Engineering, Santa Clara University

Registration: P.E., Civil Engineering, California, Washington, Nevada, and Hawaii

Certification: Registered Roof Consultant (RRC), Roof Consultants Institute, and Registered Waterproofing Consultant (RWC)

Overview:

- CEO and Senior Principal at Allana Buick & Bers.
- Former Turner Construction Employee (Project Engineering and Superintendent)
- Over 37 years experience providing superior technical standards in all aspects of building technology and energy efficiency.
- Principal consultant in forensic investigations of building assemblies, failure analysis, evaluation and design of building infrastructure and building envelope evaluation and design.
- Expert in all aspects of building envelope technology.
- Completed numerous new construction, addition, rehabilitation, remodel and modernization projects for public and private sector clients.
- Specialization in siding, roofing, cement plaster, wood, water intrusion damage, window assemblies, storefronts, below grade waterproofing, energy efficiency, solar engineering and complex building envelope and mechanical assemblies.

ABBAE Firm Overview

- **Allana Buick & Bers (ABBAE) is an Architectural Engineering firm specializing in Building Envelope Systems**
- **ABBAE is one of the 5 largest building envelope consultants in the country**
- **ABBAE has over 33 years of experience & over 12,500 projects**
- **ABBAE is also a leading Forensic Defect firm with hundreds of forensic projects (litigation)**
- **Locations – 16 offices across California, Nevada, North Carolina, Oklahoma, Oregon, Texas, Virginia, Washington, Colorado and Hawaii**

Staff & In-House Expertise

- Licensed Professional Engineers – Civil, Structural, and Mechanical
- Registered Architects
- Building Enclosure Commissioning Process Providers (BECxPs)
- Registered Building Envelope Consultant (RBEC)
- Registered Roofing Consultants (RRCs)
- Registered Waterproofing Consultants (RWCs)
- Registered Exterior Wall Consultant (REWCs)
- Registered Roof Observers (RROs)
- Certified Exterior Insulation and Finish System (EIFS) inspectors
- Curtain Wall Specialists
- ICC Certified Building Inspectors
- Quality Assurance Monitors
- Water Testing Experts
- Leak Investigation and Diagnosis Experts
- Infrared Imaging and Nuclear Moisture Scanning Experts

ABBAE Building Expertise

- Building Envelope Systems
  - Roofing Systems
    - High-Slope/Low-Slope Roofs
    - Green/Garden Roofs
    - Drainage Systems
    - Pedestrian Plazas
  - Exterior Wall Systems
    - Wall Cladding /Siding/GFRC/pre-cast
    - EIFS/cement plaster/stucco
    - Sheet Metal Flashings
  - Windows and Glazing Systems
    - Punched Windows
    - Curtain Wall/Window Wall Systems
    - Sliding Glass Doors
    - Skylights

- Building Envelope Systems (cont'd)
  - Roofing & Waterproofing Systems
    - Deck/Balcony/Lanai Waterproofing
    - Podium Waterproofing
    - Pool/Spa Deck Waterproofing
    - Above-Grade/Below-Grade Waterproofing
    - All types of low and steep sloped roofing
  - Commissioning BECx
    - OPR/BOD/Commissioning Plan
  - Mechanical/HVAC Systems
    - HVAC design
    - Plumbing systems
    - Commissioning and testing

Presentation Objectives

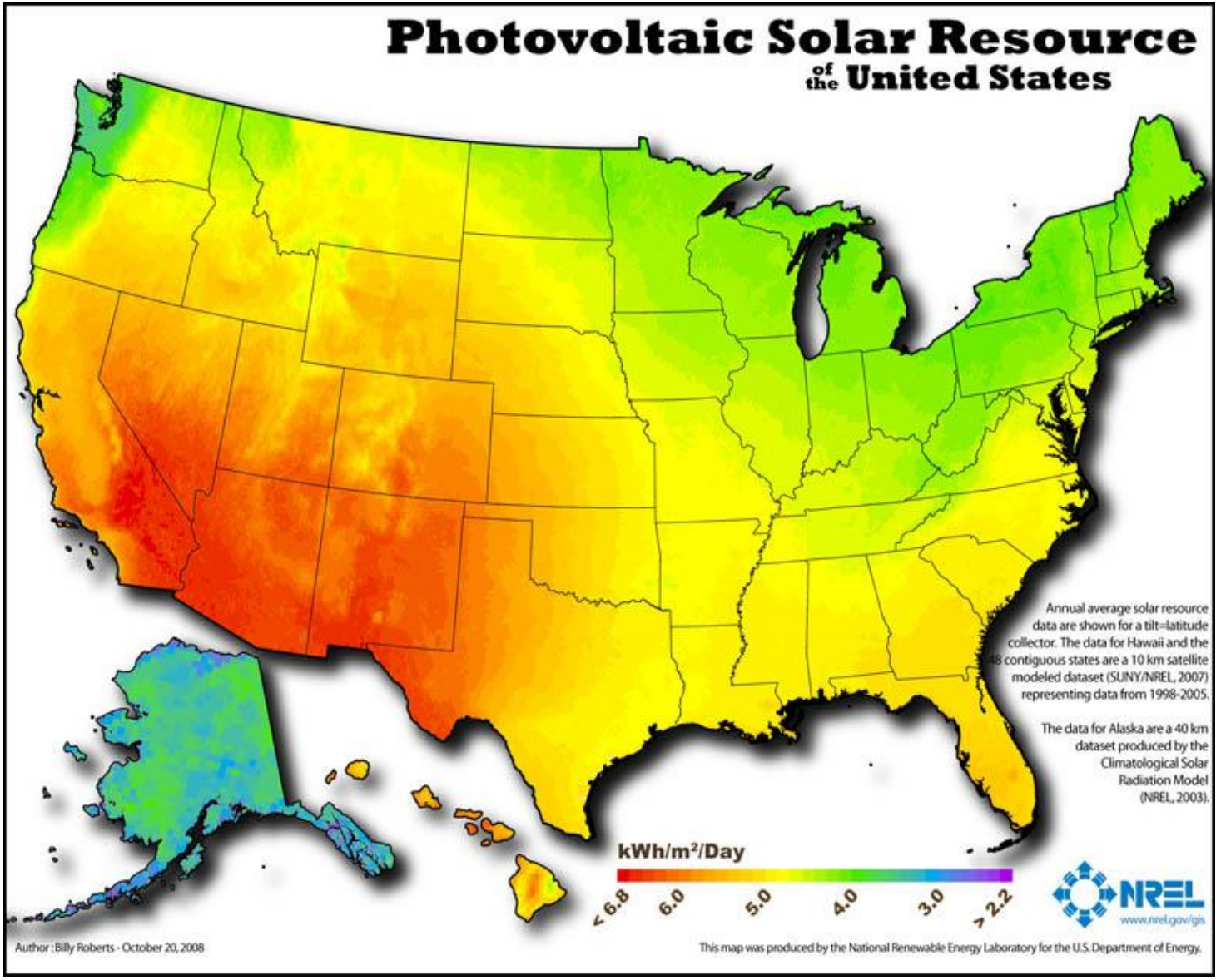
- ✓ Provide an overview of Photovoltaic system components.
- ✓ Provide an overview of Photovoltaic systems on the market, including typical system and component weight.
- ✓ Review the issues that impact the effectiveness and longevity of PV installations.
- ✓ Review roof design issues.
- ✓ Review mounting issues.
- ✓ Review and assess actual examples of Solar PV on existing roofs.

DEFINITION AND DESCRIPTION OF SOLAR PV SYSTEMS

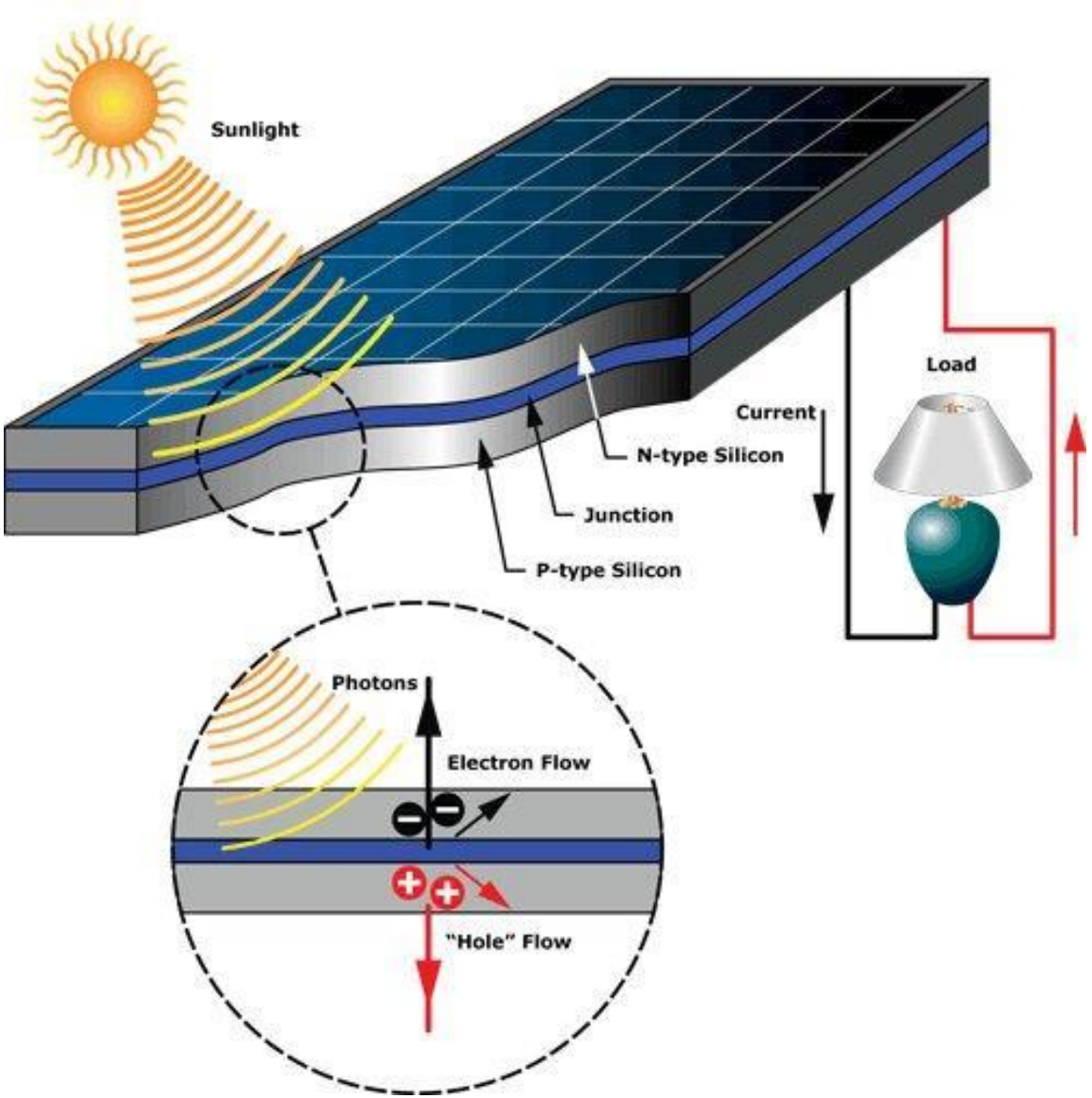
Questions for The Roof Consultant

- Are solar resources sufficient to allow solar to be installed anywhere in the country?
- How does solar PV work?
- Can Solar be installed on any existing roof?
- What does a solar PV system consist of – panels and what else?
- What are the design issues related to roof top solar?

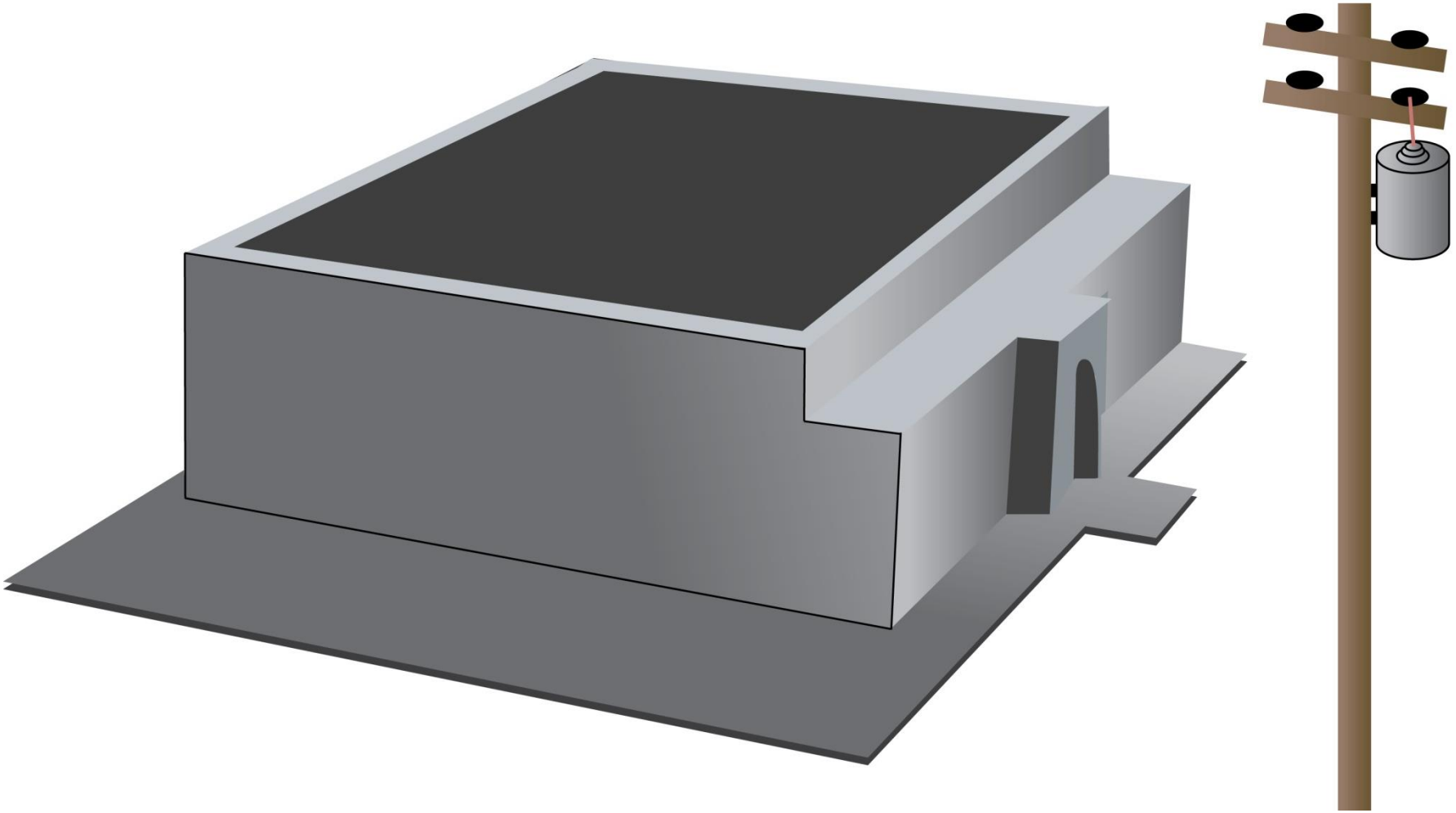
Solar Resources



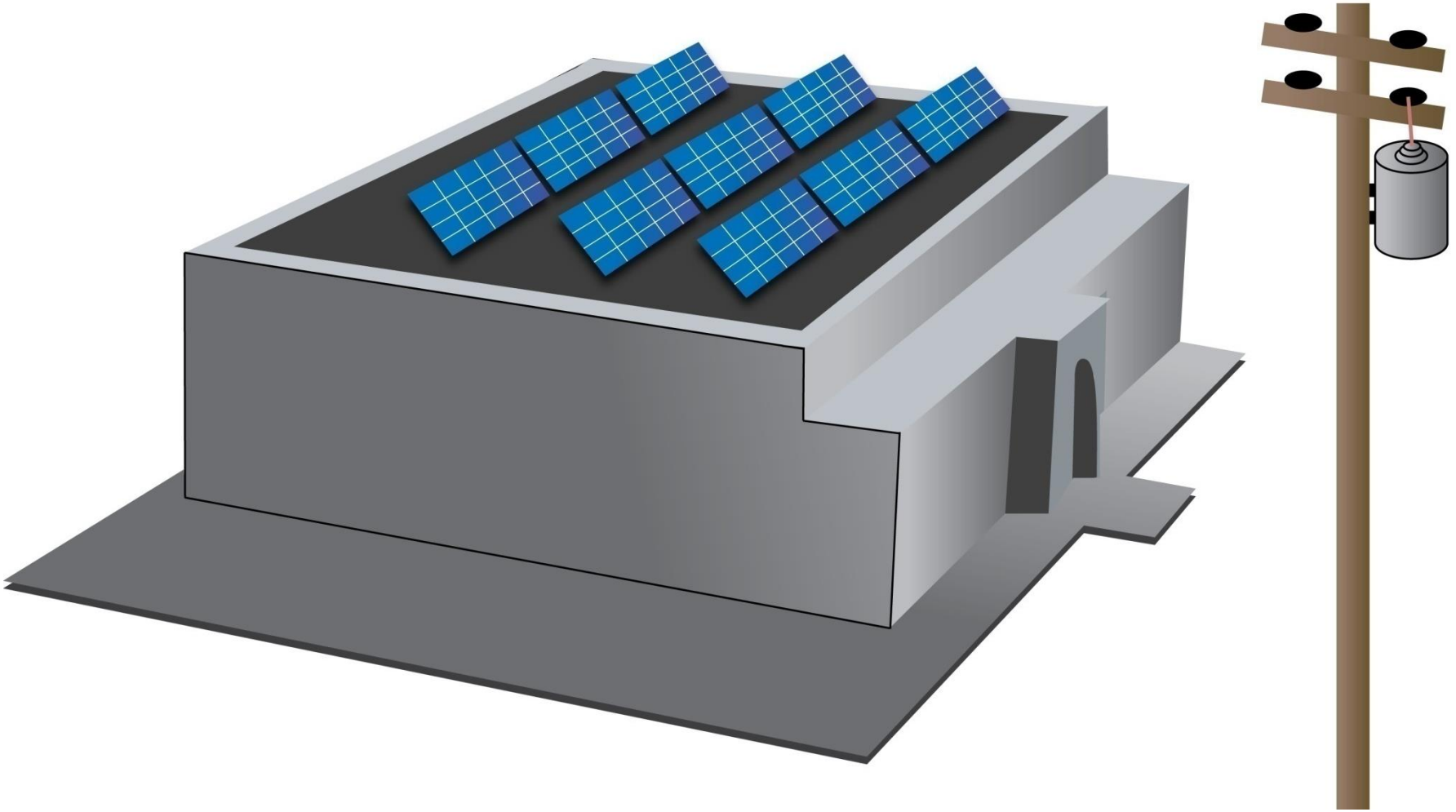
How Solar Photovoltaics Work



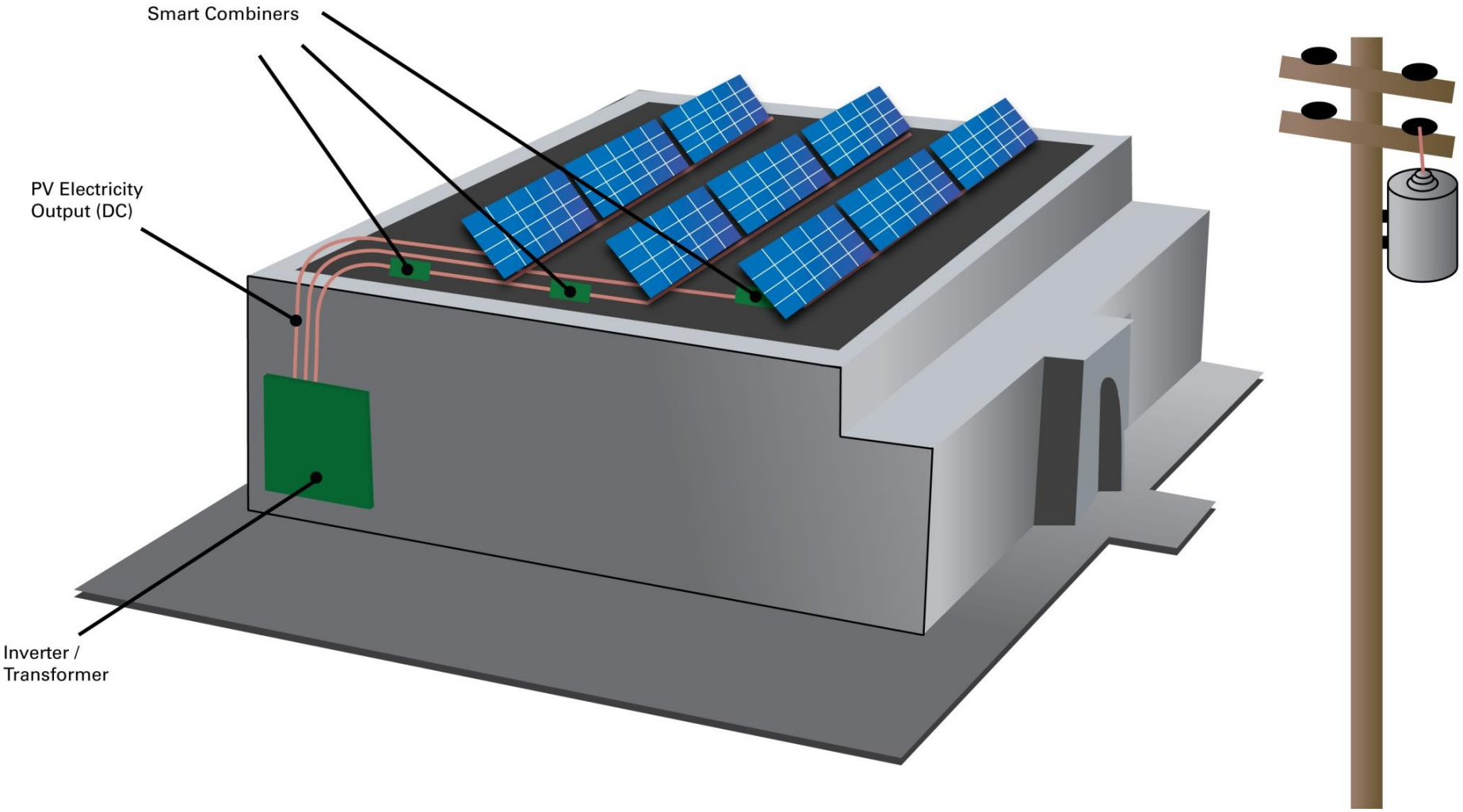
Solar Roof PV Installation Basics



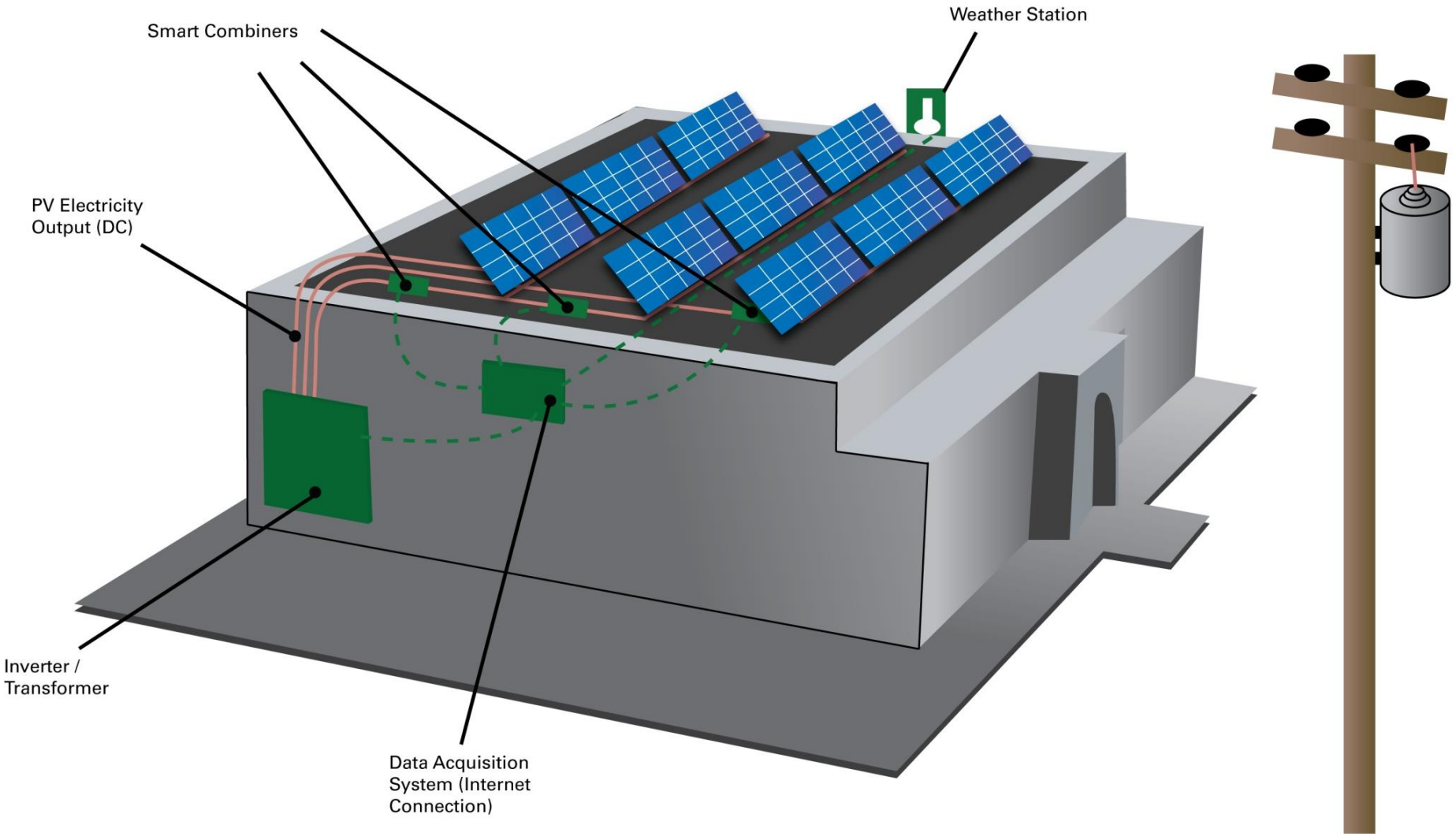
Solar Roof PV Installation Basics



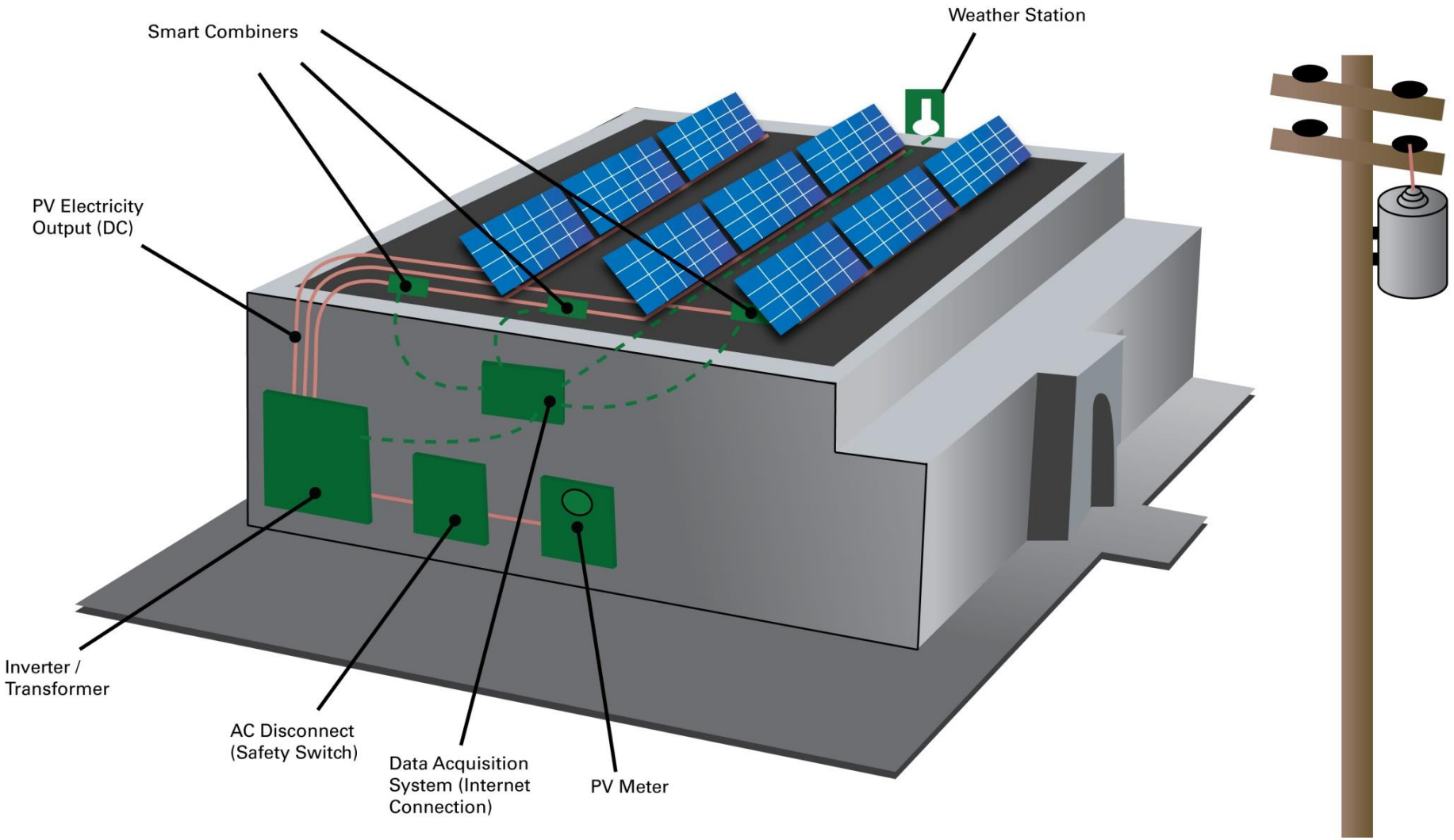
Solar Roof PV Installation Basics



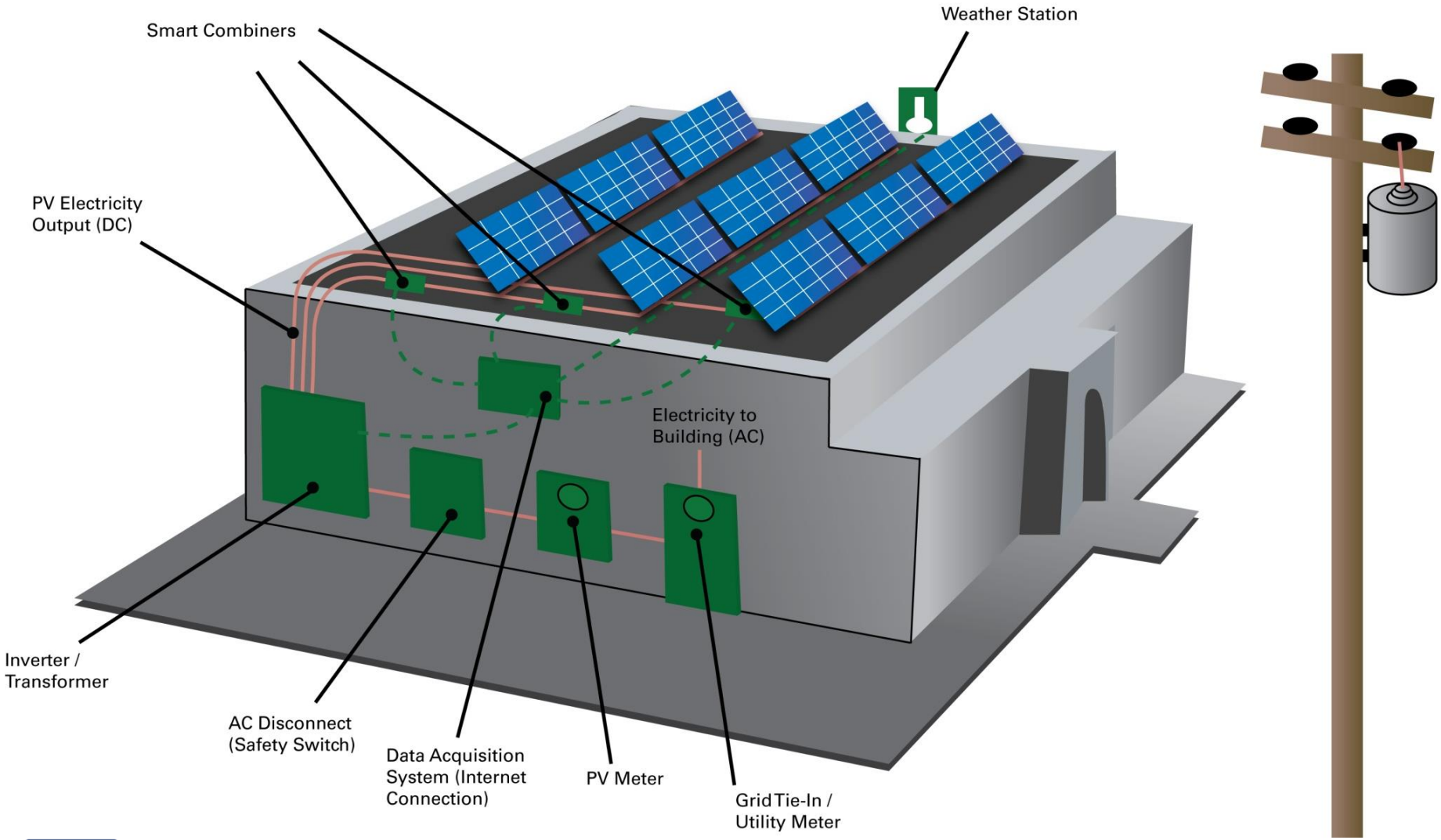
Solar Roof PV Installation Basics

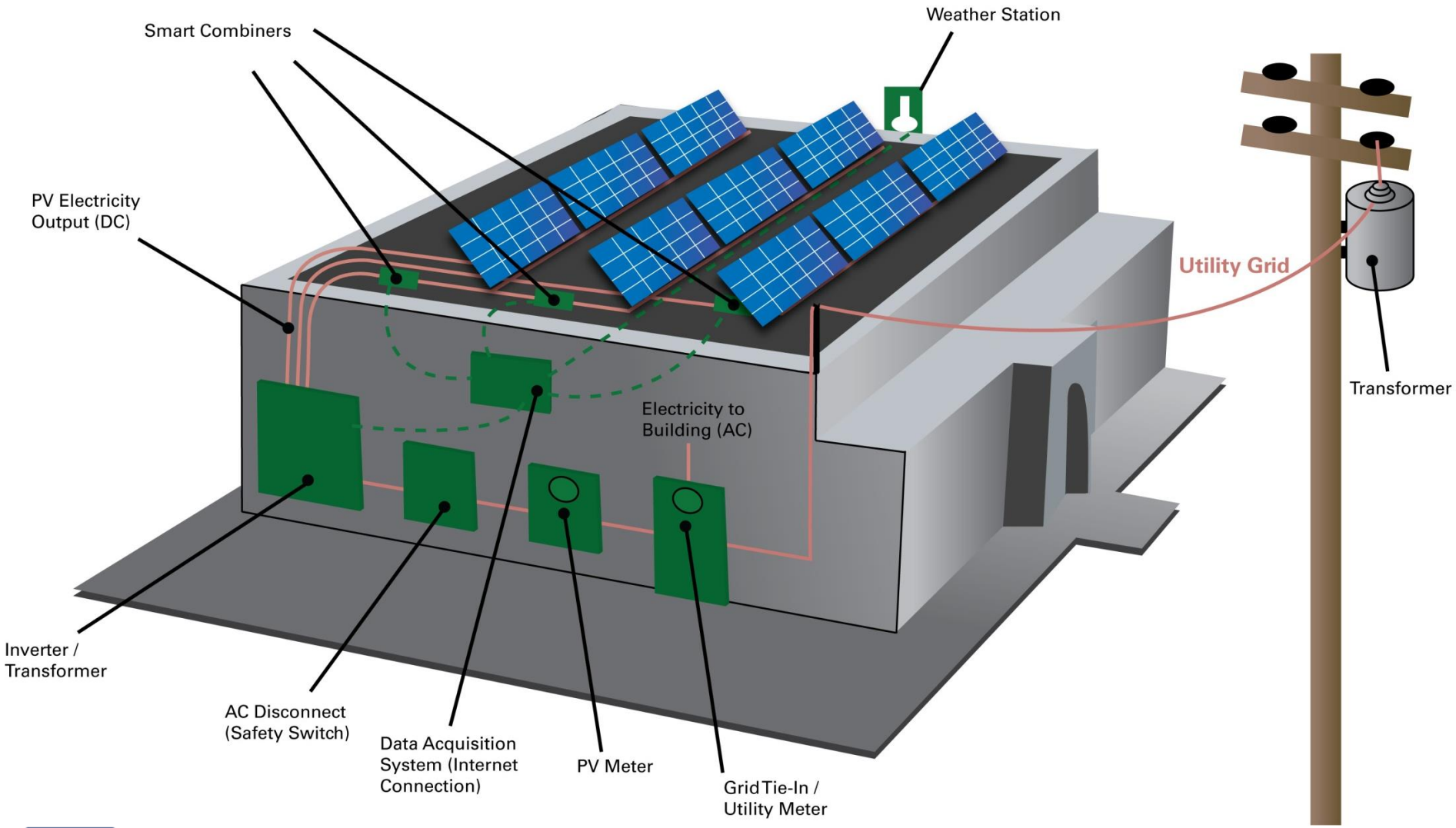


Solar Roof PV Installation Basics



Solar Roof PV Installation Basics





Additional Solar PV Components

- **Inverters**
  - PV modules generate direct current (DC) electricity.
  - The current is fed through an inverter to produce alternating current (AC) that can be used to provide energy to your building.

Additional Solar PV Components

Wall Mounted Inverter

Different Types of Solar Systems

- **Solar Thermal**
  - Residential, typically low temperature, augment domestic and pool hot water
  - Commercial / Industrial. Hot water augment boilers and evaporative chillers
  - Utility Scale, hot water/steam to power
- **Solar Photovoltaic (PV)**
  - Residential
  - Commercial / Industrial
  - Utility Scale

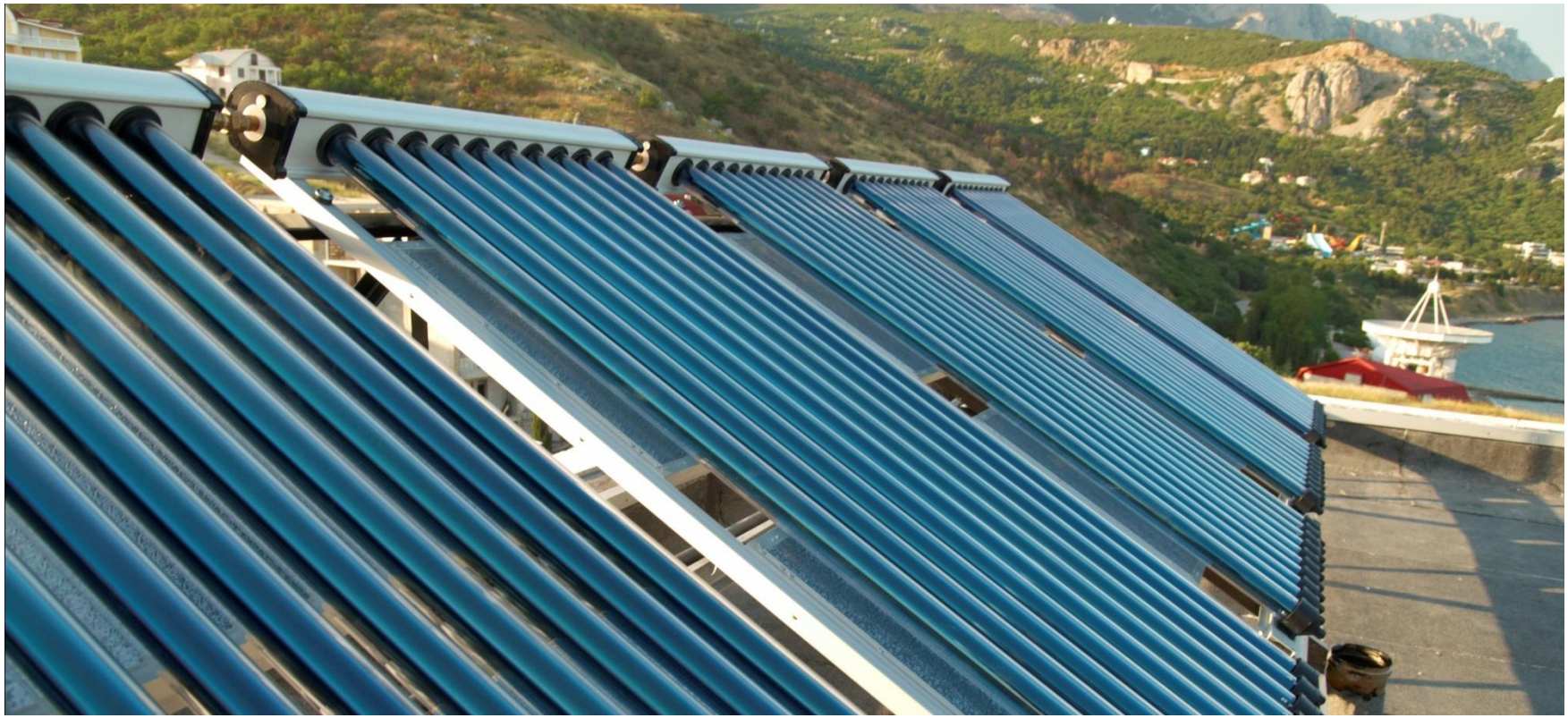
BRIEF OVERVIEW OF SOLAR THERMAL SYSTEMS

Solar Thermal

- **Low Temperature Systems - <100 Degrees Fahrenheit**
  - Most Common - Pool Solar
  - Space Heating / Cooling

Solar Thermal

Medium Temperature Systems - <204 Degrees Fahrenheit, Commercial or Residential Domestic Hot Water - (DHW)



Solar Thermal

- **High Temperature Systems - <1500 Degrees Fahrenheit**
  - Create Steam to drive turbines or a generator

Fresnel Reflectors

TYPES OF SOLAR PV MATERIALS

Different Types of Solar PV Materials

- **Thin Film**
  - Amorphic Silicon - (a-Si)
  - Copper Indium Gallium Selenide - (CIGS)
  - Cadmium Telluride - (CdTe)

- **Crystalline – c-Si**
  - Mono-crystalline
  - Poly-crystalline

Thin Film Solar PV

- **Thin Film System Types**
  - a-Si
  - CdTe
  - CIGS
- Thin film is relatively new to the commercial market, but it is a developing technology that looks promising.
- These thin film panels have the potential to produce power significantly cheaper than today's standard silicon technology.
- An advantage of thin film is its lower weight and ability to be more readily integrated or mounted to various structural components.
- Less efficient than crystalline panels.

Thin Film - Amorphous Silicon (a-Si)

Thin Film PV- Amorphous Silicon (a-Si)

a-Si Panel

- Lower performance compared to c-Si, but more flexible in its applications
- May produce savings as a-Si layers can be made thinner than c-Si.
- Can be deposited at very low temperatures (as low as 75 degrees). This allows for deposition on not only glass, but plastic as well. This makes it a candidate for a roll-to-roll process.
- Reduced roof load from panels and mounting racks

Flat Plate Collector

Thin Film - Amorphous Silicon (a-Si)

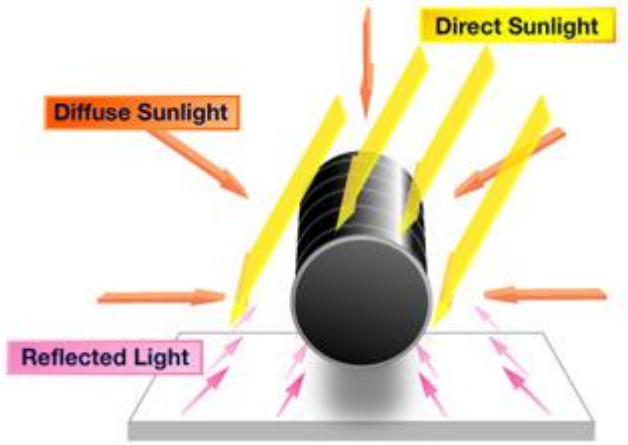
Flat Plate Collector-Rooftop

Thin Film PV - Amorphous Silicon (a-Si)

Thin Film - (CIGS)

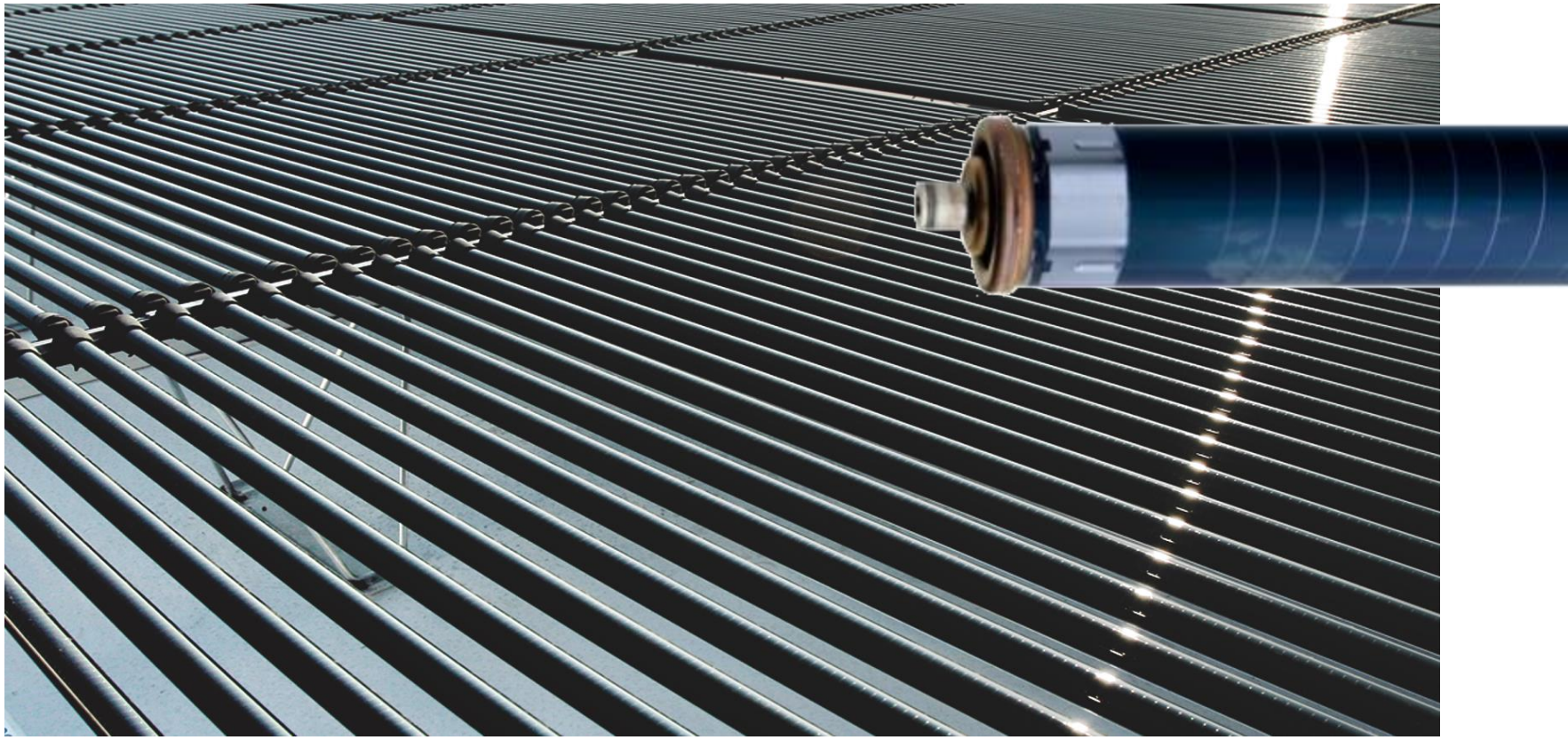
Copper Indium Gallium Selenide (CIGS)

- CIGS cells are not as efficient as crystalline, but are cheaper due to lower material costs and potentially lower fabrication cost however new economies of scale and manufacturing have brought the cost of crystalline manufacturing down in price.
- The US National Renewable Energy Research facility achieved an efficiency of 19.9% for CIGS but the is not very easy to achieve in production or to be affordable with current manufacturing techniques.
- Reportedly can take better advantage of lighter colors TPO, PVC or EPDM roofs



Thin Film - (CIGS)

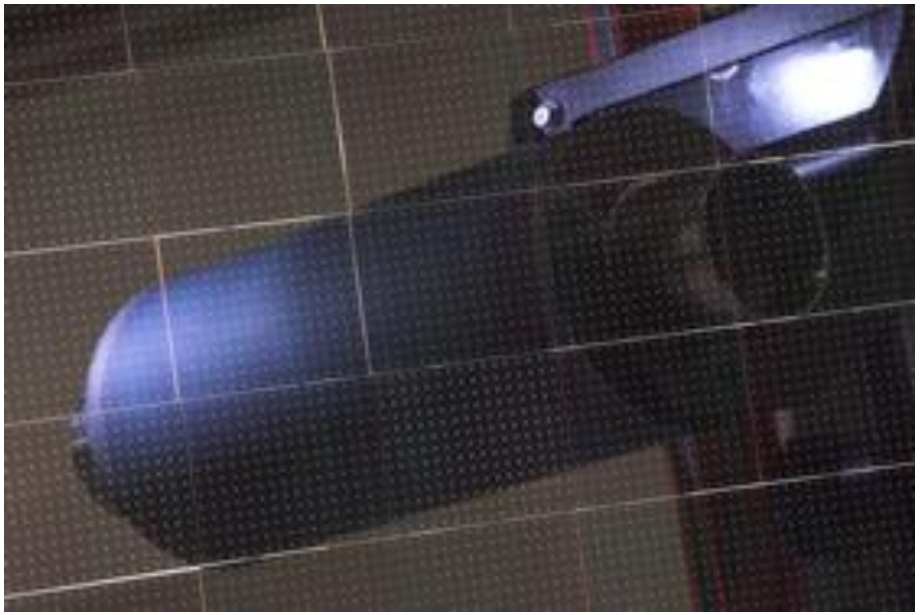
New Technology - 360 Deg. light absorption



Dimensions – Panel Grids are 1.82 m x 1.08 m x 0.05 m

Thin Film PV (CIGS) - Nanotechnology

Newer Technology - Printed Thin Film CIGS



Thin Film PV - (CdTe)

Cadmium Telluride Laminate

Cadmium Telluride

- CdTe is easier to deposit and more suitable for large-scale production.
- There has been a concern with the toxicity of the cadmium.
- CdTe is the only thin film PV technology to surpass crystalline in cheapness when used in utility scale applications.
- Efficiencies range from 8 to 15%.
- As with some other newer technologies, panels are reduced in weight

Thin Film PV - (CdTe)

Cadmium Telluride

Crystalline Solar PV (c-Si)

Crystalline Systems (c-Si)

- Two types:
  - Poly-Crystalline (multi-crystal)
  - Mono-Crystalline (single crystal)
- Crystalline silicon, a material used by the semiconductor industry, is the material used in over 90% of all PV today.
- Generally it provides 12% to 21%+ cell efficiency, generates 13 to 17 watts per square feet and has extremely low degradation.
- As one of the original PV technologies, it has a history of over 40 years of field deployed, successful installations.

Crystalline Solar PV (c-Si)

Mono-Crystalline or Poly-Crystalline

Crystalline Solar PV (c-Si)

Mono-Crystalline - Utility Scale – Ground , Fixed Mount

Solar Integrated Curtain Walls (BIPV)

Building Integrated Photo Voltaic(BIPV)

Manufacturers

Manufacturers

- **Choices, Choices!**
  - Years specifically in solar
  - Years in business overall
- **"All things being equal"**
- **What do you choose?**
- **Why?**

Advent Solar
Amonix Inc
Atlantis Energy System Inc.
BP Solar Int'l LLC
Canrom Photovoltaics, Inc.
DayStar Technologies Inc.
Energy Photovoltaics Inc,
Evergreen Solar Inc.
First Solar LLC.
GE Energy (USA) LLC
Global Solar Energy Inc.
Innergy Power Corporation,
Iowa Thin Film Technologies
Kyocera Solar Inc.
Matrix Solar Technologies
Mitsubishi Electric & Electronics USA
Mitsui Comtek Corp.
nanosolar
Pacific SolarTech
RWE Schott Solar Inc.
SANYO Energy (USA) Corporation
Sanyo Semiconductor Corporation
Sharp Manufacturing Company of America
Shell Solar Industries LP
Solar Power Industries, Inc.
Spire Corporation
Sunpower Corporation
Sunwatt Corporation
Sunwize Technologies LLC
Terra Solar Global, Inc.
Trina Solar
Tideland Signal Corporation
United Solar Ovonic LLC.
Yingli
And hundreds more!

Technology Assessment and Selection

- **Manufacturer Track Record**
- **Deployment History**
- **Experience Matters!**

  - Proof of performance
  - Lots of great new products, but… do the products last?
  - Is newer better?

Manufacturer Financial Strength

- Length of time in business
- Multi divisional - diversified
- Capital reserves
- Ability to secure commodities
- Balance sheet
- On the way up or down?
- What does Wall Street say?
- Market positioning
- Capacity
- Pricing

Technological Strength of Firm

- Deployed history for specific technology
- New technology?
- Financeable?
- 3rd party reviews - technical white papers support?
- Manufacturing processes
- Automation
- Quality controls
- Cell efficiency
- Module efficiency
- Maintenance requirements
- Reputation

ROOF TOP DESIGN CONSIDERATIONS

Rooftop Design Considerations

- Roof assessment.
- Physical constraints.
- Remaining roof life and sustainability of solar PV system over time.
- Structural loads created by the solar PV system.
- Wind uplift.
- Mounting.
- Thermal movement of PV components.
- Electrical, mechanical and other disciplines.
- Fire code.
- Maintenance of the PV system and the roof.

Roof Assessment

- Existing age and condition of roof
- Remaining roof service life
- Impact to existing warranty
- Flashing
- Drainage
- Chemical compatibility
- Impact on structural load?

Physical Constraints to Roof Mounting

Remaining Roof Service Life

- Will the roofing last the term of the Solar PV financing?
  - Most PPA's (financing) last 15 – 20 years
  - The life of solar panels and components is 30 years or more
  - But the roof live is limited, and could be less than the financing or the solar PV system

- Will the Solar PV and all associated systems withhold its integrity and last the term of the Solar PV financing or warranty?

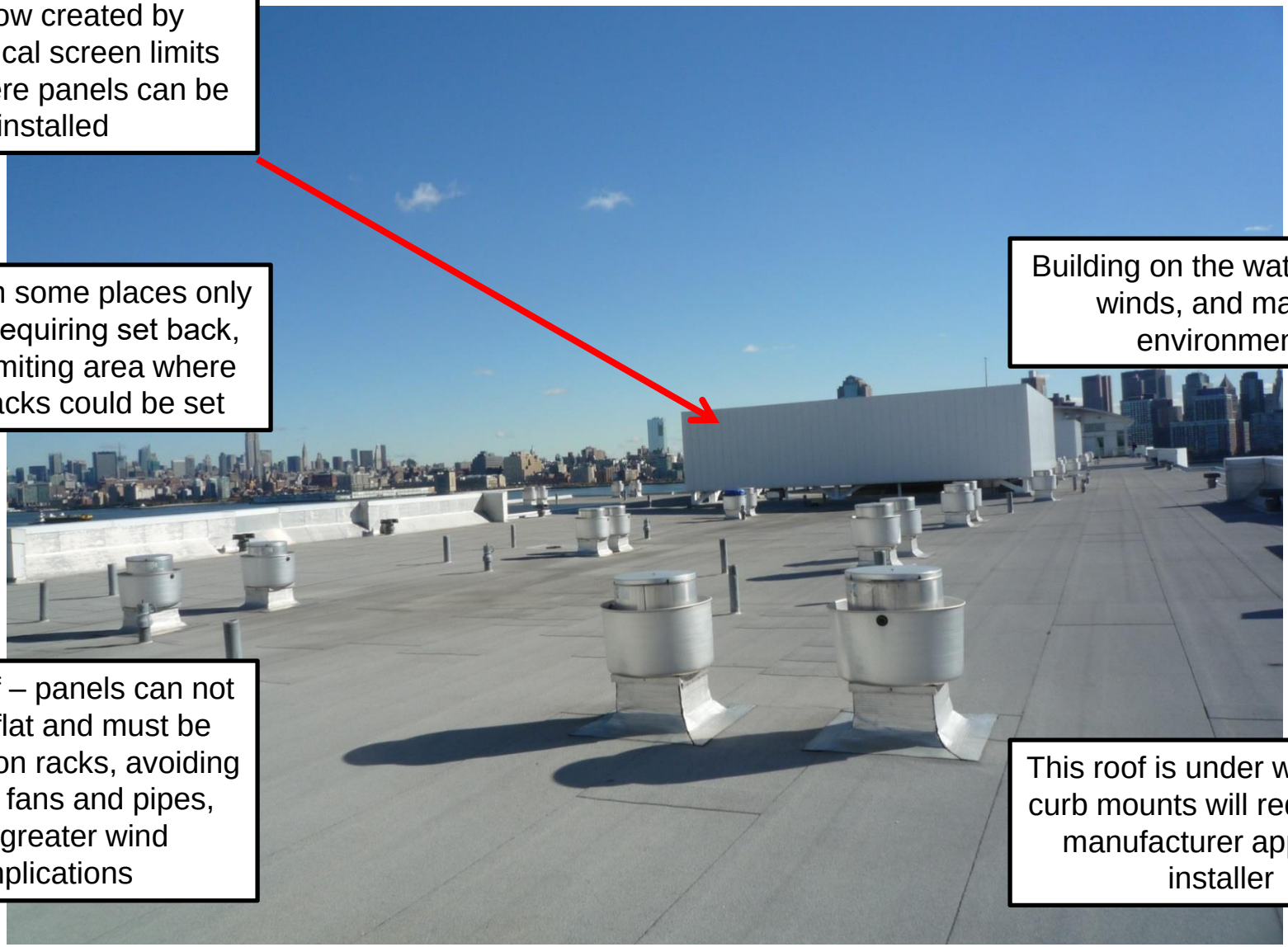
- What minimal maintenance requirements of the roof and PV systems will assist in having the lives of the roof and PV systems run concurrently?

Longevity

- Marine grade materials – aluminum is very susceptible to damage from salt air.
- Solar panels absorb heat and transmit it to the roof, potentially damaging the roof membrane.
- Some solar panels use EPS insulation – but this is not compatible with some single ply roofs (PVC).
- Value proposition of entire project?
- PV system built to stand the test of time?

Roof Top Assessment – New Jersey

Shadow created by mechanical screen limits area where panels can be installed



Parapet in some places only 6” high, requiring set back, further limiting area where panel racks could be set

Building on the water – high winds, and marine environment

Busy roof – panels can not be laid flat and must be mounted on racks, avoiding exhaust fans and pipes, with greater wind implications

This roof is under warranty – curb mounts will require roof manufacturer approved installer

Another Roof 5,000 Miles Away - Hawaii

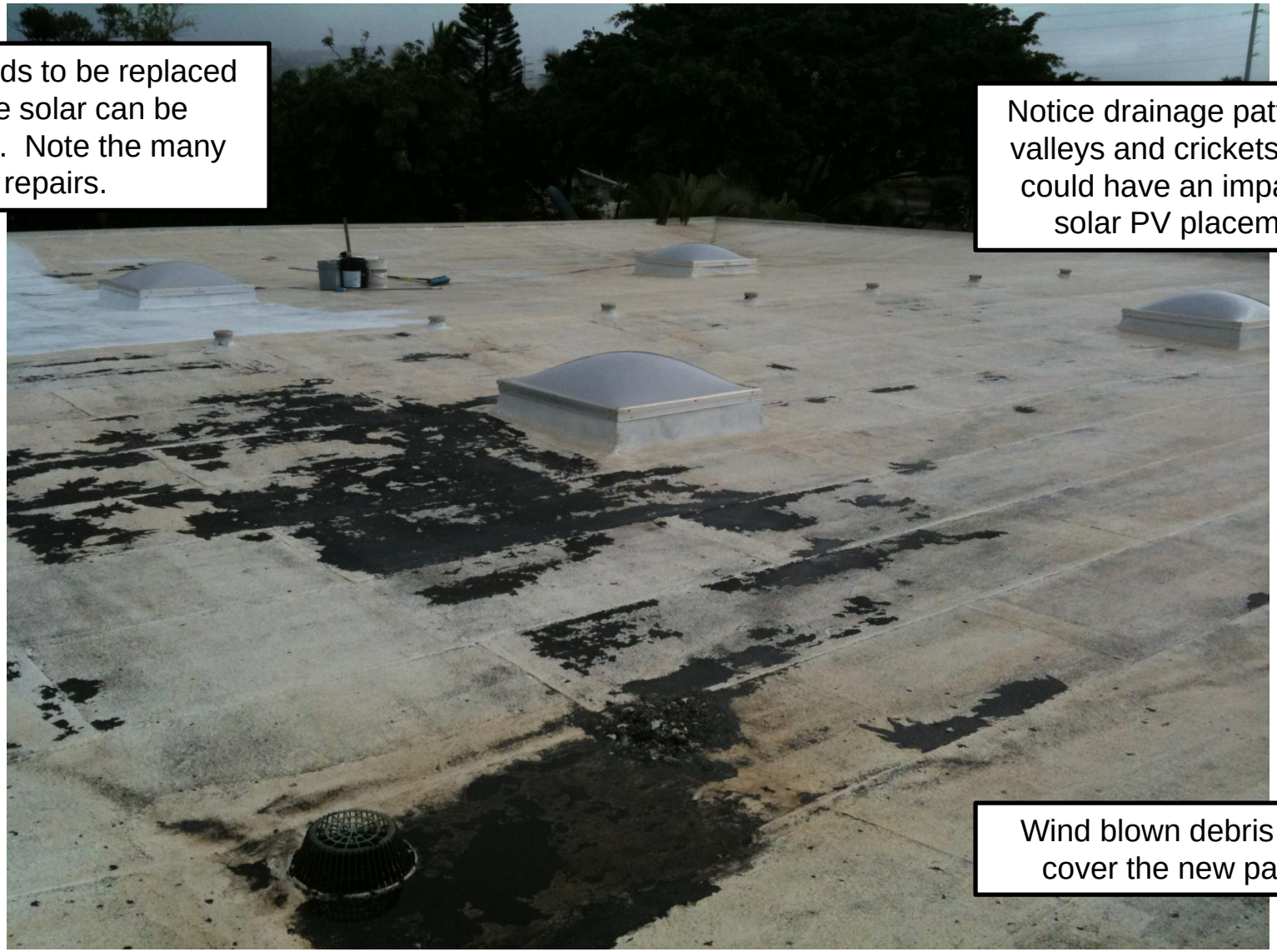
Multiple roof levels and multiple roof types

Roof condition looks suspect

Roof Assessment

Roof Assessment

Roof needs to be replaced before solar can be installed. Note the many repairs.



Notice drainage patterns – valleys and crickets which could have an impact on solar PV placement

Wind blown debris could cover the new panels

Structural Engineering

- Penetrating and ballasted systems
- Wind load
- Live load
- Dead load
- Seismic – in some states
- Thermal movement

Wind Loading

- **IBC, Chapter 16, Volume 2 already contains very good information about wind uplift**
- **Additional information is available from additional dynamic sources**
- **Biggest impact from wind:**
  - Solar panels on racks are huge kites
  - Panels need to be firmly attached to the roof deck, creating need for structural attachment design and properly flashed curbs

Solar PV Roof Mounting Systems

Solar PV – Mounting Solutions

- **Roof Mounting and Racking Systems**
  - Racked and not racked
  - Ballasted racks
  - Non-ballasted racks
- **Attachments to Structure and Penetrations**

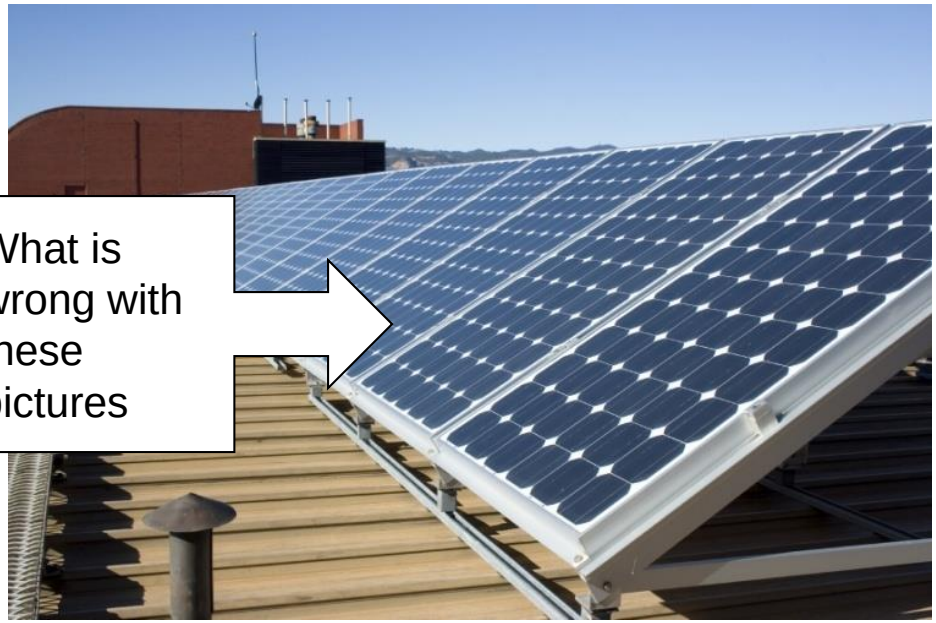
Solar PV – Mounting Solutions

- **Roof mounts**
  - Flat adhered
  - Angled attached
    - Penetrating roofing systems
- **Non-penetrating attachments**
  - Ballasted
  - Anchored/Ballasted
- **Penetrating attachments**
  - Various methods

Mounting and Racking

Roof Mount - Attached to Structure

What is wrong with these pictures

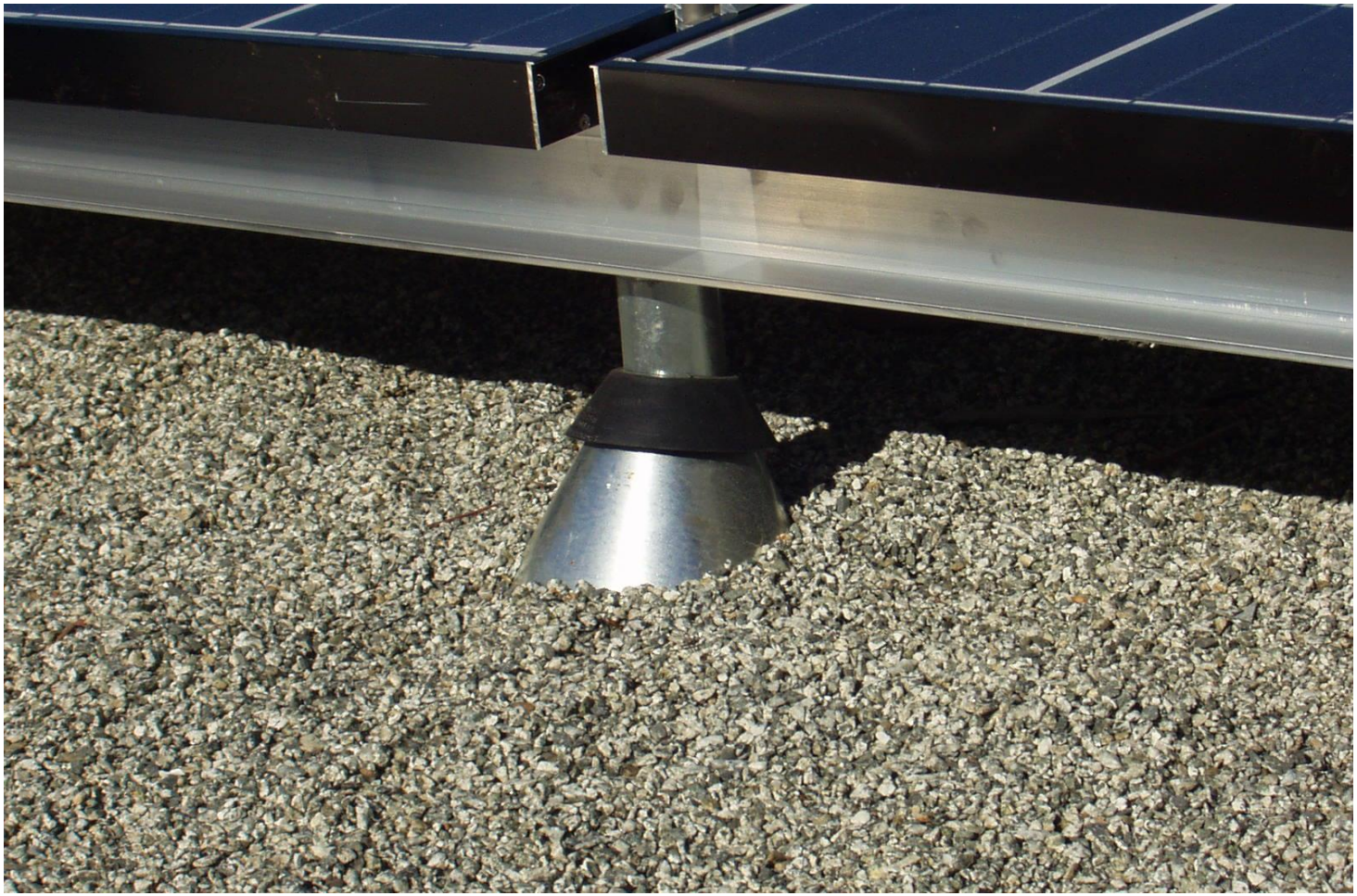


Attached to Structure

Angled Attached to Structure

Mounting and Racking

Roof Mount - Attached to Structure



Mounting and Racking

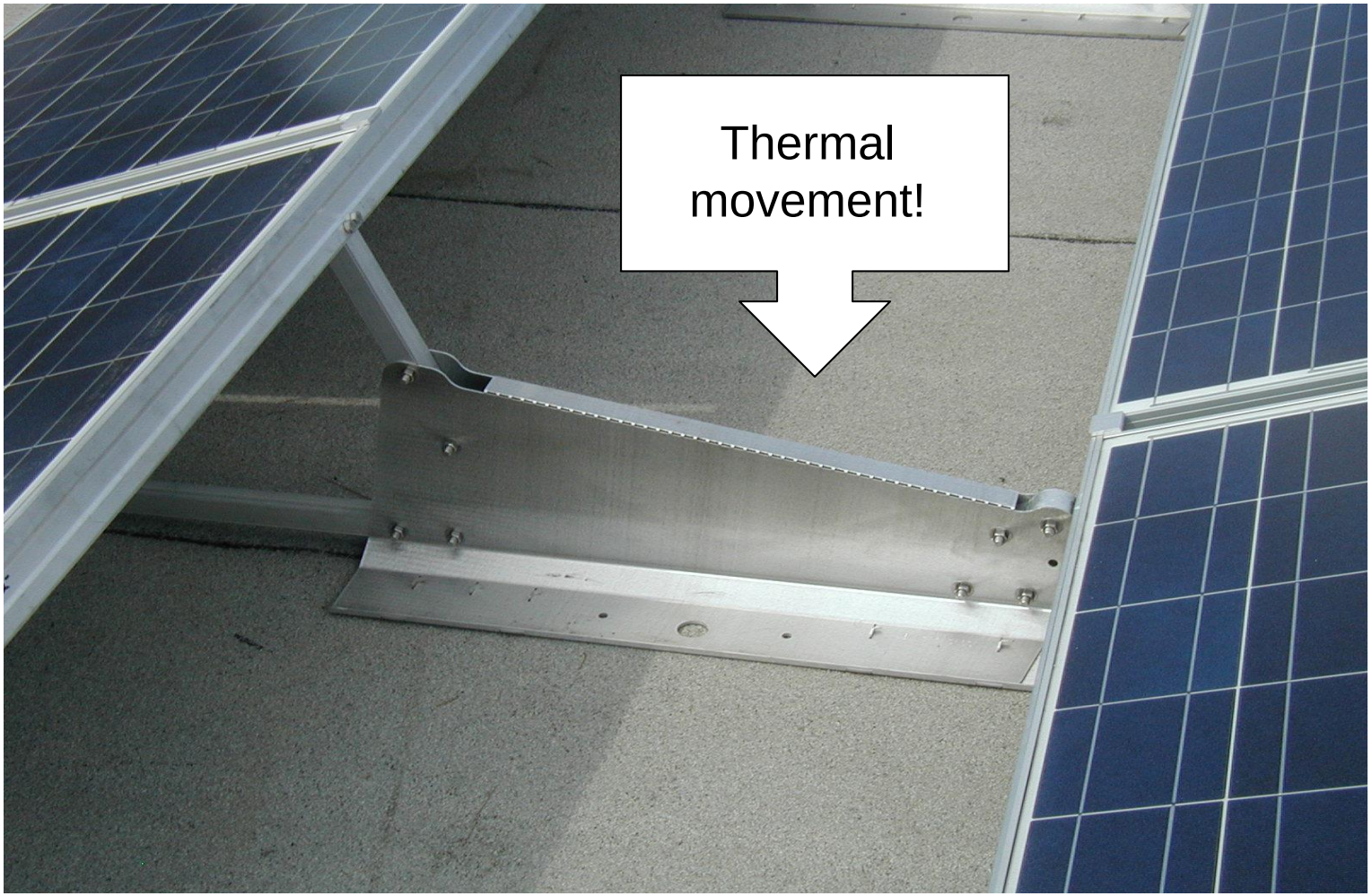
Roof Mount - Attached to Structure

Mounting and Racking

Roof Mount Non-penetrating - Ballasted

Mounting and Racking

Roof Mount Non-penetrating - Ballasted



Mounting and Racking

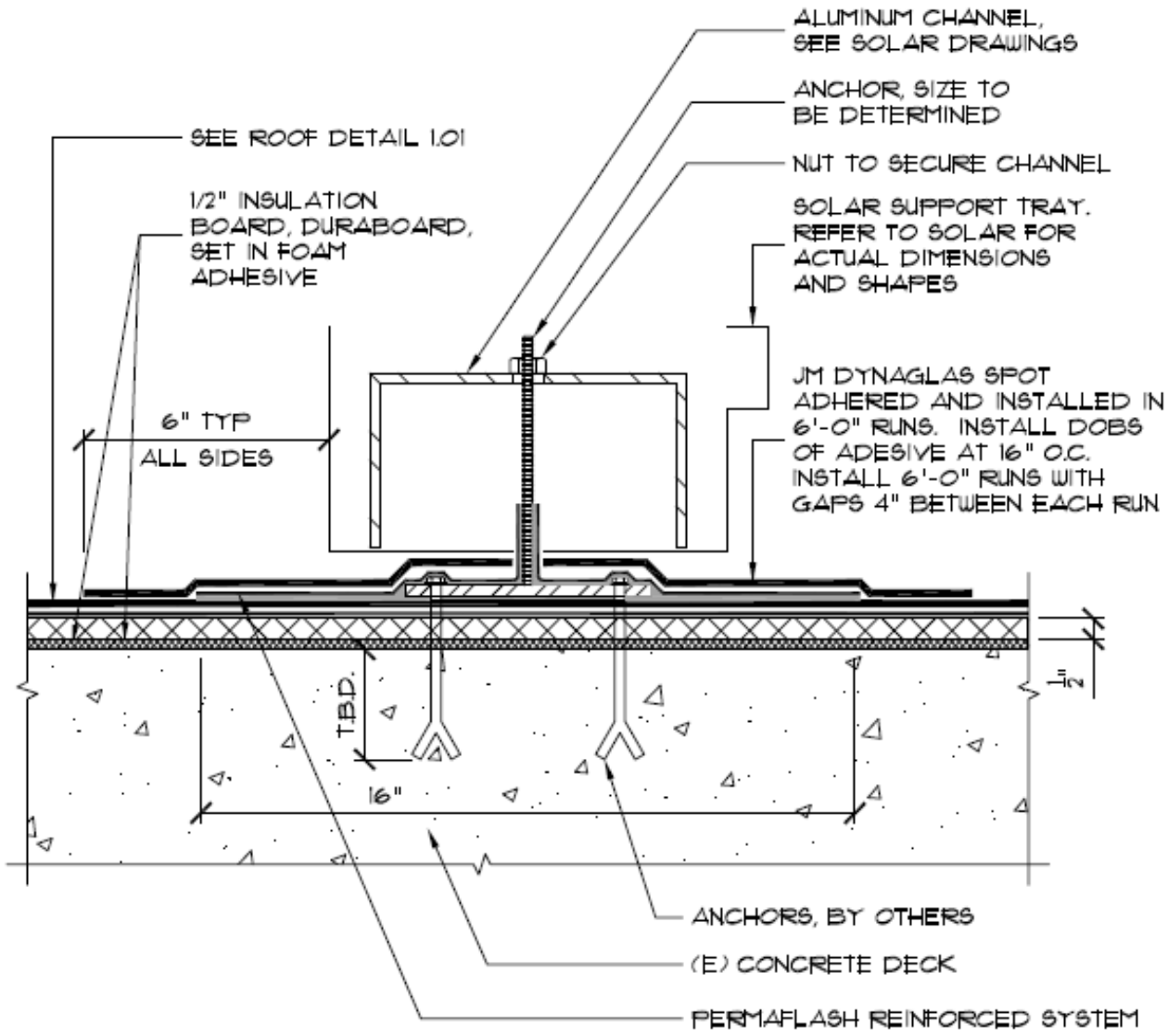
Roof Mount Non-penetrating - Ballasted

Mounting and Racking

Roof Mount Non-penetrating –Ballasted Pavers

Maintenance

Ballasted Pavers Attachment



Mounting and Racking

Thin Film Roof Mount Adhered

Mounting and Racking

Parking Structures

Mounting and Racking

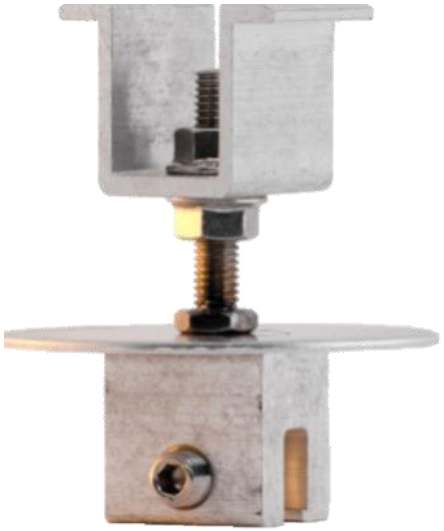
Parking Structures – Dell - Roundrock, Texas

Mounting and Racking

Parking Structures and Single Axis Tracker

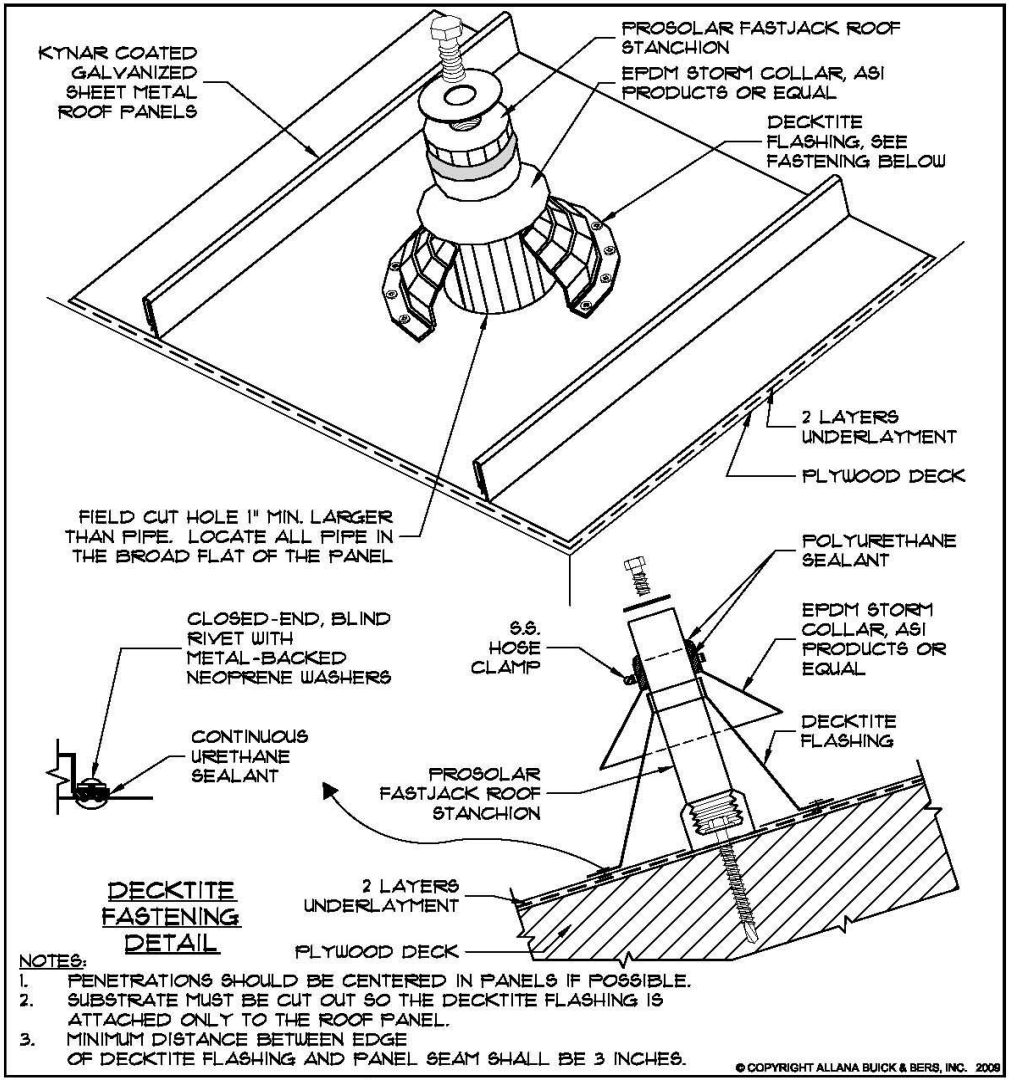
Non-Penetrating Roof Mounting

Attachment Methodologies

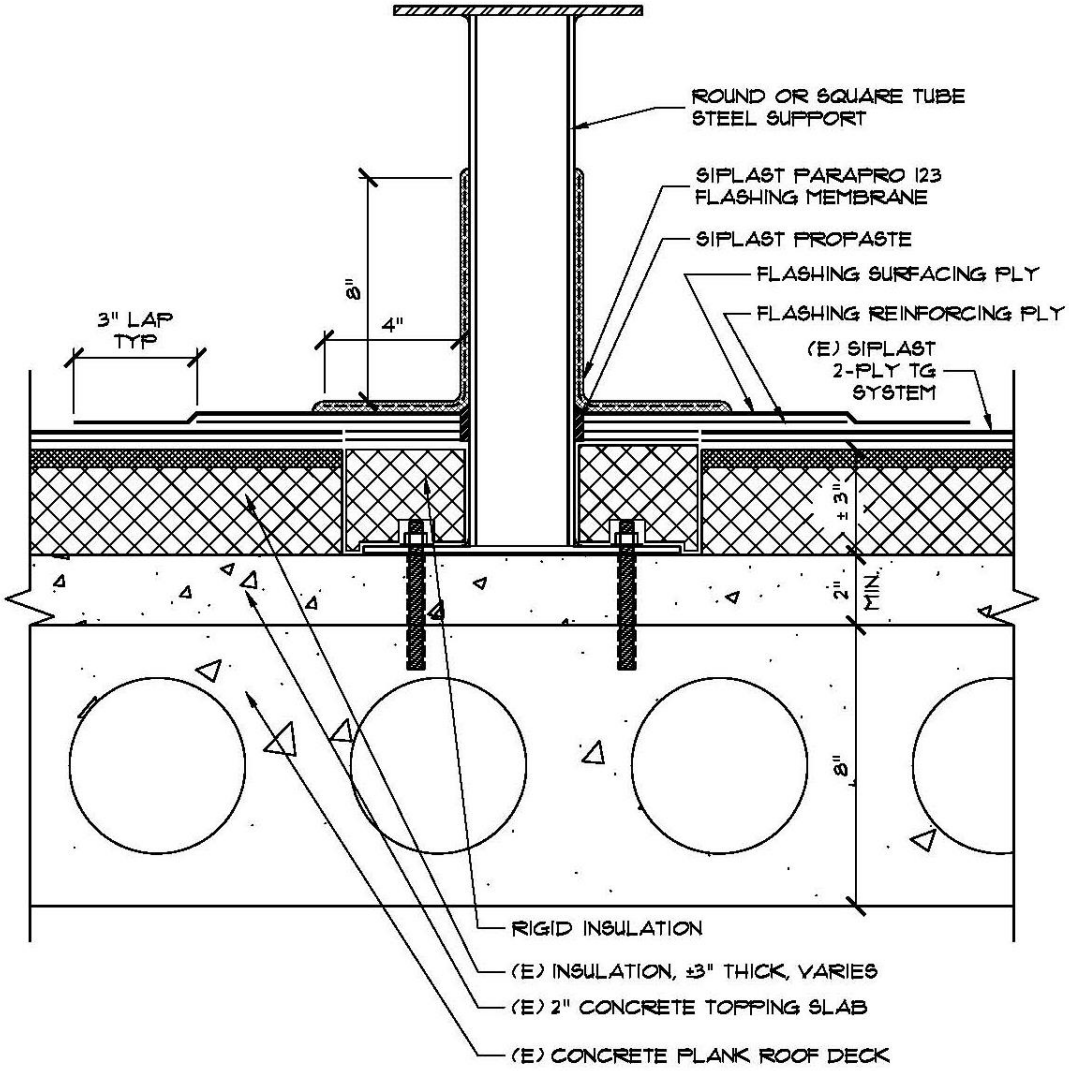


- Clip Attachment
- Thermal Movement?
- Sustainable Solution?

Metal Roof Penetration

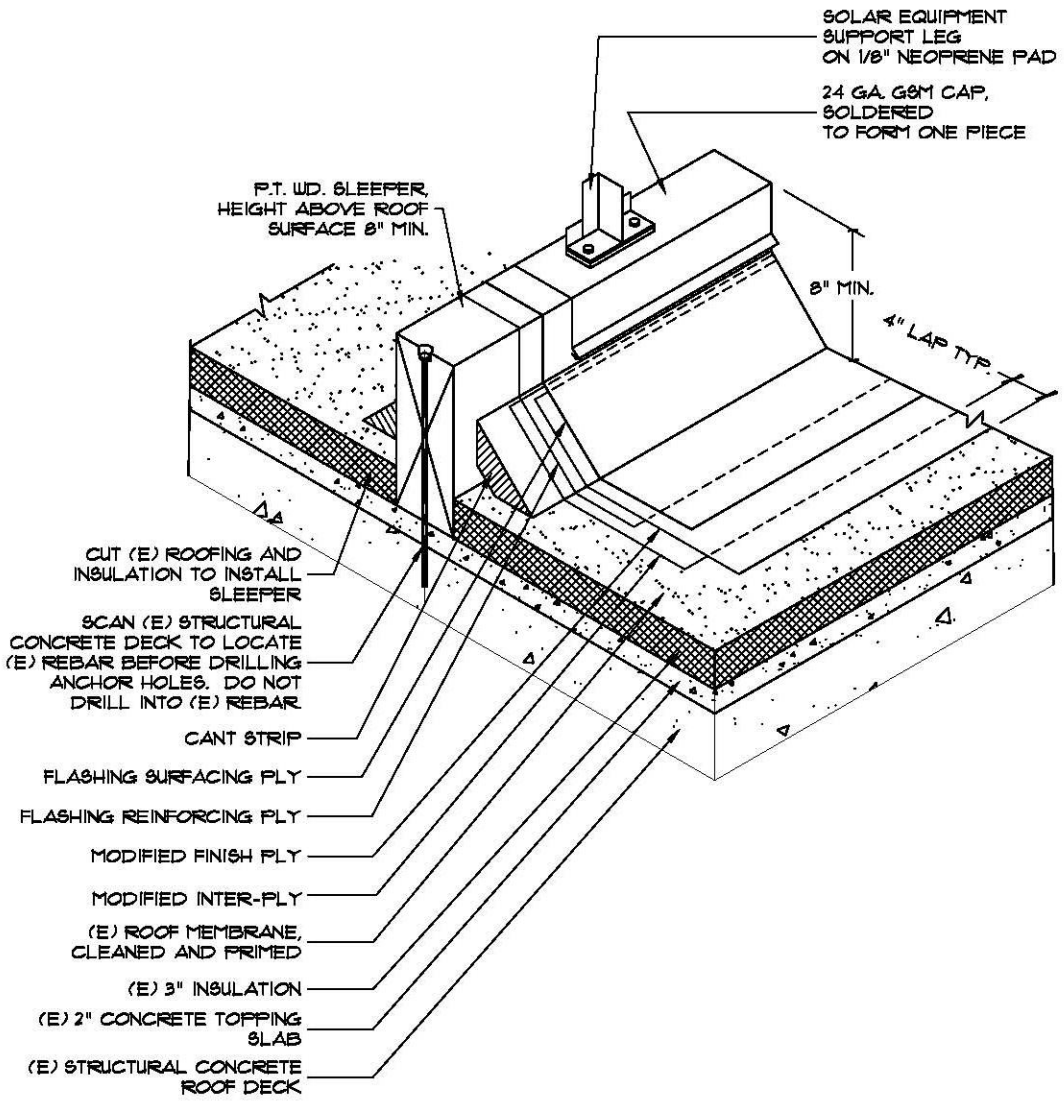


Retrofit Attachment to Concrete Deck



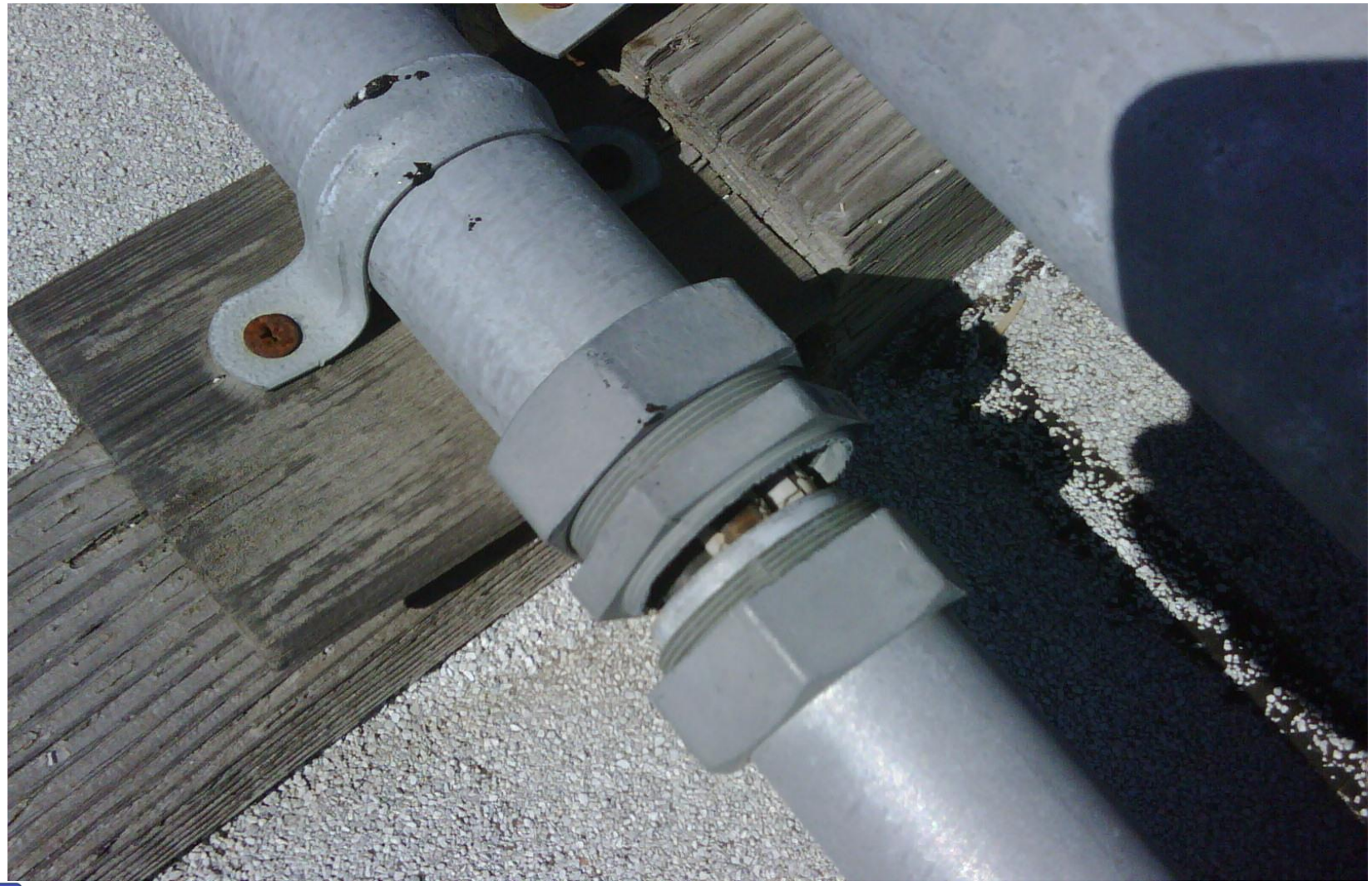
Proper Setting of a Boot

Alternative Design for Attachment to Concrete Deck

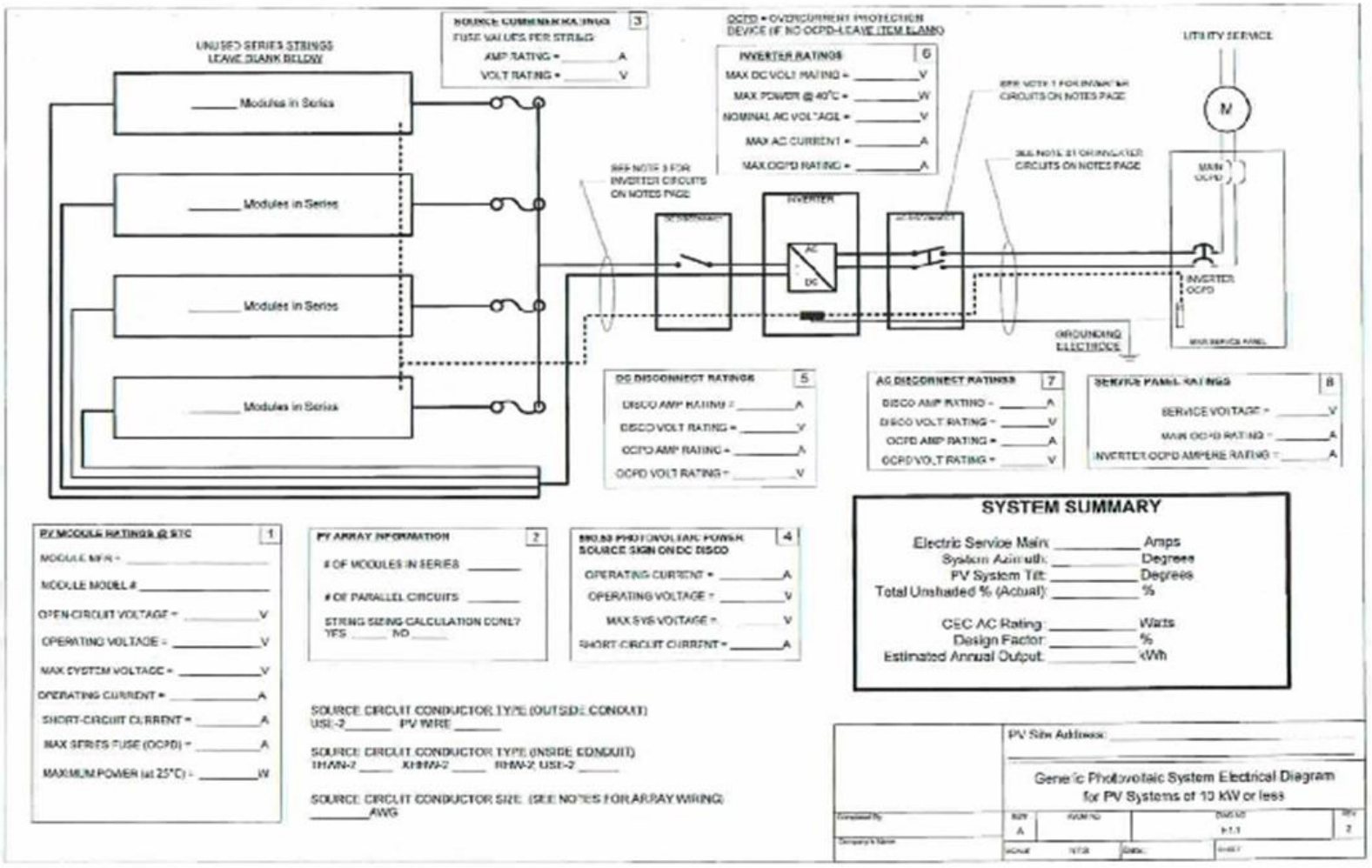


Thermal Movement

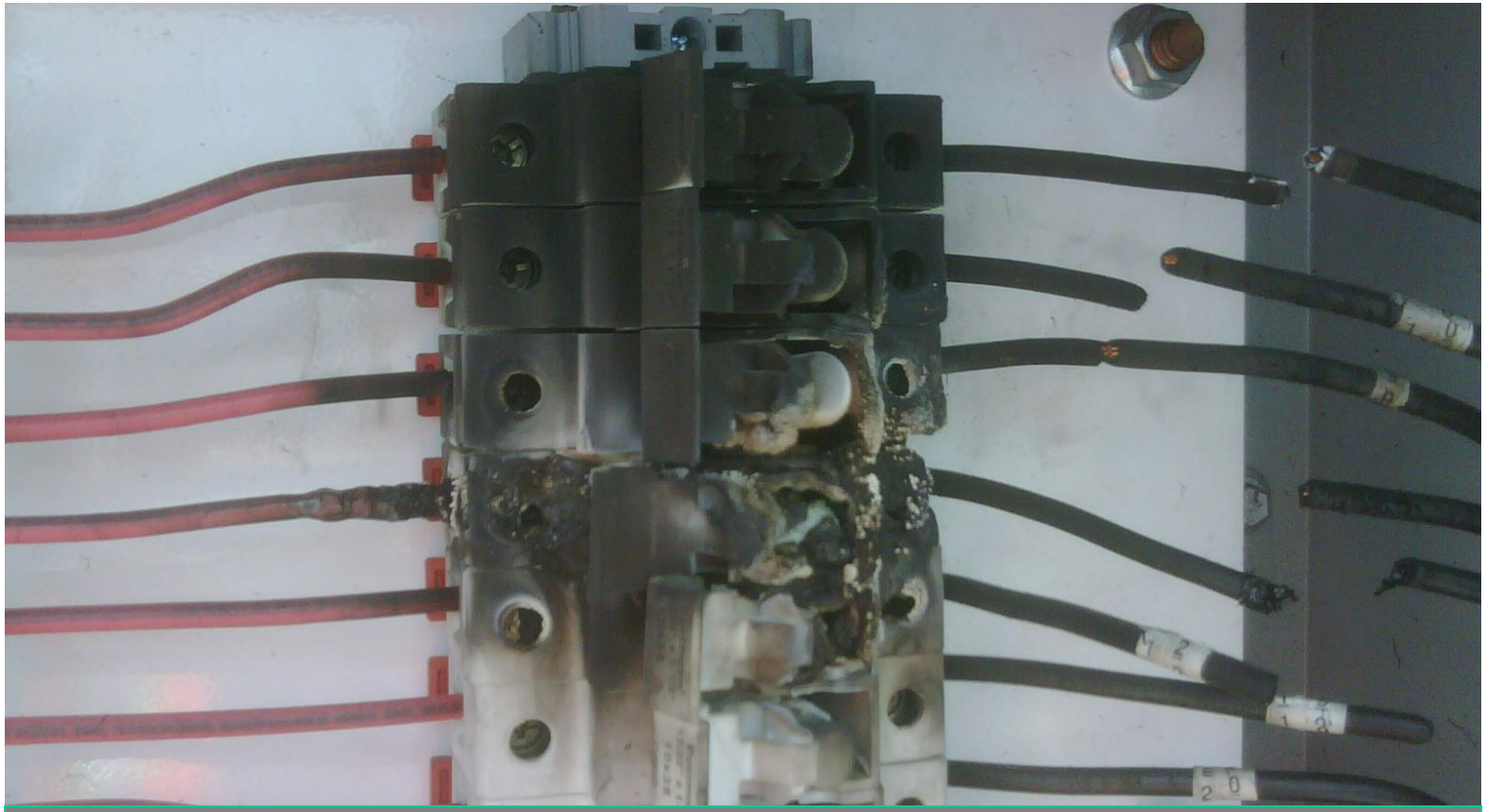
Thermal Movement



Electrical Engineering



Electrical Quality Assurance



Loose wiring and improper torque applied to lug screws - not visually evident. Infrared cameras and a commissioning process would have prevented this problem, that occurred early after project completion.

Electrical Issues

Ground fault and short circuit potential, caused by poorly planned, poorly protected and poorly installed "home run" conductors.

Fire Code Issues

- **Solar panels typically will not change the Fire Rating of the Roof Assembly.**
- **But, penetrations must be designed and installed properly following manufacturer recommendations.**
- **And the manufacturer must demonstrate that the panels have been rated and approved.**
- **Additionally, local fire agencies and local codes may require markings of the electrical power on the roof, and clear paths through the solar panels.**

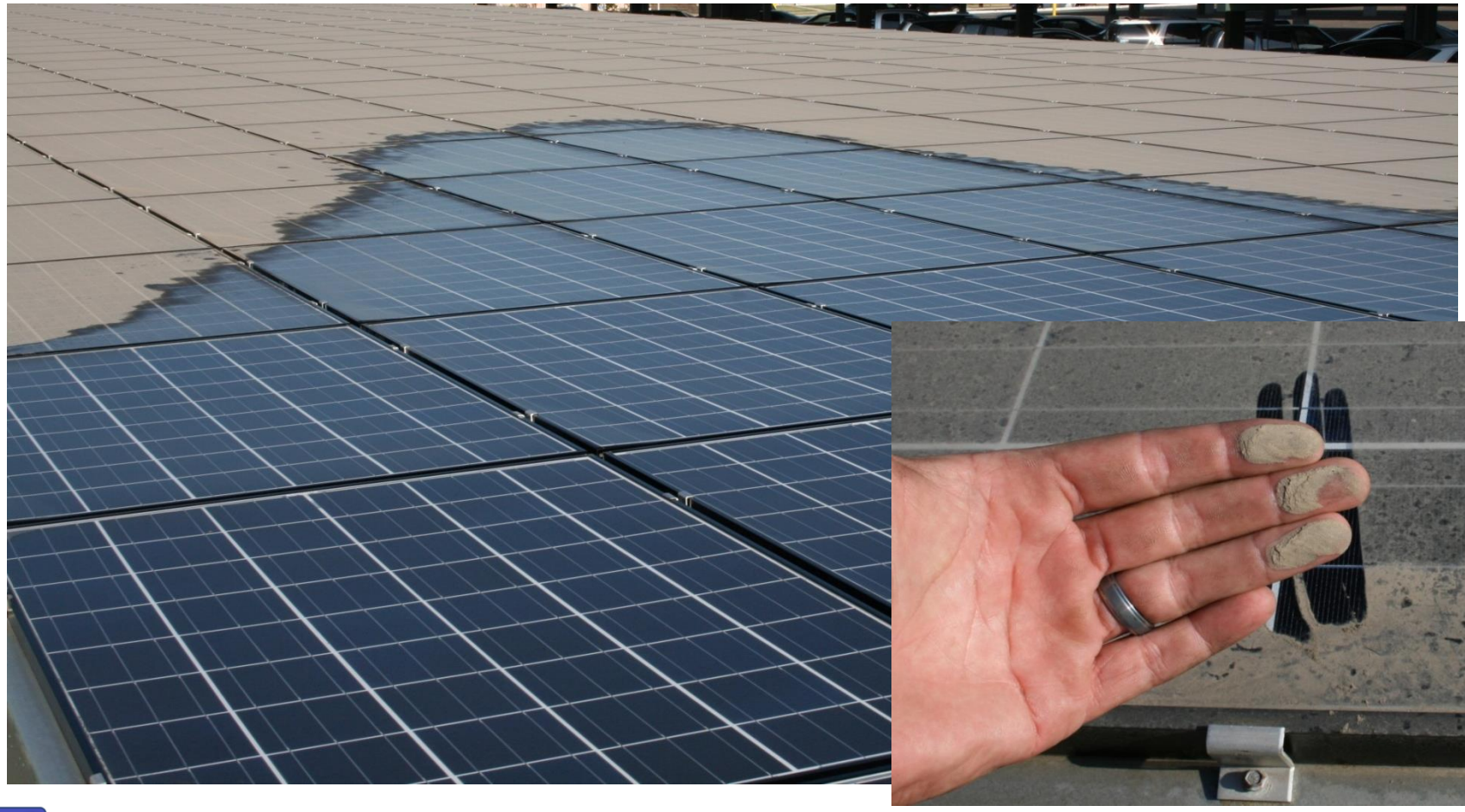
Importance of Maintenance

- **Warranties - which may not be honored if no proof of proper maintenance is documented.**
- **Inverters fail prematurely due to excessive heat build-up.**
- **Photovoltaic systems are designed to last 30-40 years**
  - Chaffing wires or faulty mounting hardware can be detected early with a regular maintenance program.
- **Simple problems may reduce the life expectancy of the PV system.**
- **Without proper inspection and cleaning, production guarantees may be violated.**
- **According to the National Renewable Energy Laboratory, soiled modules can show a deficiency of 25%.**

Maintenance

Dirt Build-up

Excessive dirt build-up on PV modules creates "Hot Spots".
Can cause cell series wiring to prematurely fail
and VOID the manufacturer's warranties



Importance of Maintenance

Excessive dirt build-up? How about the roof?

FINANCING SOLAR

How Do You Pay for Solar?

- **Many Solutions**
- **Depends on your goals**
  - Dramatically reduce utility costs
  - Predictability
  - Use Capital Investment to Lower Operating Costs
  - Tax Management

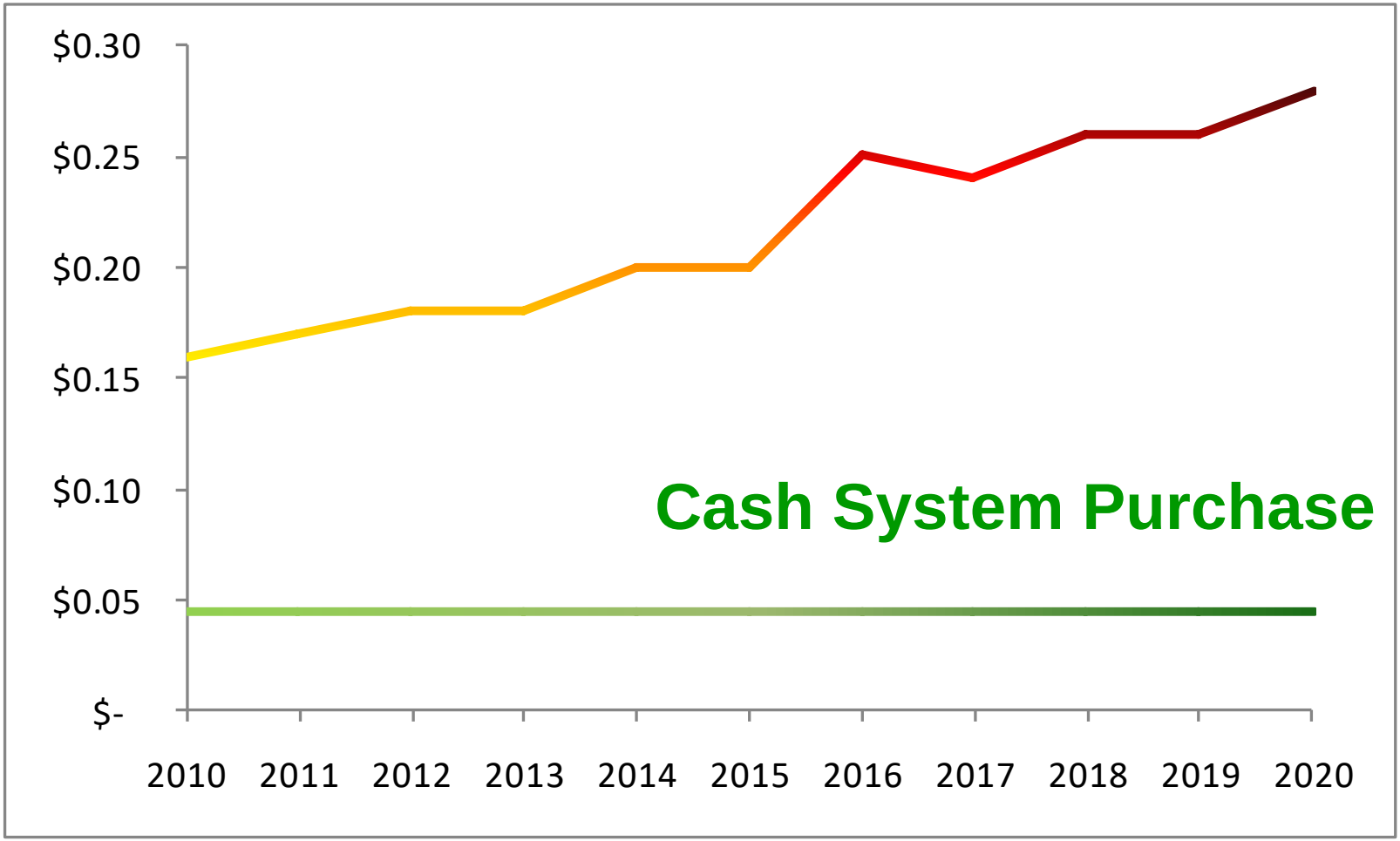
How Do You Pay for Solar?

- **Federal and State Incentives**
- **Traditional financing**
  - Loan / Lease - Varies
  - Municipal Lease
  - Municipal Bond
  - ARRA Stimulus Funds
- **Financing Solutions**
  - Power Purchase Agreement
- **Cash Purchase**
  - Great…if you have the money

Incentives

- Incentives vary from state to state – From utility to utility
- California – 34% to 56% of the system cost from State and Federal Incentives (After Tax $)
- Tax savings from depreciation - up to another 28% in system cost savings
- How do the incentives work?
- What is the best way to take advantage of them?

Cash Purchase - Return on Investment



Financing Solar

- **How many people know how a Power Purchase Agreement works?**

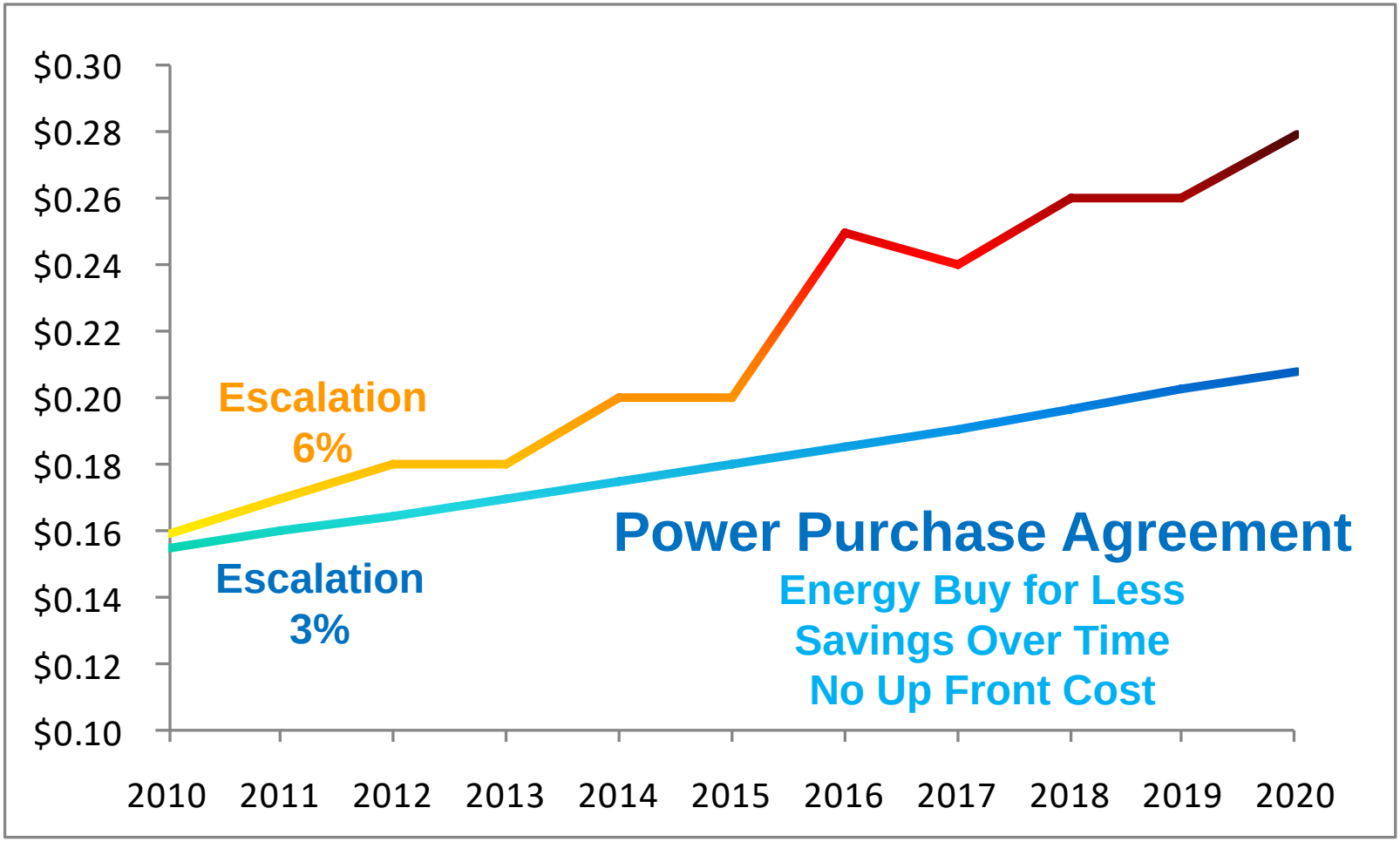
Power Purchase Agreement

- **You're buying energy not equipment**
- **Private entity - installs, owns, operates and maintains solar system on your site**
- **You buy electricity from the system through a Power Purchase Agreement**
- **No up front costs, no down payments, no maintenance costs**
- **Credit quality is important**

Power Purchase Agreement (PPA)

- **PPA Length: 15 – 25 years**
- **Useful System Life: 40 Years**
- **Optional Buyout – Fair Market Value**
- **End of contract: System removal and site restored to original condition**

PPA Costs Are Predictable



Accurate Financial Analysis

- **Buyer Beware!**
- **Accurate financial analysis is critical**
- **Not all expenses and tax implications are always accurately depicted**
- **Generally we see inflated rates of return as a result**

THANK YOU!