MASTERING THE DESIGN ISSUES OF SOLAR PHOTOVOLTAIC INSTALLATIONS ON AN EXISTING ROOF

by

Karim P. Allana, PE, RRC, RWC

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INTRODUCTION

Installations of solar Photovoltaic (PV) systems on existing roofs have grown rapidly in number and are expected to continue to grow over the next decade. This explosion has been created by building owners who want to reduce electricity bills as utility rates go higher and higher, by the concurrent development of more cost efficient PV materials and components, by the desire of building owners to "go green" to reduce carbon footprints, and by time-limited governmental and utility company incentives. And when properly planned and financed, PV systems will on certain properties, increase property values for potential buyers and investors.

Roof consultants must keep pace with changing design implications and become current with their understanding of rapidly evolving technology in PV materials and components. All solar PV systems have unique installation issues relating to roof design, water tightness, and roof longevity; and have structural complexities caused by higher dead and live loads, wind uplift, and seismic/thermal movement.

A review of recent history provides an example of the need for the roof consultant to pay attention to design implications of solar PV. In the 1970s, rapidly increasing prices in electricity, natural gas, and fuel oil directly created rapid increases in the numbers of solar PV systems installed on existing roofs. Unfortunately, lack of proper design details led to premature roof failures and other problems that could have been avoided.

To learn from history, provide the roof consultant a technical outline of solar PV types and to provide an intermediary level over-view of design issues, this paper and the presentation in Reno will present characteristics of PV systems now on the market, including the design implications for each type. It will suggest some roof assessment techniques to use before solar PV is installed on existing roofs and will explore the impacts of the installation of various solar PV types on the water tightness of roofs.

The paper will review what PV installation means to existing-roof longevity; it will also review selected structural, electrical, civil and mechanical issues; and will show some of the pitfalls to avoid.

The solar PV systems discussed in this paper are based on crystalline and thin film materials manufactured into solar panels. Also discussed are thin film material applications whereby thin film is affixed to metal and single ply roofs, or utilized in Building Integrated PV (BIPV) in curtain walls, roof shingles, and other building components.

The author will discuss structural impacts caused by the additional roof load caused by panels or thin film, how to design for various types of popular systems and assemblies now on the market, and some simple financing strategies to convince owners to install PV systems.

Briefly discussed is how financial issues are interconnected with design issues. For example, successful applications for Power Purchase Agreements (PPA's), lease-backs, governmental incentives in the form of tax rebates, and utility company incentives, all demand detailed calculations of how the solar PV system is being designed, and how reduced energy costs will pay for at least a portion of the solar PV system.

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The paper will include lessons learned from actual case studies, and real life examples of design issues faced by the roof consulting professional, in the following format:

INTRODUCTION

1. Definition and description of solar PV systems.
2. Brief overview of solar thermal systems.
3. Types of solar PV materials.
   A. Thin film.
   B. Crystalline silicon
4. Mounting systems for roof installation of solar PV.
   A. Low slope solar PV thin film adhered systems.
   B. Low slope solar PV panel systems.
   C. Solar PV panels mounted to standing seam metal roofs.
   D. Solar PV systems mounted via penetrating mounts.
   E. Non-penetrating non-ballasted solar PV panel roof mounting racks.
   F. Non-penetrating ballasted solar PV panel roof mounting racks.
   G. Snow loadings and snow drift mounting and load issues.
   H. Car port mounted, shade structure mounted, ground mounted and tower mounted tracking solar panels.
   I. Other types of solar PV systems – concentrators.
   J. Building integrated PV (BIPV).
5. A brief list of solar PV manufacturers.
6. Design issues faced by the roof consultant.
   A. Roof assessment.
   B. Physical constraints.
   C. Solar PV and new roof warranty.
   D. Sustainability of solar PV system over time.
   E. Structural loads created by the solar PV system.
   F. Fire code design issues.
   G. Electrical, mechanical and other disciplines.
   H. Peer review of design.
   I. Maintenance of the PV system and the roof.
   J. Non-engineering design issues.

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7. Financing solar.
    A. Price.
    B. Alternative financing methods.
    C. Key things to remember for the economic case.
8. Contractors and Suppliers.
    A. Criteria for selecting a solar contractor.
    B. What questions should be asked?
    C. Safety criteria.
    D. Roof and site integrity – can the firm provide it?
    E. Roofing and construction experience.
9. **CONCLUSION**

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1. DEFINITION AND DESCRIPTION OF SOLAR PV SYSTEMS

A solar Photovoltaic (PV) system generates electrical power through the conversion of solar energy first into direct current (DC) electricity, and then into alternating current (AC) electricity.

In conversion to DC electricity, sunlight falls on a material such as crystalline silicon (C-Si), either in the form of mono-crystalline silicon or poly-crystalline silicon. Other PV materials include amorphous silicon (a-Si), cadmium telluride (Cd-Te) and copper indium selenide/sulfide (CIGS). See Figure 1 depicting the process that converts sunlight into electricity.

Crystalline silicon and cadmium telluride cells are typically assembled into a PV panel; these panels are then mounted on ballasted racking systems or penetrating standoffs on the roof. PV thin-film sheets containing amorphous silicon are integrated into PV panels and roof membrane products; cylindrical roof-mounted products containing copper indium selenide/sulfide are installed on racks; and building integrated PV (BIPV) components containing various materials are integrated into curtain walls and even roof shingles.

PV panel systems can be mounted on car ports and other ground mounts and can be installed on tracking systems rotating in one or more axes to take maximum advantage of the sun as the earth rotates.

The power generated by PV panels, roof membrane systems, cylindrical products and BIPV products, varies by system type and manufacturer. Panels, sometimes called "modules" in the industry are connected in "strings" or "arrays." Multiple arrays and strings are connected together at a combiner box.

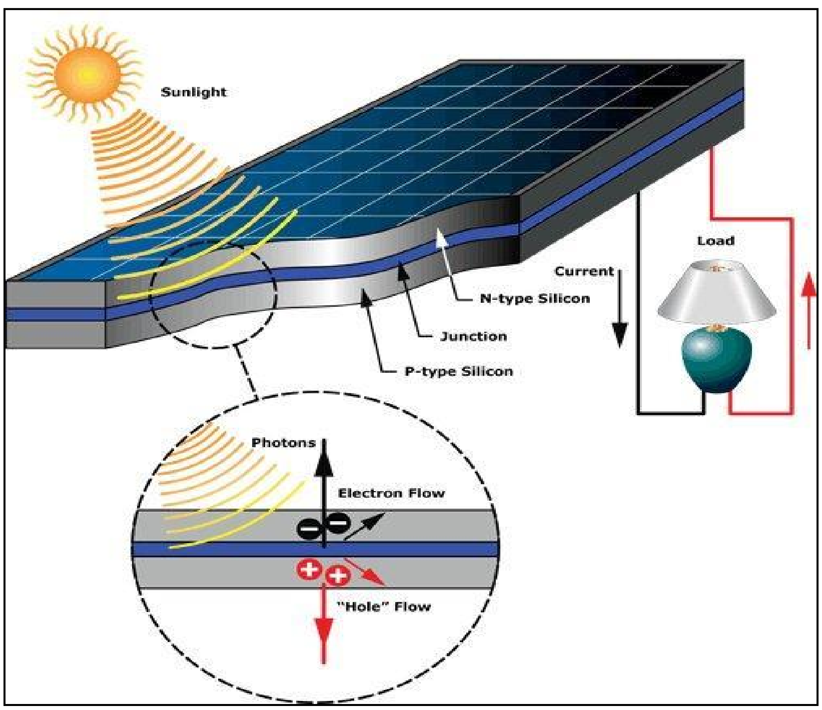

Figure 1. How Electricity is generated in a solar PV system.

The power output from PV systems is highest on a bright day with relatively mild ambient temperatures and drops as the modules heat up (such as on a very hot day). There is no power output in the dark and there is no stored energy in the panels/modules themselves.

Panels are oriented in a manner to provide the best access to sunlight. This means they are typically mounted on the south or southwest roof plane of a steep sloped roof. On a low slope

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roof, panels can be laid flat, but the power conversion efficiency is reduced below the efficiency of steep roof systems. To take best advantage of sunlight on a low-slope roof, PV panels are mounted on racks tilted to the sun at the "azimuth" angle and compass direction appropriate for the geographical area and site.

The desired azimuth angle, the orientation of the panel or module to the sun, varies by latitude of the site, but actual installed azimuth angle will vary, due to factors such as amount of space available for the array, wind uplift issues, and aesthetic issues.

At the earth's equator, flat panels would be at the most efficient angle to the sun. In the continental United States, the most efficient azimuth angle of orientation to the sun varies between approximately 26 degrees and 47 degrees from horizontal, depending on latitude (See Figure 2 for a solar resource map of the United States).

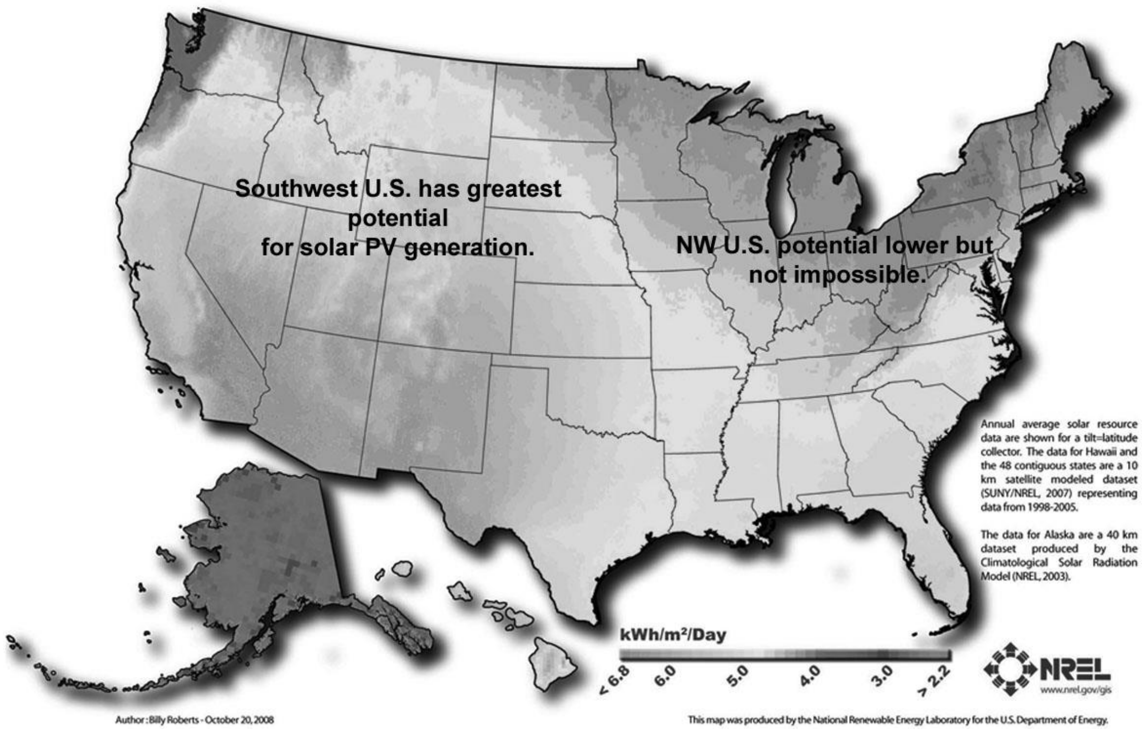

Figure 2. Solar Resource Map of the United States. This map was produced by the National Renewal Energy Laboratory for the U.S. Department of Energy.

The typical roof area required for single family home uses is about 400 ± square feet depending on location, generating approximately 2500 ± watts. For commercial and large scale applications, the required roof area will vary, based on electrical load, the size of the available roof area (shading, mechanical equipment, etc.).

PV panels and other components come in a large number of sizes, shapes, and uses, with products available across the country from more than 25 manufacturers. Panels are installed by hundreds of contractors and "integrators."

Not only is the method of mounting and type of system important to the Roof Consultant, so too is the method of installation and type of the complete PV system – including the wires and conduits carrying the DC power away from the panels, the inverter system that

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converts DC power into AC power, the utility company connection and other support components. PV generated electricity is most often used only for supplying the electrical needs of a user, although surplus power can also be sold to electrical utility companies. See Figure 3 showing the typical components of a roof mounted solar PV system.

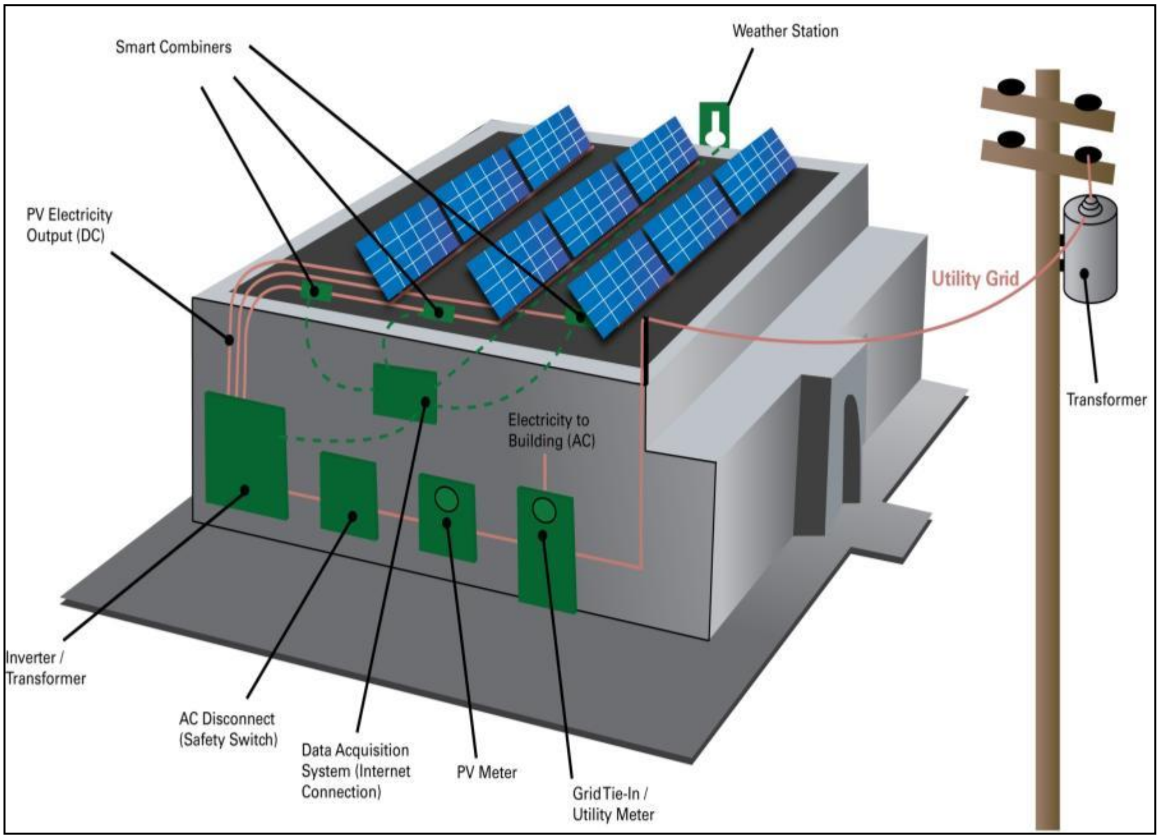

Figure 3. Typical components of a roof mounted solar PV system.

2. BRIEF OVERVIEW OF SOLAR THERMAL SYSTEMS

In addition to PV technology, Solar Thermal Energy (STE) systems also take advantage of sunlight, in order to generate heat, and are available in the low, medium and high heat ranges. Low heat systems (less than 100 degrees) are typically used in pool heating, space heating and process heating. Medium temperature systems (100 – 204 degrees) are typically used for domestic or commercial hot water. High temperature systems (under 1500 degrees) are usually large scale utility-company-owned systems, designed to concentrate sunlight to make steam to drive turbines.

STE systems are not covered in depth in this paper, although some of the same design issues (structural load, wind load, impact on the roof assembly, roof longevity, and roof maintenance) come into play.

3. TYPES OF SOLAR PV MATERIALS AND PANELS

These thin film and crystalline materials transform solar energy to electricity:

A. Thin film.

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Thin film began to see widespread commercial deployment in the early 2000s, whereas crystalline silicon panels saw widespread commercial use in the 1970s. Thin films are available from a number of different manufacturers, and can cost less per watt than traditional silicon panels; however they can require significant additional space due to their lower power efficiency, leading to higher overall system costs.

Thin film, when integrated into solar panels, is used in roofing retrofit situations, however, when integrated into single ply roofing materials for retrofits, a complete re-roof may be required, depending on the individual circumstances and condition of the roof.

Thin film materials, whether mounted into panels, directly applied to roofs, integrated onto single ply roofing, or integrated into BIPV, are available in these raw forms:

- a-Si (Amorphus Silicon)
- Copper Indium Gallium Selenide (CIGS)
- CdTe (Cadmium Telluride)

i. <u>Amorphus Silicon (a-Si)</u>

a-Si applications have a lower efficiency rating, often by half, compared to Crystalline Silicon (c-Si), but are more flexible in their applications. Thin film applications thus require larger roof space, but provide cost efficiencies and some weight savings as a-Si layers can be made thinner than crystalline applications. a-Si is deposited during the manufacturing process at very low

Figure 4. a-Si thin film application to a roof.

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.

The weights of a-Si applications in single ply roofing vary from manufacturer to manufacturer. And as noted, relatively larger roof space is required.

ii. <u>Copper Indium Gallium Selenide (CIGS)</u>

CIGS cells tend to be less expensive, due to lower material costs and potentially lower fabrication costs (although crystalline technology is also

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dropping in production costs). A research paper (Management Report NREL/MP-520-41737, June 2007, "National Solar Technology Roadmap: CIGS PV") prepared by the U.S. Department of Energy showed an efficiency of nearly 20% in research testing (higher efficiency levels than ai-Si and Crystalline Silicon), however electricity production efficiencies may be lower, depending on application and installation.

One CIGS manufacturer makes cells to take advantage of direct sunlight, diffuse sunlight and reflected sunlight from the roof surface. With a white roof, these panels can capture up to 20% more light than a black roof, according to the manufacturer. Thus, the reflectivity of an existing roof is a critical factor for this type of system. Roofs lacking the required reflectance due to age or soiling, or both, may require a significant increase in cleaning frequency, increasing costs, and affecting long range economic returns.

Also, there is a relatively short commercial deployment history of cylindrical CIGS modules compared to traditional crystal silicon panels.

iii. Cadmium Telluride (CdTe)

CdTe cells are not as cost efficient as crystalline, but are suitable for large-scale production. CdTe is the only thin film PV technology to surpass crystalline in cost effectiveness when used in utility scale applications.

As with other thin film, the weight per square foot of these systems varies by manufacturer.

Concern with the toxicity of the cadmium has been expressed by many potential users.

Figure 5. Typical CdTe panel.

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Figure 6. Typical mono-crystalline panel. Because the sizes and outputs vary, the designer needs to check manufacturer specifications.

B. Crystalline Silicon (c-Si). c-Si materials come in two types, mono-crystalline and poly-crystalline.

Crystalline silicon is used by the semiconductor industry, and is the material used in over 80% of all PV today. Generally it provides 12% to 21%+ cell efficiency, generates 13 to 17 watts per square foot, and has extremely low degradation - reduction in efficiency over time. As one of the original PV technologies, it has a history of over 40 years of field deployed, successful installation. And for retrofits, this is the most practical system, assuming the roof is good condition, because the system can be relatively easily set on an existing roof.

i. Mono-Crystalline (single crystal)

Mono-Crystalline is the original PV technology invented in the 1950's and has over 40 years of history and reliability behind it. Mono-Crystalline modules are composed of cells cut from a piece of continuous crystal cylinder sliced into thin circular wafers. Because each cell is cut from a single crystal, it has a uniform color of dark blue. See Figure 6.

ii. Poly-Crystalline (multi-crystal)

Poly-Crystalline entered the market in 1981, but is similar in history, performance and reliability. Polycrystalline cells are made from silicon material but instead of being grown into a single crystal, are melted and poured into a mold. This forms a square block then cut into square wafers with less waste of space and material than round single-crystal wafers. As the material cools, it crystallizes in an imperfect manner, forming random crystal boundaries. The efficiency of energy conversion is slightly lower. The size of the finished module is slightly greater per watt than most Mono-Crystalline modules. The cells are also different in appearance from single crystal cells. The surface has a jumbled look with many variations of blue color.

In the United States, mono and poly crystalline panels are available from at least 25 manufacturers. The so-called "typical" panel has a size of approximately 14-17 square feet, generates <200 to >240 watts, and weighs approximately 40 pounds, or from a very Rough Order of Magnitude point of

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view, 2-3 pounds dead load per square foot of panel, not including wires, connectors, conduits, other equipment, and loads created by wind, seismic, or thermal movement. See Figure 7.

Figure 7. Typical poly-crystalline panel. The dimensions of these panels vary widely, depending on the manufacturer. One of the more common sizes is a panel approximately 39 inches wide, 65 inches in length (approximately 17 s.f.), and 1.8 inches thick. The shipping weight is approximately 40 pounds.

Because sizes vary so widely, the designer must check specifications with each manufacturer.

4. MOUNTING SYSTEMS FOR ROOF INSTALLATION OF SOLAR PV

A. Low slope solar PV thin film adhered systems: Single ply thin film solar PV roofing systems are applied directly to the roof, either in the factory or in the field. For example, thin film solar PV has sometimes been adhered with adhesive to existing metal roofs, or has been factory applied to single ply roof membranes. Single ply and other low slope adhered systems are limited in application due to the condition of the existing roof membrane and insulation, how many roof membranes are already in place (as limited by local code), how many roof penetrations must be dealt with, wind uplift, and similar factors. However, thin film systems, either in single ply or manufactured into the panelized systems described above, offer significant weight and structural advantages.

B. Low slope solar PV panel systems. These panel systems are laid flat on the roof or are secured or ballasted in place, often by only their own weight, with or

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without separate protection pads. If laid flat on the roof without being secured, wind uplift and ventilation of these panels can be problematical, if not properly designed. In a retrofit situation, this can have a serious impact on remaining roof life and the safety of the panels.

C. Solar PV Panels mounted to standing seam metal roofs. Panel systems can be mounted to standing seam metal roofs with clips (See Figure 8, although clips are not approved by all governmental agencies, for example, California Division of the State Architect, involving K12 schools and some other California local-government owned buildings.).

D. Solar PV systems mounted via penetrating mounts. Penetrating roofing systems for roof retrofits include specialized mounts affixed to the roof structure, although this does cause the existing membrane to be cut, possibly affecting the existing warranty.

Figure 8. Panel mounting on standing seam metal roof.

The system providing the best answer to wind load, thermal movement and azimuth angle issues, is the system attached to the roof structure or building frame. This method does require additional roof penetrations, although with proper design can be accommodated – see Figure 10 for one example of a penetrating mount on an existing gravel ballasted built up roof. The roof consultant will need to review and implement NRCA recommendations regarding clearances, on a case by case basis.

Figure 9. Penetrating roof mount on gravel ballasted BUR. The same detail would be applicable to an embedded-aggregate roof.

E. Non-penetrating non-ballasted solar PV panel roof mounting racks. Non-penetrating non-ballasted roof solar racks consist of PV panels being set in metal frames placed on the roof over rubber or EPDM pads. These systems are somewhat similar to ballasted systems, but instead of ballast being added, take advantage of the weight of the solar PV system and the racks themselves. Some of manufacturers claim their systems can sustain winds of 90

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Figure 10. Roof Mounted, Ballasted Solar Panel System with Poly-Crystalline panels. Note the limited clearance between the panels and the roof deck, possibly creating the need to remove the panels for the purposes of roof replacement or possibly even for normal roof maintenance, leak repair or cleaning.

to 120 miles per hour, however some manufacturers claim only the capacity to accommodate a 30 degree angle from the roof deck, at such wind speeds, an angle that may be less efficient in generating power in some parts of the Country where an azimuth angle of up to 47 degrees from horizontal may be necessary for optimal solar efficiency.

F. Non-penetrating ballasted solar PV panel roof mounting racks. These ballasted systems consist of metal frames, with the addition of weight in the form of bricks or other engineered material. The manufacturers of some ballasted systems claim ballasted systems can withstand a greater tilt angle. The roof consultant should exercise due diligence by asking for back up engineering calculations from the manufacturer. Both non-ballasted and ballasted roof racks create additional weight, possibly causing the entire system to exceed the limits for the roof structure. Regardless of the PV type installed, the live and dead loads need to be calculated to determine if the roof structure can accommodate them.

G. Snow loadings and snow drift mounting issues. In some parts of the Country, solar PV installations will result in greater roof loads, from the weight of fallen or drifting snow, the weight of the racks and the weight of the panels. Taken all together the roof structure may not accommodate the extra weight.

H. Car port mounted, shade structure mounted, ground mounted and tower mounted tracking solar panels. In addition to the roof mountings of the solar PV systems discussed above, PV systems can be mounted on existing or new car ports, shade structures, ground mounts and tower mounts, to provide for tracking of the sun for greater efficiency.

I. Other types of solar PV systems – concentrators: Concentrator systems are not covered in great detail in this paper, however, these are some of the concentrator systems now available, typically for large scale, utility-company-sized systems:

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i. Heliostat concentrators. These are special towers used to concentrate the sun's energy, typically in the form of heat, on a central point, to generate steam to drive turbines, creating electricity.

ii. Concentrated solar panels use a series of lenses to concentrate the sun. These panels are thicker and heavier than the typical solar panel. Concentrated solar panels may also be mounted on sun-tracking, ground mounted towers or panels.

J. Building integrated photovoltaic systems (BIPV). Solar panels, thin film systems and other solar PV are now found in:

i. Curtain Walls (See Figure 11).

ii. Roof shingles, where the solar component is also the shingle.

iii. Shade structures.

Figure 11. Building integrated PV (BIPV) in a curtain wall.

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5. A BRIEF LIST OF SOLAR PANEL AND SYSTEM MANUFACTURERS

There are many, many manufacturers of solar PV panels. **A NOT ALL-INCLUSIVE, BUT RAPIDLY CHANGING LIST:**

ADVENT SOLAR
AMONIX INC
ATLANTIS ENERGY SYSTEM INC.
BP SOLAR INT'L LLC
CANROM PHOTOVOLTAICS, INC.
DAYSTAR TECHNOLOGIES INC.
DURO-LAST ROOFING INC.
ENERGY PHOTOVOLTAICS INC, EVERGREEN SOLAR INC.
FIRST SOLAR LL.
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.
SOLAR WORLD-USA
SOLYNDRA, 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 MANY MORE!

Each of these manufacturers offers varying sizes, dimensions, power output, configuration, ease or lack of ease of roof installation on existing, design issues to be addressed, familiarity to the installer and warranties. These differences will have an impact on the design and how the roof consultant goes about preparing plans for installation.

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6. DESIGN ISSUES FACED BY THE ROOF CONSULTANT

The information shown below is not intended to be an all inclusive list of every issue faced by the roof consultant when dealing with solar PV installations on an existing roof. As with all building components, issues dealing with solar PV are complex and extensive. But based on our firm's experience reviewing existing roofs for their capacity and capability for solar installations, we have prepared a brief overview of design issues to consider. The buildings we have reviewed include airports, multi-family residential properties, schools and commercial buildings.

A. Roof Assessment.

i. Roof age. What is the age and condition of the existing roof? Does it need to be replaced now?

ii. Remaining service life. Will the remaining roof life be concurrent with the service life of the solar PV system? Will it need to be replaced before the service life of the solar PV system ends, creating more costs? Solar PV manufacturer provide estimates of service life, these need to be compared to the remaining roof life during the design process.

iii. Existing warranty. What is the impact to the existing roof warranty – who was the manufacturer, and what is the actual warranty? What are the rules and requirements about penetration? Some warranties are also voided if a new type of roofing material is joined to the existing material.

iv. Watertightness. Are there issues to be addressed before solar is installed, and will these issues be worsened by the installation of solar? Have all existing leak conditions been repaired?

v. Drainage. Is the existing drainage system adequate and will it be made worse or even made better (not likely) by the solar installation?

vi. Chemical compatibility. Will the existing operations, especially in manufacturing or food operations, be compatible with the roof life, the solar PV material and the solar PV system installation? Will contaminants or particulants discharged from the building cause problems?

vii. Impact on structural load. The roof consultant needs to collect weight data on the entire solar PV system to determine if the existing roof can accommodate the new live and dead loads. If the roof consultant is not a licensed structural engineer or architect, a licensed professional will need to be retained in order to provide those answers.

B. Physical Constraints. These issues to be addressed are fairly straight forward:

i. Adequate roof space. Is there sufficient roof space available on the roof to handle the entire electrical need?

ii. Existing mechanical equipment. How much mechanical equipment is on roof, will it conflict with the panels and if so can it be moved or removed?

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iii. Distances between solar PV components. How is the design of clearances and separations between solar PV panels and other equipment impacted by local fire codes?

iv. Power runs. Are conduit runs possible from solar to electrical tie-in?

v. Additional space on ground for solar PV. Is space required on the ground for a partial or complete ground mount system, and is thespace adequate in size to accommodate what cannot be accommodated on the roof?

vi. Ground enclosures for solar PV equipment. Will new ground structures be required and can these ground structures take the form of parking shade structures?

vii. Locations of ground enclosures. Where will space on the ground or inside the building be provided for an inverter and equipment mounting system and is it sufficient in size, location and proximity to the solar PV system? Is a separate building required for this equipment?

viii. Trenching. Will trenching be required from the solar PV system to electrical tie-in point?

C. Solar PV and new roof warranty. Before the purchase, obtain a copy of the warranty from both the solar PV system and the roof manufacturers, and address these issues:

i. Ongoing maintenance. What continued maintenance of the roof and solar PV is required as a condition of the warranty? Is the purchaser required to sign an agreement requiring annual or other periodic maintenance, and is such maintenance necessary?

ii. Financial strength of company holding warranty. Is there financial strength behind the solar PV warranty, or is it an insurance policy from an insurance company?

iii. Extreme environment exceptions. Is maritime or extreme environment deployment approved in the warranty?

iv. Fine print. The fine print says…?.

D. Sustainability of solar PV system over time.

i. Compatibility between service lives. Will the roofing last the term of the solar PV financing? How long will the PV system last?

ii. Obsolescence of solar PV system. Will the solar PV and all associated systems maintain their manufactured integrity, and last the term of the solar PV financing or warranty?

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E. Structural loads created by the solar PV system.

The structural load can take the form of dead load caused by the weight of the panels, wires, collectors, connectors, conduits, mounting racks, and other materials. Live load issues can be created by wind loadings, thermal movement, and other factors. Design requirements to address these issues vary by state and local conditions. Some examples of dead loads have been provided in this paper however; contact the manufacturers for specific engineering detail.

Building officials from California to New York may upon your submittal of a building permit application, request calculations of the ability of the affected lateral system components to resist additional seismic loads and the impacts of thermal movement created by the solar PV system equipment.

F. Fire code design issues.

i. Markings. Solar PV systems normally should be marked with weatherproof materials indicating it is a solar system, including the individual components, in order to provide safety from electrical shock, to the firefighters working around the systems in case of a roof fire for example. Many jurisdictions require name plates displaying voltage ratings of the components. Many jurisdictions also require locations of power disconnects to be clearly marked.

ii. Access and pathways. Fire codes in most jurisdictions require adequate access to panels, adequate paths of travel between roof-mounted solar PV equipment, access to the roof from the ground level (varies by jurisdiction), and emergency egress from the roof. Some jurisdictions have been known to require a 6 foot wide safety path around the perimeter of the roof. Some jurisdictions require the path of travel to be over structural elements.

iii. Size of arrays. Some jurisdictions limit the size of individual arrays.

iv. Non-habitable buildings. In some jurisdictions, the fire requirements do not apply to non-habitable structures such as carports, shade structures and other ground mounted arrays, although a vegetation-free area of 10' is required in some jurisdictions.

v. Impact on fire rating of roof assembly. The designer needs to determine if and how the PV system will impact the fire rating of the existing roof assembly; this information may be required when permits are requested.

G. Electrical, mechanical and other design disciplines.

Solar PV systems are unique – requiring design by electrical engineers of adequate wiring sizes and conduits; design by mechanical engineers to provide for existing roof mounted mechanical equipment; design by structural engineers for structural issues; and civil engineering design of trenching, etc. Solar system power modulation, ground fault and short circuit potential needs to be studied including how well wires are protected in metal and other raceways, and how they are protected from the weather. Thermal movement also impacts conduit runs.

H. Peer review of design. Solar PV installations, being so complicated, are an excellent candidate for peer review by other engineers.

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I. Maintenance of the PV system and the roof. One of the issues often forgotten by the designer is maintenance, including the roof, the PV system itself, the electrical conduits and the racks, to name a few. See the photos below showing some of the possible long term problems. The answer to these problems can be found in proper design.

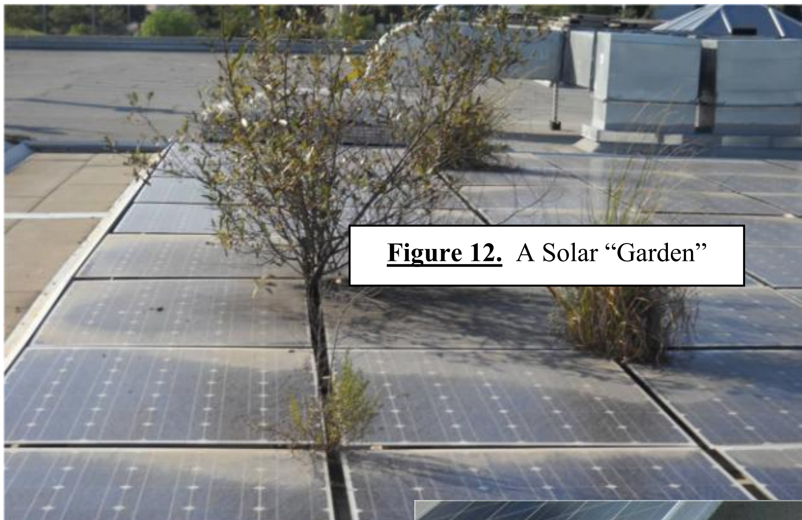

Figure 12. A Solar "Garden"

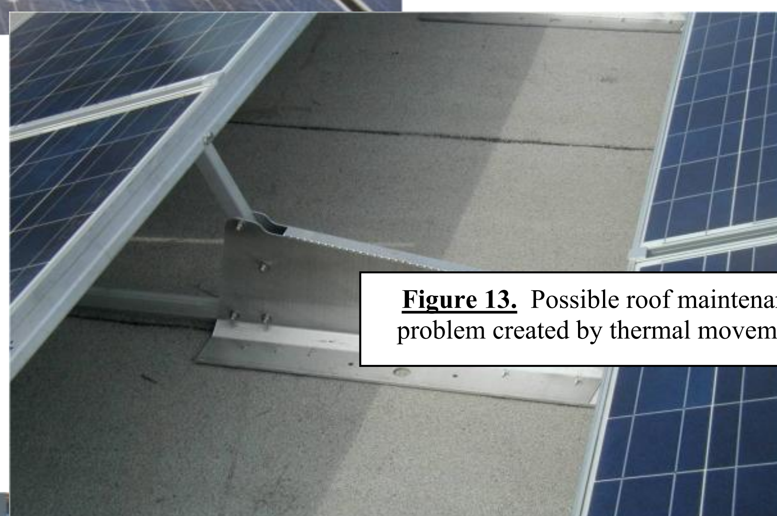

Figure 13. Possible roof maintenance problem created by thermal movement.

Figure 14. Possible maintenance and safety issues caused by electrical conduit lying on roof and not properly supported.

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J. Non-engineering design issues.

i. Appropriate materials – reflected light is an issue on campus settings. For example, solar installations on a single story building can reflect glaring light into existing or planned taller buildings.

ii. Sizing.

iii. Aesthetics.

iv. Location – solar can go anywhere, right? No.

v. Making sure the PV system remains in continuous operation

vi. Security issues during installation and operations

7. FINANCING SOLAR

How and why to finance solar need not be difficult if the following issues are taken into consideration:

A. Price. What's the_best way to pay for solar PV and is the price reflective of all needed options? The overall question is: Does solar make financial sense for your unique situation? And the big picture is: Utility costs are increasing rapidly, utility costs are and will continue to be volatile, rebates and tax credits are limited, and money spent on energy is money not spent on growth. So Solar enables you to control and predict utility costs, and save money.

B. Alternative financing methods.

i. Cash Purchase - Great…if you have the money, some financial analysts have shown a 10-18% return on investment and an 80% to 98% reduction in energy costs.

ii. Federal and State Incentives.

iii. Traditional financing using a capital loan or lease.

iv. Municipal leases for municipal bonds.

v. American Recovery and Reinvestment Act (ARRA) stimulus funds.

vi. Power Purchase Agreements (PPA). This financing method allows control of utility costs without capital investment, provides increased savings over time. Municipalities which cannot otherwise benefit from tax incentives can in effect allow others to reap the benefits, at much lower costs to the municipality.

a) Finance company installs, owns and operates the solar plant on your site. There are a number of different PPA providers: prices and terms can vary greatly, and the proven ability to commit and close as promised is critical.

b) You do not pay for the equipment, or the maintenance.

c) You're buying energy not equipment – this is strictly an energy buy.

d) You buy energy from the system, and you only buy as much energy as the system produces.

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e) Because this is an agreement to buy energy, not a lease, or a loan, the financing agreement is not reflected on the client's balance sheet.

f) Credit quality is key: can the parties fulfill their obligations for 20 years?

C. Key things to remember for the economic case.

i. Utility costs are increasing unpredictably.

ii. Incentive levels decline over time, often much faster than expected, so there is urgency to act quickly.

8. CONTRACTORS AND SUPPLIERS

A. Criteria for selecting a contractor. The issues to be addressed when selecting a contractor are:

i. Is the "contractor" an integrator or a contractor – is the work self performed or is the work performed by a subcontractor?

ii. Quality of construction and experience with similar projects.

iii. Does the contractor/integrator have a strong balance sheet?

iv. Are good communication practices, procedures and methodologies in place?

v. Safety procedures and practices.

vi. Number of sub-contractors.

vii. What are the quality standards to reduce future costly repairs?

viii. What methods does the contractor use to avoid delays and problems, increasing enthusiasm for the project within your community/constituency, reducing stress on your business operations, reducing your business/organization's risk for on-site accidents, improving the integrity of your roof or site, and eliminating repair disruptions in years to come?

B. What questions should be asked?

i. Is this integrator/contractor experienced in construction?

ii. Does this integrator/contractor understand my whole building?

iii. Will the integrity of my roof system be protected?

iv. Does this integrator/contractor deliver quality construction on-time and on-budget?

v. Is this integrator/contractor an expert in every step of analysis, design, sourcing, and cost-control?

vi. Can I trust this integrator/ contractor to work safely and prevent costly accidents?

vii. Does the firm have the ability to execute on-time and on-budget?

C. Safety criteria

i. Full-time safety managers.

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ii. Written safety plans.

iii. On-site audits.

iv. Personal fall-arrest systems.

v. Experience Modification Rate (EMR).

vi. Compare rates.

D. Roof and site integrity – can the firm provide it?

E. Roofing and construction experience criteria

i. Infrastructure to support complex projects.

ii. Construction planning and operations excellence.

iii. Local cross-trained workforce.

iv. Experienced solar project managers.

v. B, C-10, C-46 contractor's license (California examples, Other states have similar requirements.

vi. NABCEP certified technicians.

vii. Highly qualified project superintendents.

CONCLUSION

Installation of solar PV on existing roofs is complicated, complex and ambitious, but worth the time and effort in cost savings, and the ability to have a positive impact on the environment. Most importantly, the issues addressed and answered in this paper will assist the roof consultant in keeping pace with the rapidly changing practice in the installation of solar roofing systems. The financial means and methods do exist to allow installation of solar PV systems on many existing roofs across the United States. Following these simple guidelines will lead to a successful, rewarding project.

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