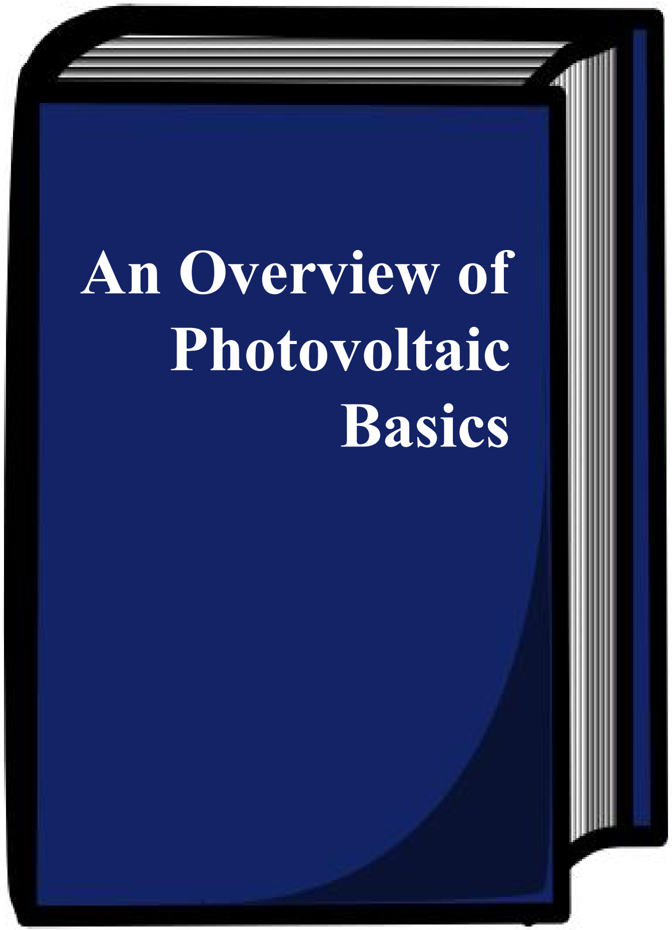


An Overview of Photovoltaic Basics

Environment friendly e-library

SMRCA JAC

UNITED UNION OF ROOFERS, WATERPROOFERS AND ALLIED WORKERS
FOUNDED 1903

An Overview of Photovoltaic Basics

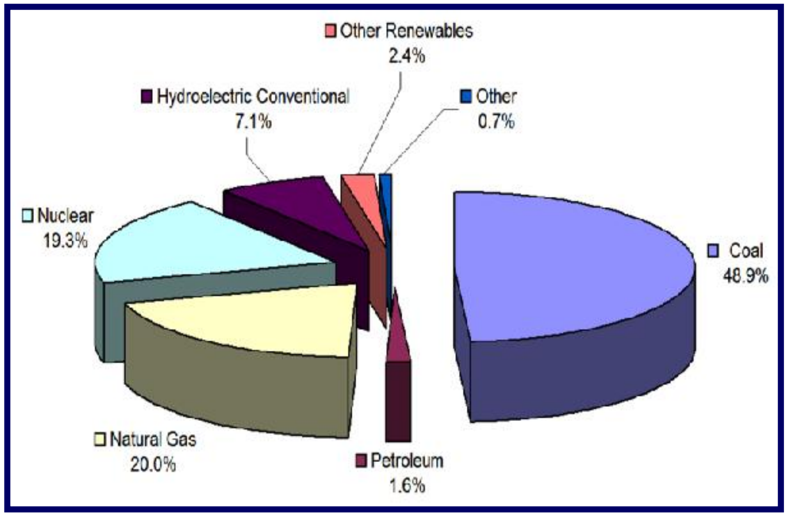
- Market Drivers
- Review of common terms - concepts
- Types of photovoltaic cells
- Converting solar energy
- About the inverter
- Substrate and roofing considerations
- Photovoltaic system design
- Calculating the cost and ROI
- Maintenance

Market Drivers

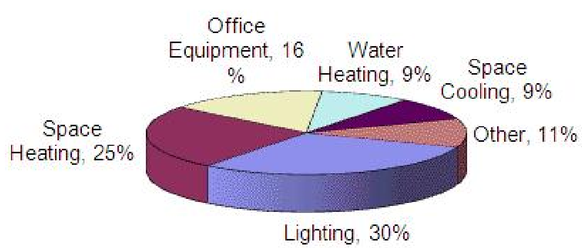
- $1 trillion in global electric power market
- Global power demand to roughly double by 2025
- China building 1 new coal plant per week – 600 planned
- Solar power market share today < 0.1%
- Policy driven by rate increases, security and environment
- Solar power within reach of mass-market cost-effectiveness

Market Drivers

World Electricity Generation by Fuel Type



Office Buildings End Usage *(US Avg.)*



Market Drivers

Availability

- Key Environmental Benefits - Solar generates electricity without air or water emissions, noise, vibration, habitat impact or waste generation
- Ease of Access – Universal availability of sunlight makes solar accessible for all customers (commercial through residential)

Solar Makes Financial Sense

- Eliminate Fuel Volatility - Unlike fossil and nuclear fuels, solar energy has no risk of fuel price volatility or delivery risk
- Offset Peak Energy Demand and Prices - Maximum sunlight hours usually correspond to typical peak demand periods when electricity retail prices are highest

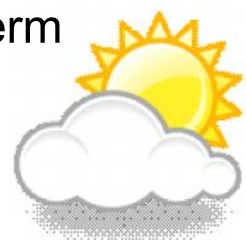
Ease of Use

- Customized solutions - Deployed in many sizes and configurations to meet business needs
- Reliability - No moving parts or regular maintenance required

Review of Common Terms - Concepts

Energy produced by a solar cell is affected **primarily** by two components:

•Sunlight intensity. The term used for the intensity of sunlight is:
solar irradiance



The estimated amount of sunlight for a region is referred to as:
insolation

Insolation is typically the previous 30 year average.

Review of Common Terms - Concepts

http://rredc.nrel.gov/solar/pubs/redbook/ is the link to tables on solar insolation for any location in the U.S. for a 30 year period 1961-1990.

adiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1.6	2.5	3.5	4.6	5.6	6.2	6.1	5.2	4.0	2.7	1.7	1.3	3.8
1.4/1.9	2.1/3.0	3.2/3.9	3.8/5.1	4.6/6.7	5.4/7.3	5.6/6.5	4.7/6.0	3.2/4.8	2.3/3.3	1.4/2.0	1.1/1.6	3.6/4.0
2.4	3.3	4.2	5.0	5.7	6.0	6.1	5.6	4.7	3.6	2.3	1.8	4.2
1.8/2.8	2.6/4.2	3.7/4.8	3.9/5.7	4.6/6.9	5.3/7.2	5.5/6.5	4.8/6.5	3.5/5.8	2.8/4.5	1.6/3.0	1.4/2.5	4.0/4.5
2.6	3.6	4.3	4.9	5.3	5.6	5.6	5.4	4.8	3.8	2.4	2.0	4.2
1.9/3.1	2.7/4.6	3.7/5.0	3.8/5.6	4.3/6.4	4.8/6.6	5.1/6.1	4.6/6.2	3.5/6.0	2.9/4.8	1.6/3.3	1.5/2.8	4.0/4.5
2.8	3.7	4.2	4.5	4.7	4.8	4.9	4.9	4.5	3.7	2.5	2.1	4.0
2.0/3.3	2.7/4.8	3.6/4.9	3.5/5.2	3.8/5.7	4.2/5.7	4.5/6.3	4.2/5.7	3.3/5.8	2.8/4.9	1.6/3.5	1.6/3.0	3.7/4.3
2.6	3.4	3.4	3.1	2.8	2.7	2.8	3.1	3.3	3.1	2.2	2.0	2.9
1.8/3.2	2.4/4.5	2.8/4.2	2.4/3.6	2.3/3.3	2.5/3.0	2.5/3.0	2.7/3.6	2.3/4.2	2.3/4.1	1.3/3.1	1.4/2.9	2.7/3.1

Installed watts x 365 days x average sunlight per day (about 4 hrs) = potential watts x degradation (80% max)

Note that the table has an uncertainty value of +9 or -9 %.

Review of Common Terms - Concepts

Factors that affect the amount of solar radiation received by a PV Module

- Latitude at Location (height angle)
- Season of the Year (height angle)
- Hour of the Day (azimuth angle)
- Module Orientation and Tilt Angle
- Other factors (ex. shading, soiling)

Facing SSW and tilted at latitude angle is best.

Review of Common Terms - Concepts

- **A watt** of power is the result of two variables:
- **Volt** – think of a volt as the speed or force of electricity. Volts are reduced when surface heat is high. Volts are increased when surface heat is low.
- **Amp** – an amp is the rate of electricity. Visualize amps as a highway that can have two, three, four or more lanes. Amps are affected by irradiation. The higher the irradiation the higher the amps.

A solar system will generate more watts of power on a cold sunny day than on a very hot sunny day. Why? Volts will be reduced by heat.

Review of Common Terms - Concepts

The capacity of a solar cell is discussed in watts of energy. Always be clear about two distinctions:

•Design or installed watts. This is the watts that in theory could be generated if we had "standard test conditions" in a laboratory. (one sun of 1000W/m^2 at 25 degrees Celsius.)

•The actual watts delivered is an estimate based on "irradiation" and "degradation". Degradation is a term that refers to loss of generating power over time of a solar cell. For most installations this can be about 1% a year.

Review of Common Terms - Concepts

Rated 144 watts

Installed actual watts produced will be less

Look for PV USA Test Conditions or PTC rating which is less than STC due to the higher solar cell temperatures. A higher PTC means more production.

Types of Photovoltaic Cells

There are four types of solar cells currently on the market:

- Mono-crystalline silicone
- Poly-crystalline silicon
- Amorphous silicon or (thin film)
- Copper-indium-gallium-selenide (thin film)

Types of Photovoltaic Cells

An amorphous cell has an efficiency rating of 8%, the copper-indium-gallium-selenide,cigs, has an efficiency of about 14%, the poly-crystalline cell has a rating of 15% and the mono-crystalline cell has a rating of 20%.

Can you think of a condition where an amorphous cell would be capable of delivering more watts than the other two types of cells?

The amorphous cell works at lower sunlight so it works a "longer day" and therefore produces more watt hours of energy per watt of capacity per day.

Types of Photovoltaic Cells

Types of Photovoltaic Cells

Mono-Crystalline	Poly-Crystalline	Amorphous-Silicon	Copper-indium-gallium-selenide
Longest history	Medium history	Shorter history	New in the market
High efficiency	Good efficiency	Moderate efficiency	Estimated moderate efficiency
Stable electrical characteristics but does degrade about 1% per year.	Stable electrical characteristics but does degrade but does degrade about 1% per year.	Out put improves during first 3 months then degrades.	Unknown
Durable	Durable	Durable – can be walked upon	Glass encased cylinders.
Heavy (approx. 5lbs. PSF.)	Heavy Heavy (approx. 5lbs. PSF.)	Light weight (less than 1lb PSF.)	3.3 PSF.
Rigid	Rigid	Can be made flexible	Rigid

Types of Photovoltaic Cells

Characteristics

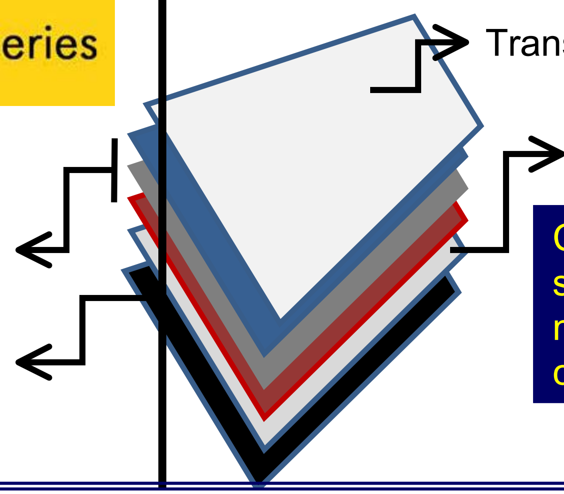
- The Solar Spectrum shifts seasonally (more red in the winter and more blue in the summer).
- Additionally, the solar spectrum shifts temporarily toward blue on cloudy or diffuse light days.

FlexLight Solar Laminate PVL Series

Types of Photovoltaic Cells

Characteristics

- *Mono-crystalline and poly-crystalline silicon* cells have an optical gap (i.e. band gap) close to the energy level of red photons (~600-800 nm).
- *Amorphous silicon* has an optical gap closer to the energy level of blue photons (350-600 nm).



Captures the full spectrum of sunlight making it one of the most efficient photovoltaic cells

Types of Photovoltaic Cells

Mounting Systems

FlexLight Solar Laminate PVL Series

No Penetrations

Adhered to roof

Types of Photovoltaic Cells

Mounting Systems

Mono and Poly Crystalline

Roof Penetrations

Installed on rails mounted on roof. About 70% of roof leaks are found at penetrations, vertical transitions and terminations.

Battery Back-up

Battery storage will add about 30% to cost of installation. There are many different types of batteries but the *DEEP CYCLE LEAD-ACID Battery* is the most common type used in photovoltaic systems. Other types of energy storage include raised water tanks and (in the future) hydrogen.

Battery Back-up

Common Battery Blunders

•Lack of a protective environment.

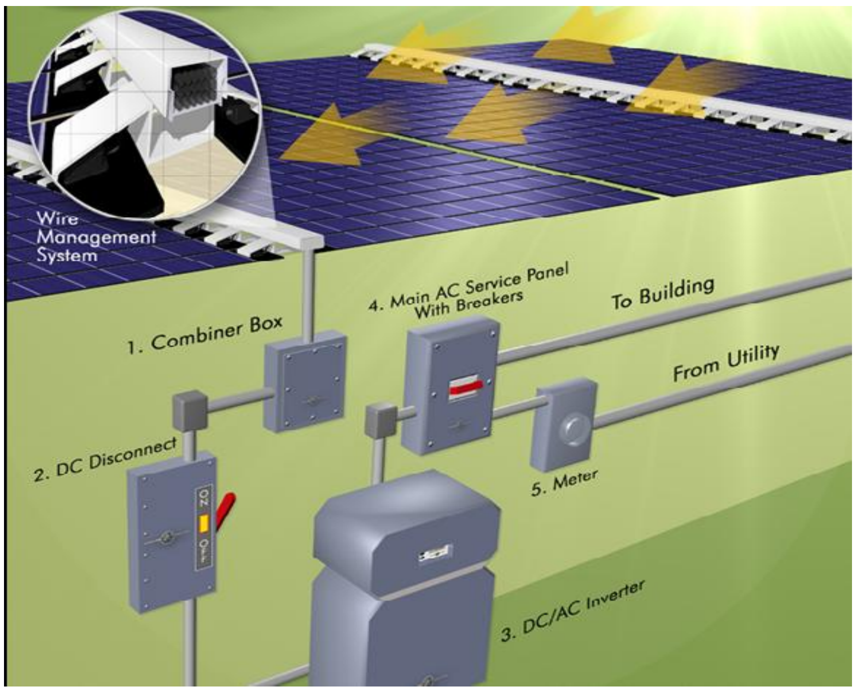
•Failure to prevent corrosion.

•Lack of charge control.

•Lack of monitoring discharge.

Converting Solar Energy

Illustration of a Thin Cell Commercial Roof Solar Power Installation



Converting Solar Energy

Energy is lost in all installatios by the conversion of power from DC to AC. Power is converted by an "inverter".

•The inverter looses up to 5% of power.

•You will want to select the most efficient reliable inverter.

•To avoid power loss the inverter should be placed as close as possible to the PV array

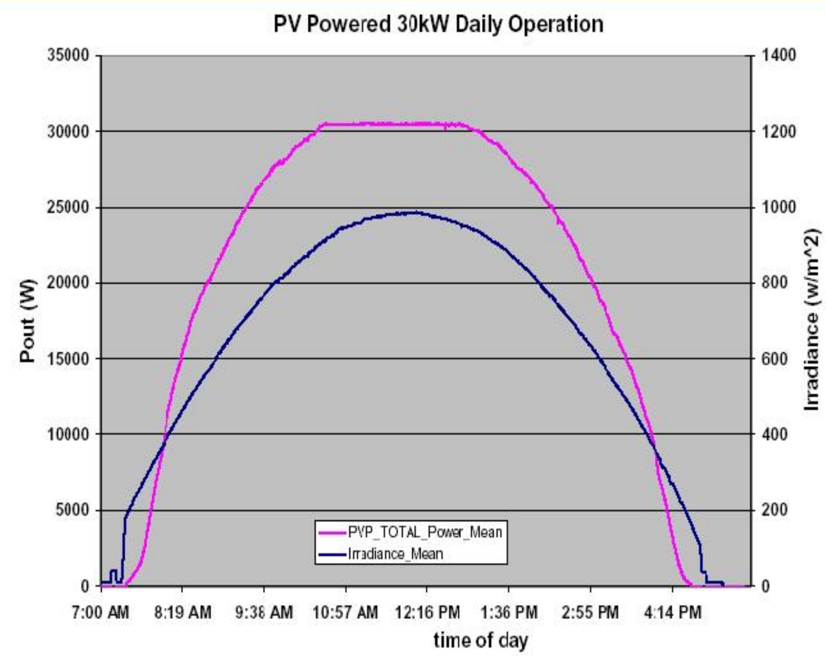
Inverter Information

PVPowered

- Highest efficiency
- Highest reliability
- Lowest life time cost
- Low cost data monitoring
- 10 Year warranty, optional 15 year and 20 year
- UL listed and tested May, 2007

Inverter Information

Sandia National Laboratories



Inverter Information

Core PV Powered Value: **Simplify…..**

- 30, 75, 100 kW systems
- Exceptionally low part count
- Modular design for easy service.
- Requires about a 5’x5’ clearance area.
- Easily fits through a standard door.

Inverter Information

Inverter Information

Maximum Energy Harvest

- >95% peak efficiency and 94% CEC efficiency
- Integrated 98% efficient, Energy Star rated isolation transformer
- Best in class components for reliability & long life,
  - Medical Grade DC Power Supply
  - Film Capacitors
- Web-based monitoring to find and solve problems fast
- Night time disconnect
- Field configurable 208V or 480V AC output

Continue...

Substrate and Roof Considerations

•Photovoltaic systems will last 20 to 30 years. The roof must last as long especially with a thin cell system that is adhered to the roof membrane.

•Use good roofing practices

•New design and construction:

- •To avoid shading, roof shadows created by parapet walls, penthouses, screen walls and HVAC units, HVAC units should not be on the roof.
- •The deck must have positive drainage to reduce ponding water.
- •In our region the slope should be toward the south.

Substrate and Roof Considerations

Challenge: Design or refurbish industrial facility without roof top units.

Challenge: Eliminate ponding water due to poor design or deflected deck.

Substrate and Roof Considerations

•Seams are a weak point in most roof systems. Roof systems should be water tested prior to installation of a photovoltaic system. Seams need to be thoroughly checked.

•Metal details need to be designed to last. Coping and edge details should not use fasteners on the top or sides but rather use a clip.

Substrate and Roof Considerations

Challenge: Seams have to be installed correctly and last 25 years or more.

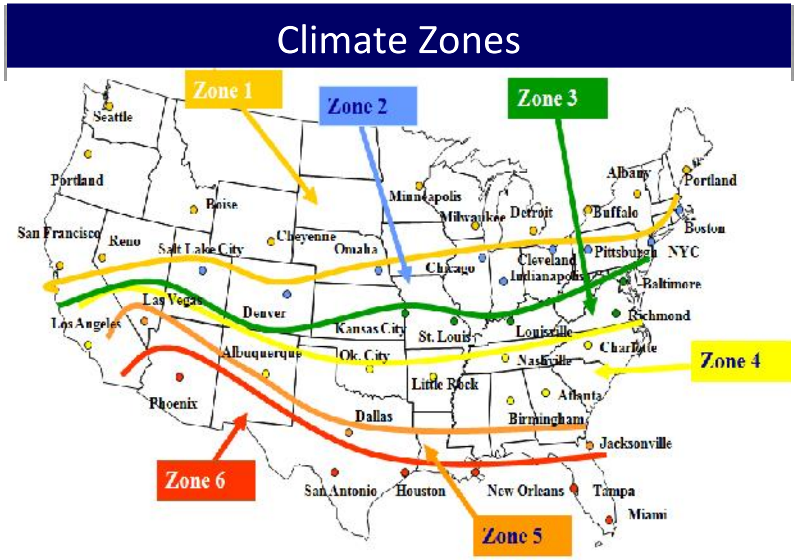
Challenge: Metal details must also last 25 or more years.

Substrate and Roof Considerations

•Regardless of climate zones high reflectivity roofs are best as they can reduce roof surface temperatures by 100 degrees Fahrenheit. Keeping cells cooler improves output.

•A more constant temperature reduces thermal shock, which occurs when cool rain hits a hot roof, causing a sharp drop in temperature. During temperature changes, a roof expands and contracts, causing stress and degrading the roof life.

Substrate and Roof Considerations



Substrate and Roof Considerations

•Flashings are another weak point in most roof systems.

- •Many manufacturers have a “heavy duty” flashing detail.
- •Where possible membrane should be run up and over curb boxes, coping walls. Continuous sheets of membrane perform better than sheets that are terminated on the vertical surface.

•Walkway pads need to be installed on any area of the roof where traffic will be anticipated.

- •To units
- •Around - between the photovoltaic systems.

Substrate and Roof Considerations

Substrate and Roof Considerations

•In colder climates where insulation is required use two layers of insulation.

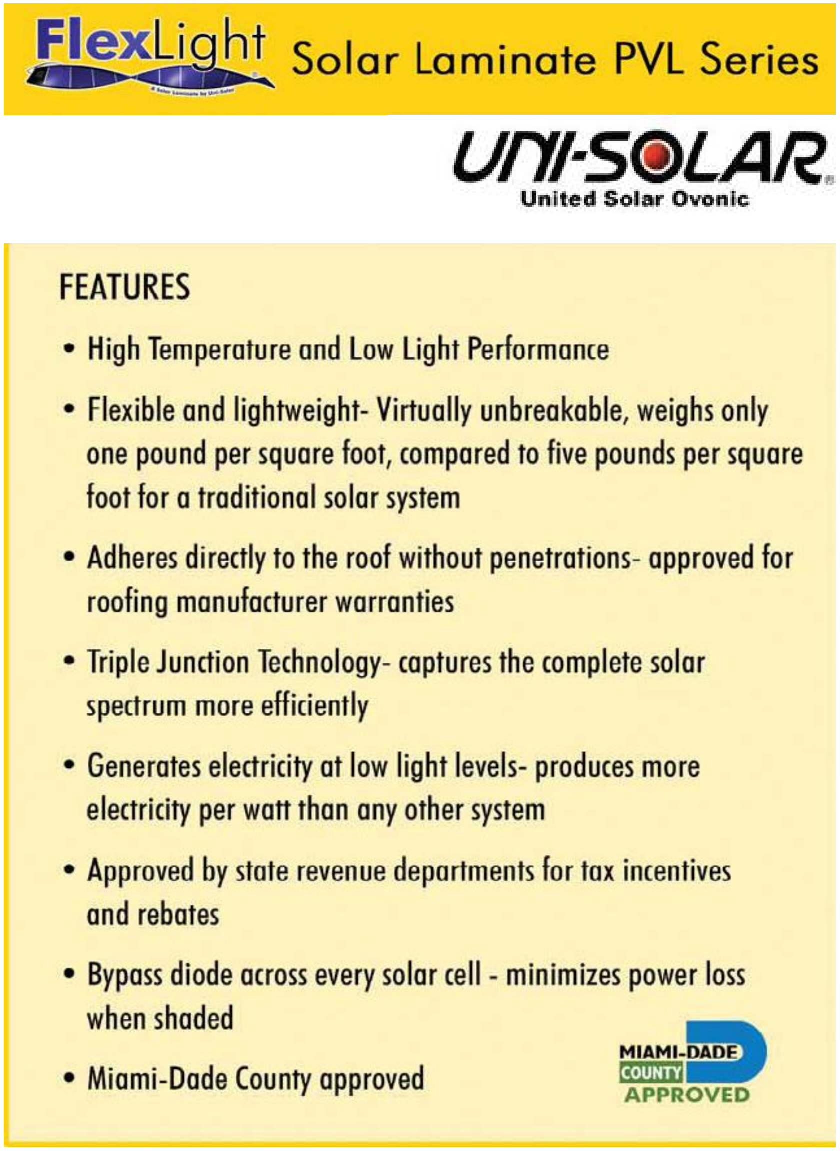
•Using a single layer of insulation can cause a loss of R-Value through a process called thermal bridging. An example is a metal fastener transferring heat or cold through insulation. Some data suggest a 5% reduction in overall R-value is caused by thermal bridging.

Substrate and Roof Considerations

•When possible insulation should be set in adhesive or use two layers of insulation with staggered joints. The bottom layer of insulation can be mechanically attached while the top layer is set in adhesive.

•This design avoids fastener back-out.

Photovoltaic System Design



Photovoltaic System Design

Construction Characteristics

- 15 year warranty 90% of power 25 year warranty on power output of 80%
- Three size panels all are 15.5" wide and will fit comfortably on a standing seam metal roof. Sizes are:
  - 1144w, length - 216"
  - 124w, length - 197.2"
  - 68w, length – 112.1"
- Adhesive – ethylene propylene copolymer with microbial retardant
- Quick connect terminals

Modules are also available for TPO and EPDM membranes. Modules have the photovoltaic cells adhered at the roof membrane factory.

Photovoltaic System Design

Determining the size of the system by space available

FlexLight Solar Laminate PVL Series

System Solution	Avg. System Area	Avg. Yearly kWH[§]
10 kWAC	2,320 ft^2	20,440
20 kWAC	4,633 ft^2	40,880
30 kWAC	6,949 ft^2	61,320
50 kWAC	11,582 ft^2	102,200
100 kWAC	23,164 ft^2	204,400

Photovoltaic System Design

A polycrystalline or monocrystalline system takes about 2/3 the space of a typical amorphous silicone system.

Photovoltaic System Design

There must be enough power to turn on the inverter. "String sizing" is the term used to describe the number of solar panels needed to generate enough power to turn on the inverter.

Three strings

Photovoltaic System Design

Series Strings of Modules - The volts add up while the amps stay the same.

Parallel Strings of Modules - The amps add up while the voltage stays the same.

Rule of Thumb - Always make your series connections first, and then make your parallel connections.

-OR-

Do it the easy way -visit: http://string.mypvpower.com for a String Calculator. Must use temperature range in Centigrade.

Photovoltaic System Design

Roof Top Wire Management System

Is required for most Uni-Solar installations and may be required for other systems depending on system design.

FEATURES

- Lightweight
- Easy to assemble
- Durable
- Adheres firmly

18’ lengths

Photovoltaic System Design

Location of Inverter

- The inverter should be located near the photovoltaic array. Increased distance reduces power.
- The Inverter, combiner boxes and other electrical components can be located outside.
- A 6’x6’ space is needed for a typical inverter.

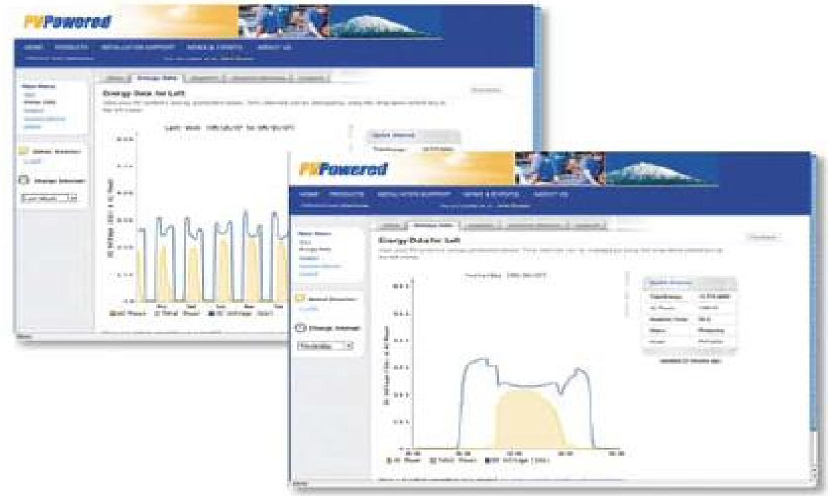
Photovoltaic System Design

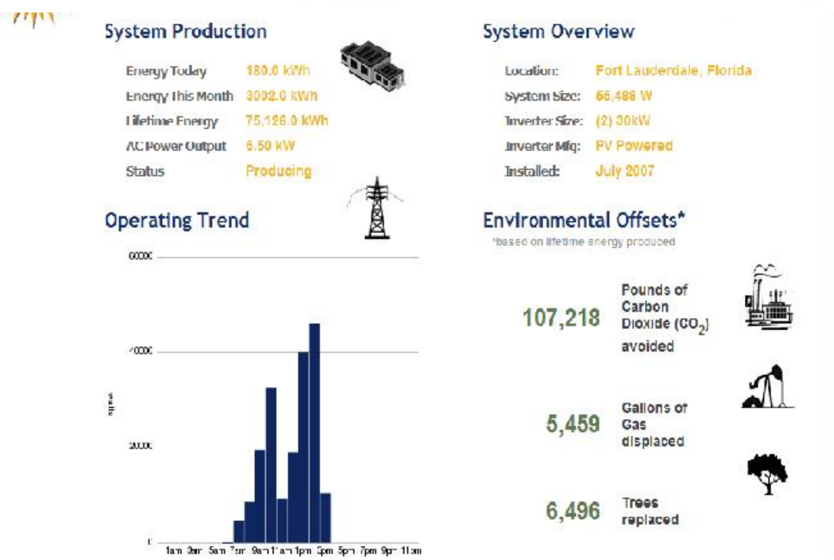
Monitoring System Performance

Features

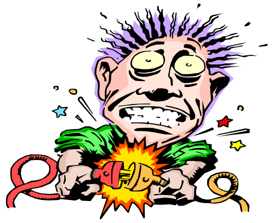
- PV Powered inverters have a monitoring module with easy field installation inside the inverter
- Detailed power data can be reported with better than +/- 5% accuracy.
- Energy output graphs include hourly, daily, weekly, monthly graphs of voltage vs. power output. Updated every 15 minutes.
- Data is compatible with performance monitoring reporting services for performance based incentive reporting.

Photovoltaic System Design





Calculating the Cost and ROI



Variables

- Size
- Insolation
- Installed cost of system *(range $6 to $8 per watt not including roof)*
- Tax incentives – current federal tax credit is 30% plus accelerated depreciation.
- Federal State tax incentives and local rebates can be viewed at www.dsireusa.org.
- Fuel cost at location
- Projected increase in fuel cost
- Cost of money
- Life of system
- Depreciation

Calculating the Cost and ROI

Ask us about a ROI calculation

Your return on investment based on below	6.03%	
Years until positive return on investment	18	2026
Reduction of carbon per year (tons)	62	

Building and Electricity Information	
Building's roof area	13,500
Estimate of % approximate usable roof area	60.00%
Total watts	47381
Current cost per kwh	$0.125
Total dollar value of electricity generated	$7,782

Aproximate Installed Cost	
Approximate installed cost per watt	$8.00
Cost of installation	$379,045

Cash Flow	Variables	2008	2009	2010
Purchase price		$ (379,045)		
Tax credit	30%	$ 113,714		
Depreciable amount		$ (265,332)		
Depreciation rate		20%	32%	19%
Depreciation		53,066	84,906	50,944
Tax rate		36.00%	36.00%	36.00%
Taxes saved		19,104	30,566	18,340
Electrcity revenue escalating	6.00%	$ 7,782	$ 8,249	$ 8,744
Installation		$ (379,045)		
Investment Credit		$ 113,714		
Tax savings from depreciation		19,104	30,566	18,340
Net (outflow)/inflow		$ (238,445)	$ 38,815	$ 27,084

Maintenance

•The design life of most roof systems is 15 to 25 years but most systems last 10 to 15 years due to poor maintenance.

The National Roofing Contractors Association and most roof manufacturers recommend twice a year roof inspections.

•A competent roof inspection typically cost about 2 cents per square foot.

According to CARE literature and our own experience the extended life of the roof more than pays for the cost of the inspection.

•The Photovoltaic installation should be washed, not power-washed, every 90 to 120 days or as needed.