Solar Energy Systems

Overview of components, design considerations and function of solar energy systems

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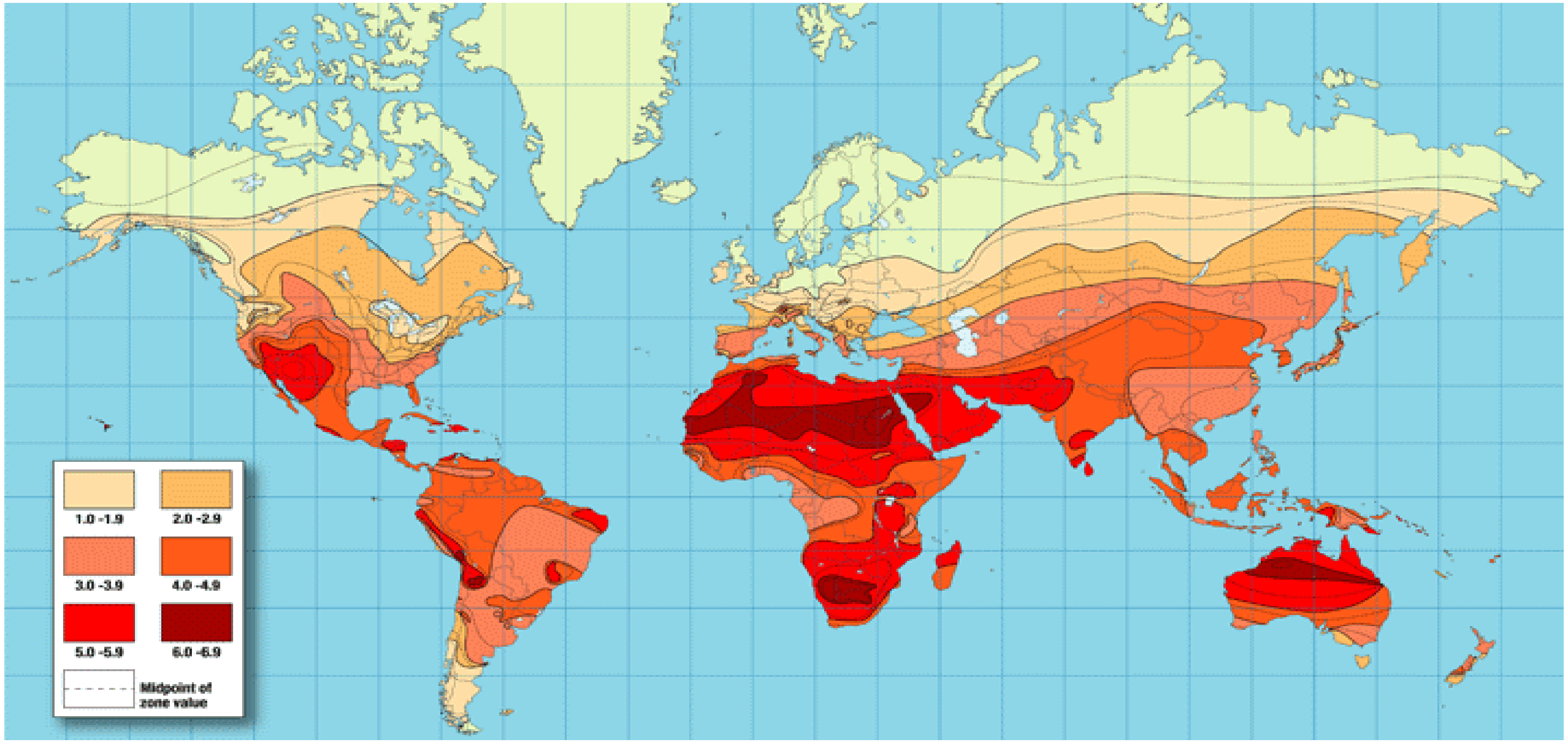
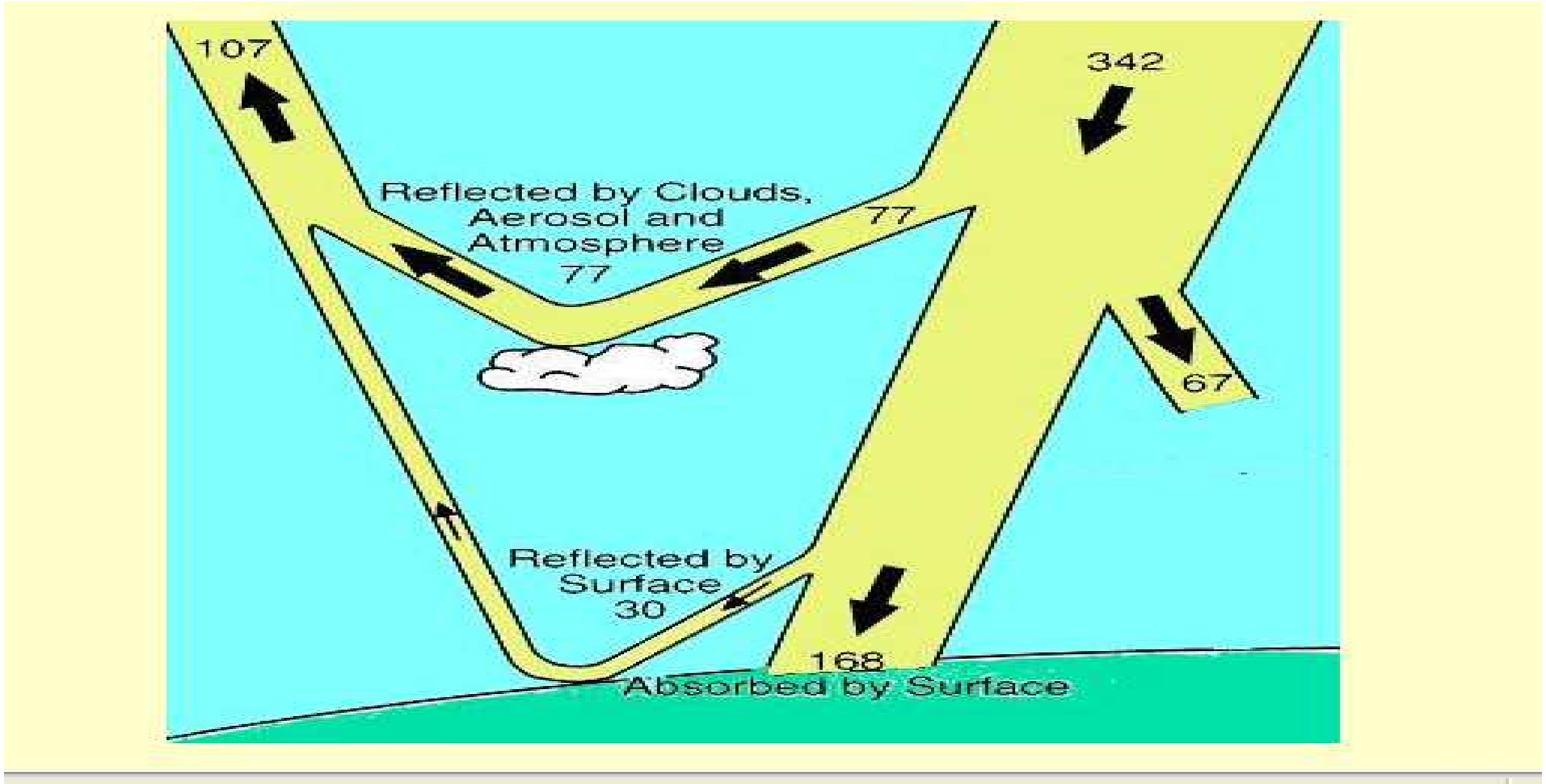
Standard Renewable Energy
"renewable solutions to everyday needs"
www.sre3.com

Solar Energy Potential solar radiation map



Solar Energy Potential



What is the goal of this discussion?

The solar industry is expanding rapidly with more people adopting a low energy lifestyle. The Economic Stimulus bill has also helped with public sponsored systems across the country

How does the solar power system integrate and fit into the facility Appearance, size, attachment methodology, proximity to other components, cost, options etc…

How much power will they make, how much do they cost, how Effective are they in reducing power costs etc…

With so many options and a myriad of new products.
How do you start to understand them all and what is right for me?

All Things Photovoltaic

- How Solar Photovoltaic energy systems work
- Light and the Photovoltaic cell
- Cell and Panel Operation
- Measuring Photovoltaic performance

Types of solar cells & materials

- Silicon ingots, poly crystalline, monocrystalline cells
- Other Materials Cadmium Telluride- first Solar
- Thin Film and laminates
- Cylindral panels-Solyndra
- BIPV-building integrated
- Supply Chain expanding

PV Cell Operation

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- A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load
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- **Figure 1. Diagram of a photovoltaic cell.**
- Regardless of size, a typical silicon PV cell produces about 0.5 – 0.6 volt DC under open-circuit, no-load conditions. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is proportional to the intensity of sunlight striking the surface of the cell. For example, under peak sunlight conditions, a typical commercial PV cell with a surface area of 160 cm^2 (~25 in^2) will produce about 2 watts peak power. If the sunlight intensity were 40 percent of peak, this cell would produce about 0.8 watts.

Solar Cell Operation

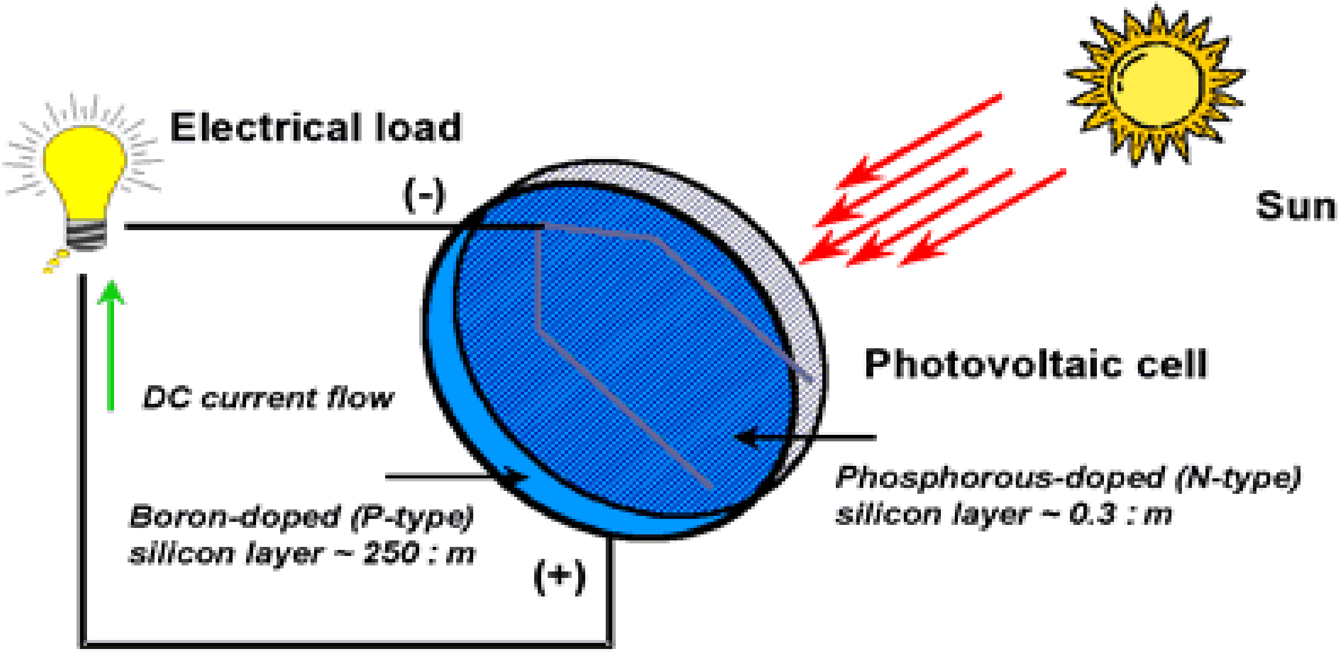

Figure 1. Diagram of a photovoltaic cell.

Cells Modules Arrays

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- Photovoltaic cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems. Photovoltaic panels include one or more PV modules assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels.
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- **Figure 1. Photovoltaic cells, modules, panels and arrays.**
- The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25o C (77o F), and incident solar irradiance level of 1000 W/m2 and under Air Mass 1.5 spectral distribution. Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually 85 to 90 percent of the STC rating.
- Today's photovoltaic modules are extremely safe and reliable products, with minimal failure rates and projected service lifetimes of 20 to 30 years. Most major manufacturers offer warranties of 20 or more years for maintaining a high percentage of initial rated power output. When selecting PV modules, look for the product listing (UL), qualification testing and warranty information in the module manufacturer's specifications.

Cells Modules and arrays

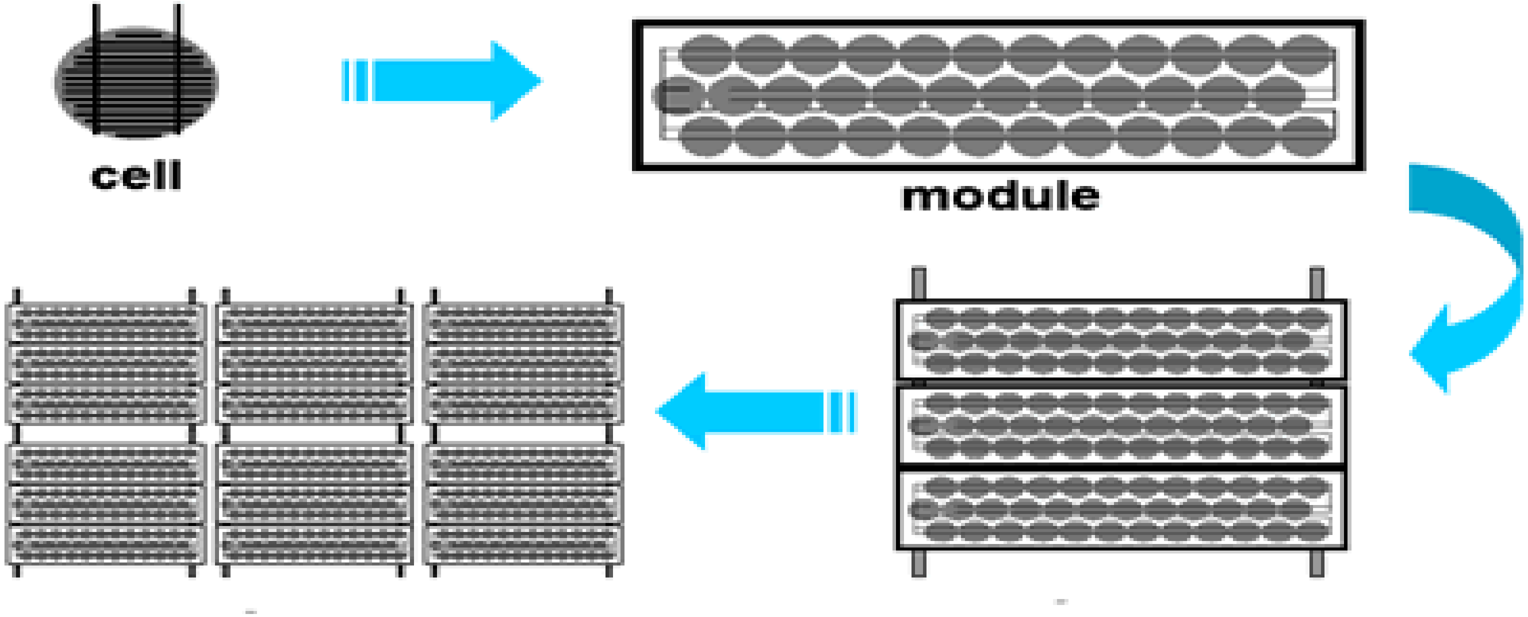


Figure 1. Photovoltaic cells, modules, panels and arrays.

Solar Energy Systems-PV

- Components
- Mechanical Fastening Systems
- Wiring Systems
- Breakers, safety, Inverters, Interconnect
- Monitoring systems

Solar Energy Systems Operations and Maintenance

- Grid tie systems are fully automatic with little necessary maintenance necessary
- Monitoring systems aid in system performance
- System inspection- mechanical, wiring, grounding, record readings, done yearly
- Panel cleaning is helpful for optimum power

Unisolar Laminate

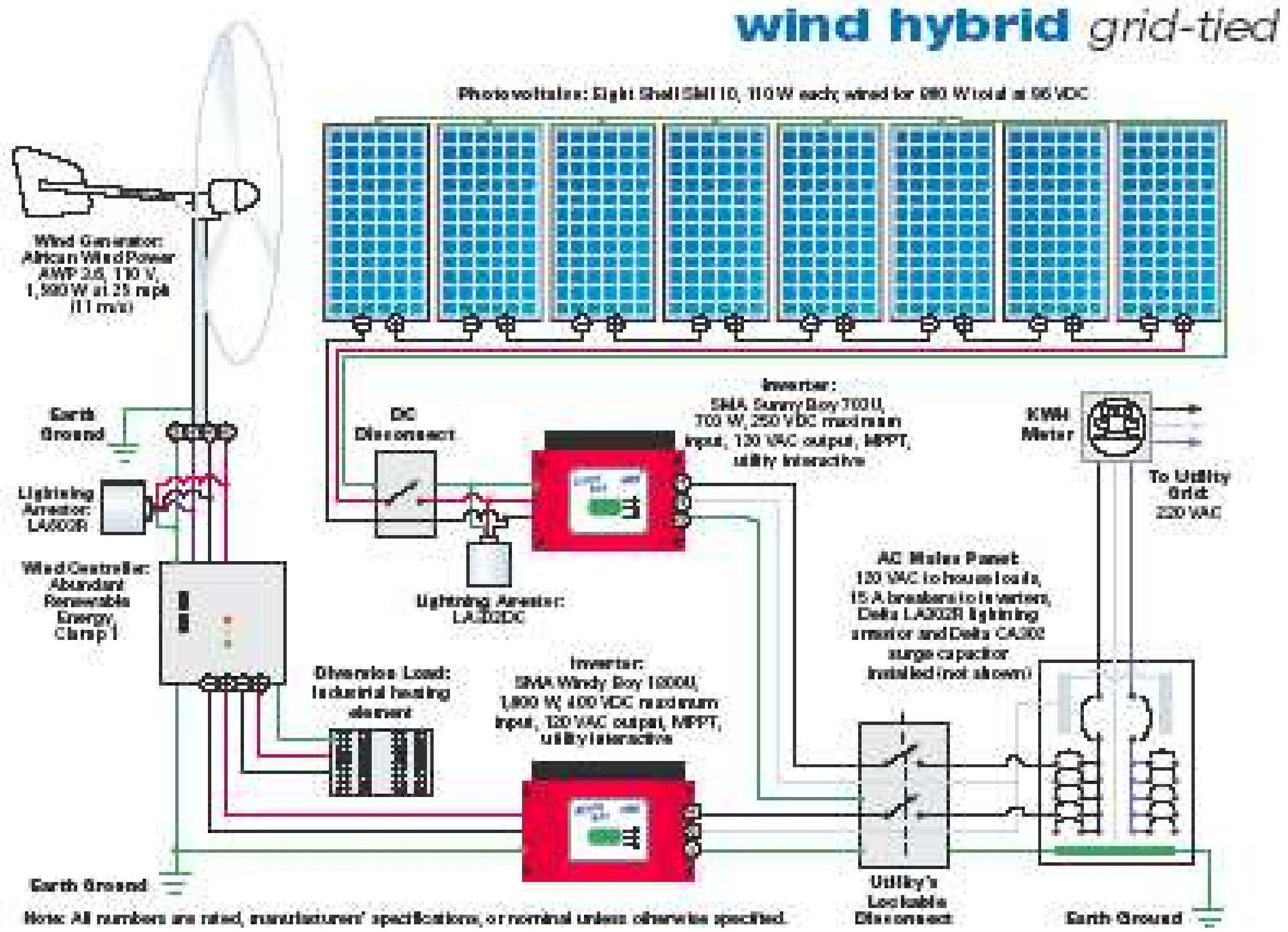
The Unisolar laminate product has a number of advantages for flat roofs that provide for a robust energy harvest and very reliable service. The technology has been around for 20 years, it has patents on their triple junction cell which captures three of the 7 light spectrums not just visible light and it does not suffer from flat orientation or high heat deployments, both characteristics of flat roofs. Panels can be bonded directly to the roof or to membranes that bond to the roof around the perimeter.

UniSolar's proprietary Triple Junction spectrum-splitting amorphous silicon cell design achieves high performance. These cells are constructed of three separate p-i-n type, amorphous semiconductor solar sub-cells, each with a different spectral response characteristic. This allows the cell to convert the different visible and near infrared wavelengths of sunlight with optimal efficiency. The thin-film cells are made in a patented continuous roll-to-roll deposition process on a flexible stainless steel sheet. Each of the nine thin-film semiconductor layers that comprise the cell is sequentially deposited in separate, dynamically-isolated, plasma enhanced chemical vapor deposition (PECVD) chambers as the stainless steel substrate progresses through the machine. The result is a unique, flexible, light-weight cell.

Battery Systems

- Solar Panels
- Charge Controllers- fusing, wiring
- Batteries
- Inverters
- Mounting
- Wiring, grounding
- Monitoring

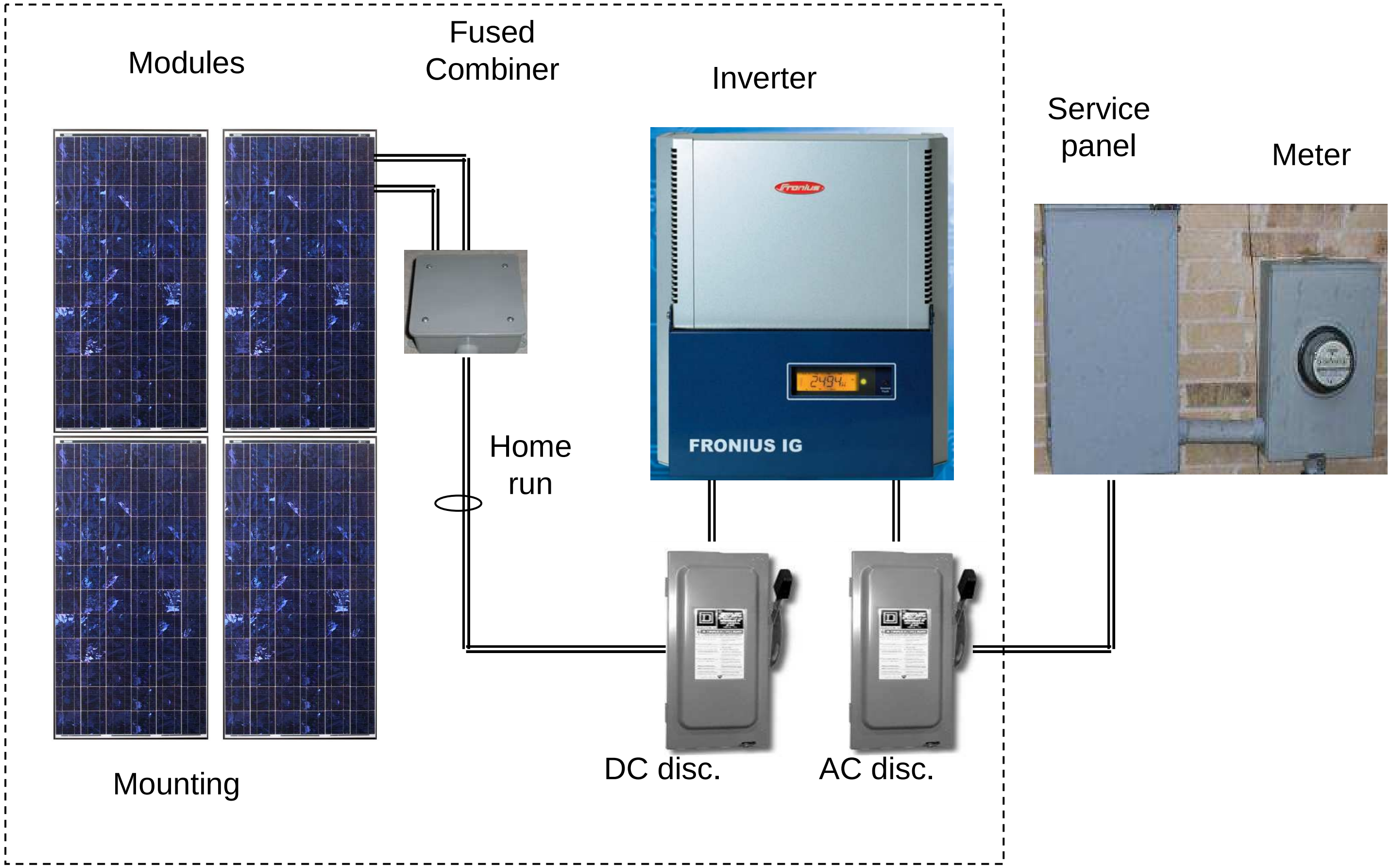
Solar & Wind Hybrid Systems



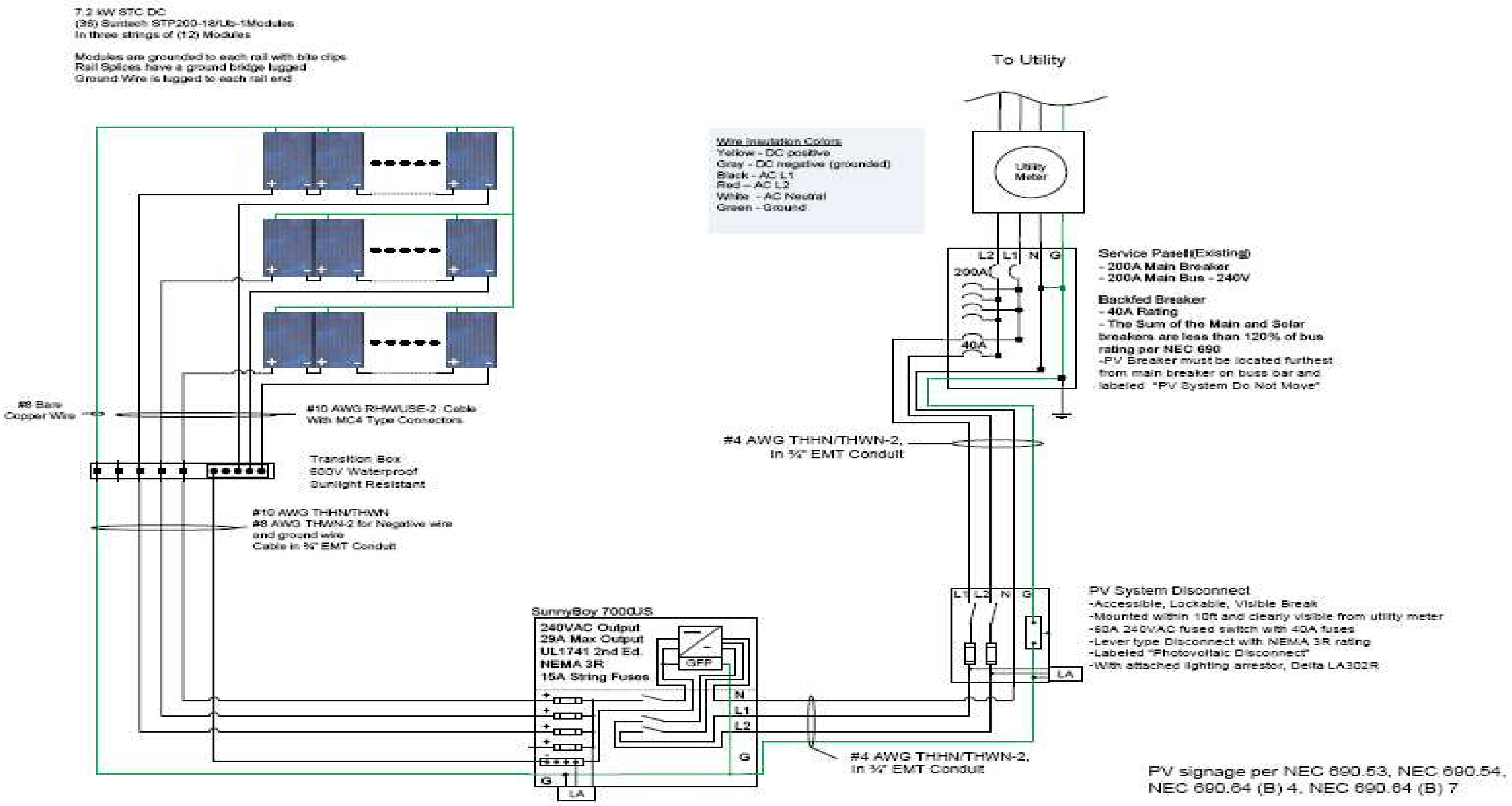
Types of Systems PV

- Grid Tie Systems are simpliest, solar energy directly converted to AC power
- Battery Based Systems provide both grid power and battery back up for emergencies- more complex
- Hybrid Systems marry the two together

Grid Tie Drawing



Grid Tie Detailed Drawing



Grid Tie Systems

⌘ Four components make up these systems

1. Solar Panels make DC power
2. Racking to hold at the proper angle and anchor in place
3. Wiring, fusing, breakers, conduit, connectivity
4. The Inverter to convert from DC to AC power

Solar Panels

⌘ Many Choices in this area

1. Solar Panels make DC power usually 24 to 33 volts each
2. Stringing them in rows serially boost voltage to 300 to 450 Vdc
3. Panels can be combined in like strings of same size panel and numbers
4. Strings combined on roof with home run wire from panels to Inverter.

Racking

⌘ Racks are industry term for mechanical systems to hold panels on roof

2. Mostly made of Aluminum to match panel frame material
3. Attachment to roof is critical
   1. Standoffs for height and cooling
   2. Depends on roof type, orientation
4. Important to ground racking properly

Wiring, Breakers, Fusing

- Panels come with attached cables
- Easy to string them together for strings
  of 8 to 15
  Strings are combined in fused weatherproof box.
  Panel frame grounding for lightning
  protection
  Fused breakers, disconnect boxes,
  Lockable AC disconnect within 6 feet of the meter
  Wire Size calculated for low wire loss from panels to inverter

Solar Panel Considerations

- ⌘ Type - mono, poly, amorphous, ribbon, bop, concentrated, silicon or copper based
- ⌘ Function to generate POWER - move electrons
- ⌘ Density - wattage per square foot
- ⌘ Efficiency - conversion of light to energy
- ⌘ Durability - withstand the elements
- ⌘ Physical properties, heat tolerance, mounting, wiring, grounding, spacing
- ⌘ Appearance, form and function, dual use deployment
- ⌘ Manufacturer and availability, warranty, useful life

Loss factors in Solar Power-77% typical harvest percentage

DC wiring loss

Inverter efficiency

Orientation-shading

Dirt, dust, environmental

Panel mismatch

Heat dissipation

AC wiring loss

Monocrystalline Solar Panels

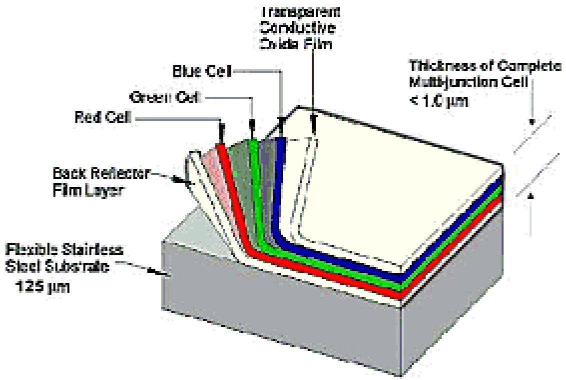
- Monocrystalline - high efficiency, high density (12 watts/sq ft) glass encased, 25 yr warranty, black or blue, aluminum framed, lose some power with heat, silicon based, many mfg and readily available, purest type of silicon
- Cost 5.00 per watt, many sizes and voltages 12, 24, 48,

Polycrystalline Solar Panels

- Slightly less efficient, slightly less dense (11.5 watts/square ft) lose some power under heat, glass encased, aluminum framed, 25 year warranty, bright blue speckled appearance, dark blue, can be odd shaped panels, many mfg. Waste product of silicon production,
- Cost 5.00 per watt, many sizes and voltages 12, 24, 48

Unisolar Laminates

UniSolar's proprietary Triple Junction spectrum-splitting amorphous silicon cell design achieves high performance. These cells are constructed of three separate p-i-n type, amorphous semiconductor solar sub-cells, each with a different spectral response characteristic. This allows the cell to convert the different visible and near infrared wavelengths of sunlight with optimal efficiency. The thin-film cells are made in a patented continuous roll-to-roll deposition process on a flexible stainless steel sheet. Each of the nine thin-film semiconductor layers that comprise the cell is sequentially deposited in separate, dynamically-isolated, plasma enhanced chemical vapor deposition (PECVD) chambers as the stainless steel substrate progresses through the machine. The result is a unique, flexible, light-weight cell.



C-si roofing membrane panels

- **C-si Roofing Membrane panels**
- The Applied Solar and Lumeta Solar product is made up of traditional Crystalline solar cells bonded to a compatible roofing membrane (PVC now but TPO to follow) and covered with a polymer clear coating that protects the modules is UV stabilized, reduces the effects of heat by reflecting some of the heat better than glass and is hail resistant. This type of roofing membrane is a unique solution that combines outstanding power generation with a very lightweight product that works in a limited amount of space. It’s easy and inexpensive to install, with no complicated rack mounting required. And it can be easily expanded as your needs expand. Since there are no roof penetrations involved, it maintains the roof warranty. Our membrane is a superior choice over thin film membrane because it produces high power output per square foot of roof coverage. And because it’s so lightweight, it works on virtually all

  buildings that have a flat roof such as various membrane, bitumen and concrete roofing.

CSI Laminates

- Deployment on a flat roof will lessen the power generation of the panel somewhat similar to traditional panels that lose over 10% of their power generation on a flat orientation. The product has over 500 kW installed and is now undergoing UL certification due in late 2009. Lumeta is a similar product available now.

C-s i Framed Solar Modules

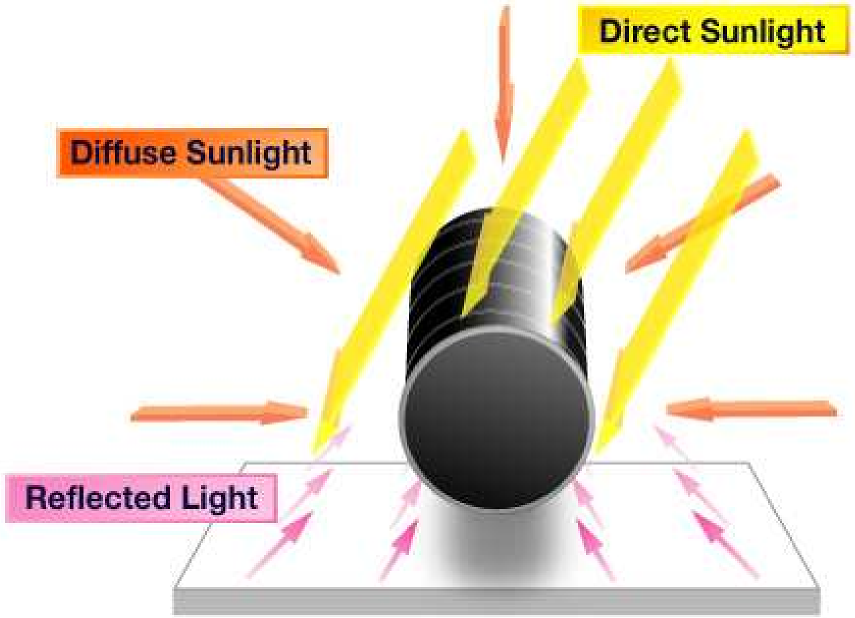
- C-s i Framed Solar Modules
- Framed Solar panels and thin film glass encapsulated panels can be mounted in ballasted racks typically at angles of 2 to 30 degrees south and offer a simple, modular approach to solar roofs that is very popular and effective in generating power. Panels can be mounted in linked mounts like these from Sunlink to lessen the effects of wind and allow for minimal roof penetrations. Warranties are 25 years, power output is very predictable, to achieve 5 degree angle it is possible to do this without roof penetrations, we would need to study the wind load of the building. Cost can be very competitive and the warranty and system output is very good. Most any panel from BP Solar to Sharp or Kyocera would work on these racks. They are used around the world for solar roofing energy systems. Flat mount would be lower angle with spacing between the panels for maintenance. Glass is laminated so any breakage would result in small pieces that are still held together by the laminate.

Large interlocking racking

Solyndra tubular panels

- **CIGS thin film tube modules**
- Solyndra is a new product that is very unique in the industry utilizing CIGS technology and a cylindrical deployment that allow wind to escape from under the module, cooling it and producing more power per sq. ft. The system is engineered to install very quickly and not require any roof penetrations. System is glass covered but independent electrically so if one of the tubes has problems the rest still produce. System achieves very good energy harvesting, some from direct and some from indirect diffused light. Cost is comparable if not better than other technologies with less impact from flat orientation.
- The Solyndra system’s ability to cover more roof and capture more light results in more annual solar electricity generation. Solyndra panels employ cylindrical modules which capture sunlight across a 360-degree photovoltaic surface capable of converting direct, diffuse and reflected sunlight into electricity. This self-tracking design allows Solyndra's PV systems to capture more sunlight than traditional flat-surfaced solar panels, which require costly tilted mounting devices to improve the capture of direct light, offer poor collection of diffuse light and fail to collect reflected light from rooftops or other installation surfaces.

Solyndra panels



Amorphous Solar Panels

- Less Dense, Less efficient, dark blue, flexible, encased in acrylic, walk able, durable, low light production (more hours per day) shade tolerant, heat tolerant, directly glued to roof or in aluminum framed panels. Triple junction cells capture visible, infrared and ultraviolet wavelengths. Can be shingles or laminates
- Cost 5.0 per watt, unisolar mfg. available

Concentrated Solar Panels

- High efficiency, high density, less cells, Fresnel lens concentrator, thicker, limited supply and mfg. Solar cells less visible than traditional, very heat sensitive-dissipate heat. More wiring issues due to high voltage. Tracking increases power,
- Cost higher, limited producers and stock

Ribbon Solar Panels

- Less efficient, less dense, cheaper, black, thin, flexible or framed, black with lines, more roof space required, ok heat tolerance, less silicon needed, different shapes possible. Several mfg.now and more in development, will be cheapest type eventually
- Cost 4.5 per watt, 3 main mfg. available

Building integrated Solar Panels

- Less efficient than mono, poly, less dense, some can be transparent, nice colors, can provide more than one function. Wiring issues, aesthetic issues. Cost savings by using for other uses like awnings, windows. Limited supply, more expensive, custom sizes or stock
- couple of mfg, cost is higher than others

Inverters for grid tie

- Many inverter brands and sizes for grid tie systems
- Central Inverters like Sunny Boy and Xantrex make up large part of market with 95% efficiency
- Micro Inverters are new and convert each panels energy to AC power directly- more efficient

Inverters becoming more efficient

- Inverter technology is evolving to be more efficient, reliable and affordable
- Power Point tracking and other methods to squeeze the most power from the sun
- Systems now come with 10 year standard warranty
- Monitoring systems help keep track of production

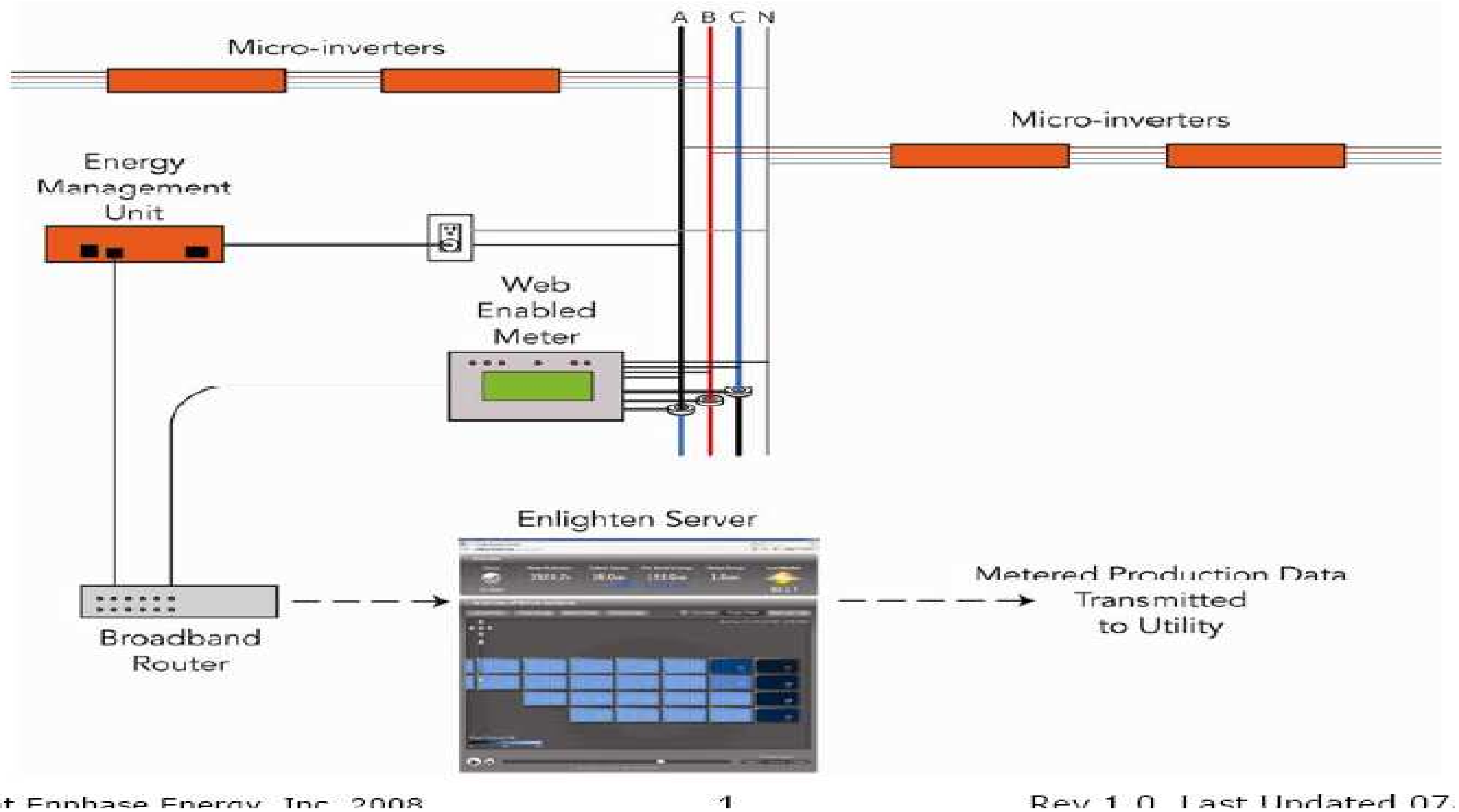
Monitoring Systems

- Real time and historical output from solar system to web showing production
- Also available to track energy usage
- Several companies to watch including google, SRE and Others

Central Inverters

	SB 5000US	SB 6000US	SB 7000US
Recommended Maximum PV Power (Module STC)	6250 W	7500 W	8750 W
DC Maximum Voltage	600 V	600 V	600 V
Peak Power Tracking Voltage	250–480 V	250–480 V	250–480 V
DC Maximum Input Current	21 A	25 A	30 A
Number of Fused String Inputs	3 (inverter), 4 x 20 A (DC disconnect)	3 (inverter), 4 x 20 A (DC disconnect)	3 (inverter), 4 x 20 A (DC disconnect)
PV Start Voltage	300 V	300 V	300 V
AC Nominal Power	5000 W	6000 W	7000 W
AC Maximum Output Power	5000 W	6000 W	7000 W
AC Maximum Output Current (@ 208, 240, 277 V)	24 A, 21 A, 18 A	29 A, 25 A, 22 A	34 A, 29 A, 25 A
AC Nominal Voltage Range	183 – 229 V @ 208 V 211 – 264 V @ 240 V 244 – 305 V @ 277 V	183 – 229 V @ 208 V 211 – 264 V @ 240 V 244 – 305 V @ 277 V	183 – 229 V @ 208 V 211 – 264 V @ 240 V 244 – 305 V @ 277 V
AC Frequency: nominal / range	60 Hz / 59.3 – 60.5 Hz	60 Hz / 59.3 – 60.5 Hz	60 Hz / 59.3 – 60.5 Hz
Power Factor (Nominal)	0.99	0.99	0.99

Enphase Micro Inverters



Inverters DC to AC with battery charger

- Wave form - modified sine, pure sine wave
- Output 120 or 240 volts
- efficiency of conversion DC to AC
- idle draw, wire size acceptance
- monitoring and reporting functions
- Run and Surge capability, generator input or charger
- Noise, heat dissipation, size, complexity
- Many mfg. Many sizes, polarity and single output
- can be integrated into power panel for clean look,
- computer interface, web based controls and monitoring

Wiring Sizes, Complexity, Grounding

- Proper wire size for distance to minimize loss, MC connectors for quick connect
- Fine stranded copper wire, uv tolerant
- combiner boxes, conduit, direct wiring, wire ties, protection from elements, no sharp angles.
- Ground the frames to earth for lightning protection. Ground the electronics DC to AC
- NEC code issues must be followed pertaining to wire
- Strings of panels matching your voltage wired in parallel
- protection, segmentation from shade, faults, survivability to outages.

Batteries, the heart of the system

- You live off the batteries, size them right, twice the size, days of autonomy
- System voltage dictates number
- They become conditioned - hard to add to system after 6 months
- sealed, lead acid, gel, agm
- longevity, venting, temperature sensitive, location, container.

Putting it all together

- Load analysis yields battery bank size, yields solar panel bank size, controller capacity, fusing, wire size etc...
- Higher voltage is better, less wire loss
- Standardized is better, cheaper, more selection
- Design considerations, compatibility of components, same vendor
- Aesthetics, Function, Color, Mfg, availability, sponsors, size of panels, how to mount to house, optimize sun
- changing on item affects them all, keep it simple and build from there
- calculate system overall efficiency

Solar Energy Economics

- Begins with site assessment to measure solar potential, intertie requirements, costs derived from this
- Cost per kWh of power purchased, what is escalation % yearly.
- Fixed costs versus variable costs, payback analysis

Financing options

- ⌘Solar Purchase
- ⌘Solar Finance- Home Equity Loan
- ⌘Commercial financing
- ⌘Vendor financing, Sharp, Suntech
- ⌘PPA- Power Purchase Agreements
- ⌘Solar Leasing
- ⌘Where there is a will there is a way

Government impact

- Power Purchase Agreement
- Financed by savings systems
- Third Party Owned with attractive tax credits
- Government is a great sponsor of these projects large and small
- Schools, Municipalities, Army Bases, Parks and government entities all sponsor solar systems

Solar Tax Credits

- Federal 30% tax credit for solar energy systems installation
- State tax credits and incentives in 28 states help offset the up front cost
- Utility incentives for distributed generation
- State wide funds for clean energy programs or Renewable Energy Targets
- Homebuilder, solar company incentives

DSIRE Website of Incentives

- www.dsire.org database of state energy incentives
- Incentives help build a thriving renewable energy business sector to serve the growing market. Critical mass is needed to achieve lasting momentum.
- State Renewable Energy standards help also
- Fees on customers utility bills to promote solar are an excellent way to stimulate growth

Solar Return on Investment ROI

•Return on Investment is traditional way to measure impact of systems on company financially

•Tax credits must be considered along with energy savings, depreciation and tax shield on depreciation and expected annual energy cost increase should all be considered in figuring out ROI

•Payback in 10 to 14 years is typical for commercial and slight longer for consumers

•Here is handy spreadsheet to aid in figuring ROI, depreciation rates have changed

Payback Analysis and Average Yearly Yield

Location: **Oklahoma** Utility: **Big U** **Customer: Sean McGreen**

System Information			**Cost Information**		
	4800 watt	**Grid tie**	Proposed System Cost per Watt	**$7.00**	/watt **PTC**
Tracker mount					
System's PTC Rating	**4.80**	kWPTC	Estimated Tax Bracket	**34%**	
Location's Avg Sun Hours	**5.1**		Current Utility Rate ($/kWh)	**$0.12**	/kWh
Est. Annual Production (kWh/yr)	**7,595**	kWh/yr	**Est. First Year Utility Savings**	**$911**	/year

Total Installed System Cost		***$33,600***
SELF-GEN $2.50 per Watt Incentive	-	***$0***
Net System Cost		***$33,600***
Federal 30% Tax Credit	30% of Net System Cost	***$10,080***
Modified Accelerated Depreciation	Over 5 years. See Schedule below.	***$11,424***
Energy Savings over 5 years	Based on 6% annual utility increase	***$6,357***
System Cost After All Incentives and 6 Years Energy Savings		***$5,739***

Yr	Utility Rate	Utility Savings	Incentive Returns	Net Cost $33,600	Yearly Yield
1	0.120	$911	$12,365	20,324	32.71%
2	0.125	$966	$3,656	15,702	2.71%
3	0.131	$1,024	$2,193	12,485	2.88%
4	0.137	$1,085	$1,316	10,083	3.05%
5	0.143	$1,151	$1,316	7,616	3.23%
6	0.150	$1,220	$658	5,739	3.42%
7	0.156	$1,293		4,446	3.63%
8	0.163	$1,370		3,076	3.85%
9	0.171	$1,453		1,623	4.08%
10	0.178	$1,540		83	4.32%
11	0.186	$1,632		1,549	4.58%
12	0.195	$1,722		3,271	4.86%

MACRS Depreciation Schedule

Based on 95% of Net System Cost $31,920

Yr	Bonus Depreciation	Accelerated Depreciation
1	$0	$2,285
2		$3,656
3		$2,193
4		$1,316
5		$1,316
6		$658
	$0	$11,424
	TOTALS	**$11,424**

3.8 kW Solar Array

Texas

Annual Electricity Produced: *4,840 kWh*
Annual Savings: *$680*
Car Miles Avoided Each Year: *7591 miles*

A retired railroad engineer's technological curiosity and willingness to improve the environment drove him to invest in this solar photovoltaic array. We enabled him to achieve his environmental goals while keeping cost low.

23,800 kW Solar Array

Houston, Texas Fall 2008

Annual Electricity Produced: *34,272 kWh*
Annual Savings: *$18,560*
Equivalent to Removing: *1104 cars per day*

Texas largest solar home is going up this fall in Houston and will be a net exporter of solar energy to the grid. This SRE project features not only solar roof but battery back-up as well for times when power is down as well as geothermal AC and rainwater recycling for domestic use

System Size	22.44 kW
Panels	132 BP SX170W
Inverter	3 SMA 7000US
Roof Type and Mounting	Non-penetrating ballasted design
Annual Production	28,500 kWh
Annual CO_2 Emissions Prevented	60,000 lbs
Approximate Value of Rebates and Tax Credits	$120,000
Completed Date	April 2007

This ballasted system was designed to integrate into the architecture of this company's location in the hills of Austin, Texas. The system was designed in 3 different arrays to ensure full production was achieved at varying directional headings and was designed to maximize the Austin Energy solar rebate.

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Conclusion

- Solar energy is here to stay
- System efficiencies are increasing, cost is decreasing
- Payback is from 5 to 14 years
- Many financing options are available
- Tap into the sun today for your energy needs
- Money you will spend anyway, many environmental benefits as well

References and Links

- www.energysavers.gov
- http://www.fsec.ucf.edu/en/
- www.crest.org
- www.dsireusa.org
- www.nrel.gov
- www.sre3.com

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