EverbrightSolar™

SolPower PEOPLE

Webinar Series

Custom Solar PV Modules and Operation

Discover how Innovative Versatile Design Powers Possibility

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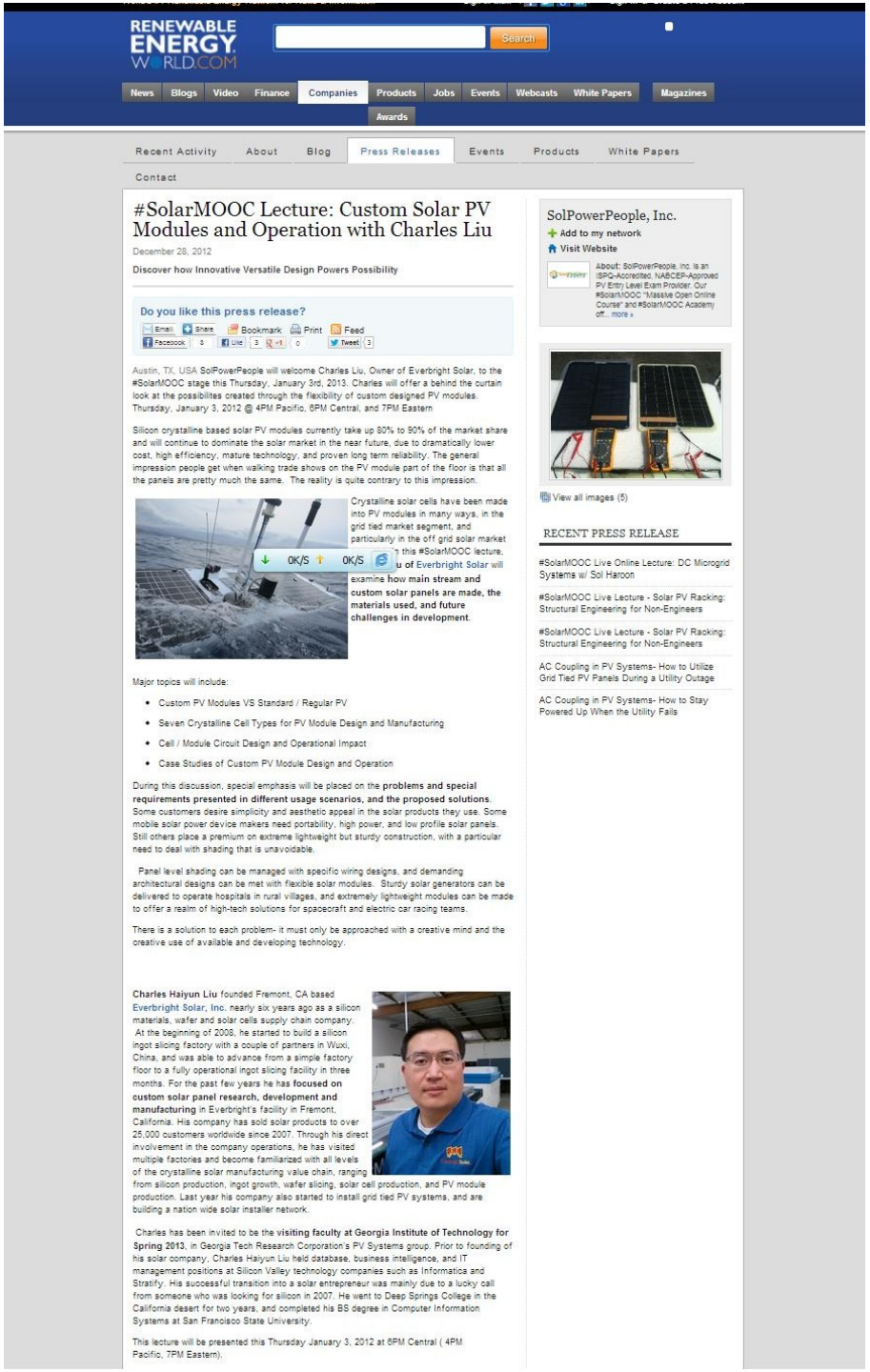

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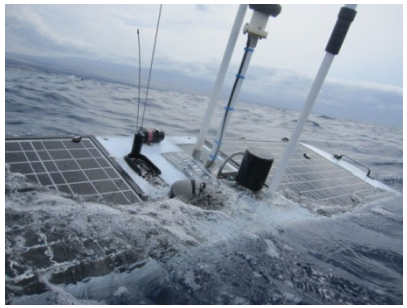
Custom Solar PV Modules and Operation

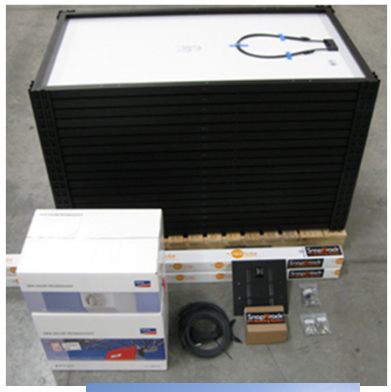
Topics

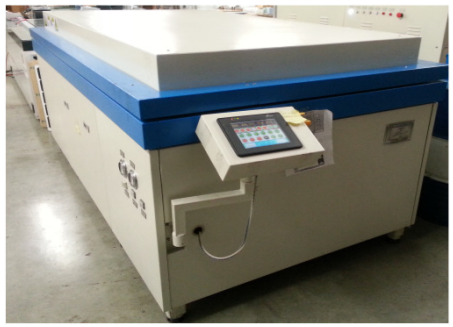
1) Self Introduction and Company Introduction
2) Custom PV Modules VS Standard / Regular PV
3) Silicon Crystalline Solar Cell Basics
4) Seven Crystalline Cell Types for Module Design
5) Cell Circuit Design and Operational Impact
7) Case Studies of Custom PV Module Design and Operation
8) Questions and Answers

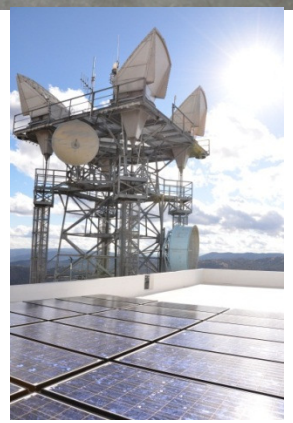
Custom Solar Panels, Installation Kits Manufacturer

- Founded in 2007 by Charles Liu
- 25,000 accumulated customers
- Custom solar panels R&D & production
- Solar cells kits for DIY solar panels
- Turnkey solar system installation kits
- Solar electric systems design & install
- Solar R&D outsourcing and prototyping
- Product development partnership with other companies / organizations. Areas include super light weight, durable panels, space solar panels, CPV receivers, energy storage batteries etc.







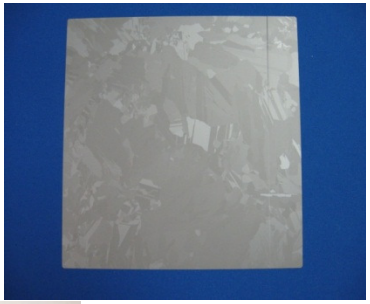


Crystalline Solar Value Chain / Major Terms

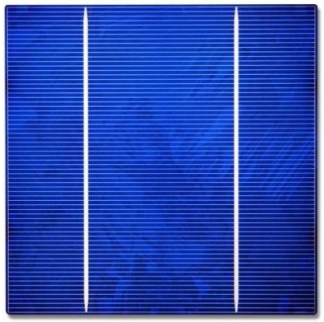
From Silicon Upstream to Project Development Downstream

1 Silicon

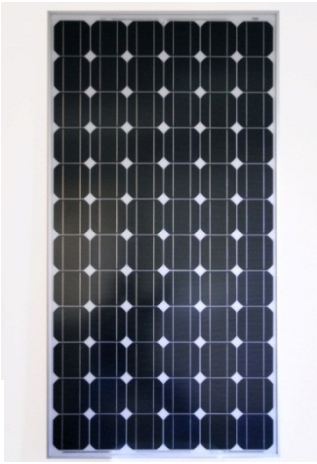
2 Wafer



3 Solar Cell



4 Solar Panel / PV Module



5 PV Array / System

Standard Modules VS Custom

Grid Tied Solar Panels Are Standard; Hard to Find (Often Off Grid) Are Custom

Standard Modules

- Generally 180w – 300 w for grid
- 60 cells in series– 6 inch
- 72 cells in series– 6 inch
- 72 cells in series– 5 inch
- Higher power modules target larger solar farm market
- Glass and aluminum frame construction very typical
- Products generally 'indistinguishable' from one another, in trade shows
- Most pursue the grid tied market due to size of business
- Commoditization – low price!

Custom Modules

- Generally off grid, <180w
- 36 cells very common
- Much higher # of cells involves parallel connection and smaller cell sizes.
- Variety of encapsulation form factors, in addition to glass and aluminum frames
- Most PV companies do not make panels < 5 watts – electronics business
- Most not UL listed
- Initially off grid panels were the 'standard' – little grid tied market existed. Great leap forward after German FIT

Standard Modules VS Custom

Begin with an End in Mind – Know The Competition

Standard Modules Competition

- Grid Utilities Price – PG&E

Tier 1 - $0.128 / Kwh – Hard
Tier 2 - $0.146 / Kwh – Hard
Tier 3 - $0.295 / Kwh – Easier
Tier 4 - $0.335 / Kwh – Easy

- Cost reduction the main driver of grid tie standard modules design & operation
- High safety and reliability and longevity requirements
- Tough business!

Custom Modules Competition

- Cost of losing expensive robots
- Cost of not having lights in rural clinics during child birth
- Cost of utilities company bring power to remote sites
- More design options and flexibility, less price sensitive

Standard Modules VS Custom

Common Design Requirements for PV Modules

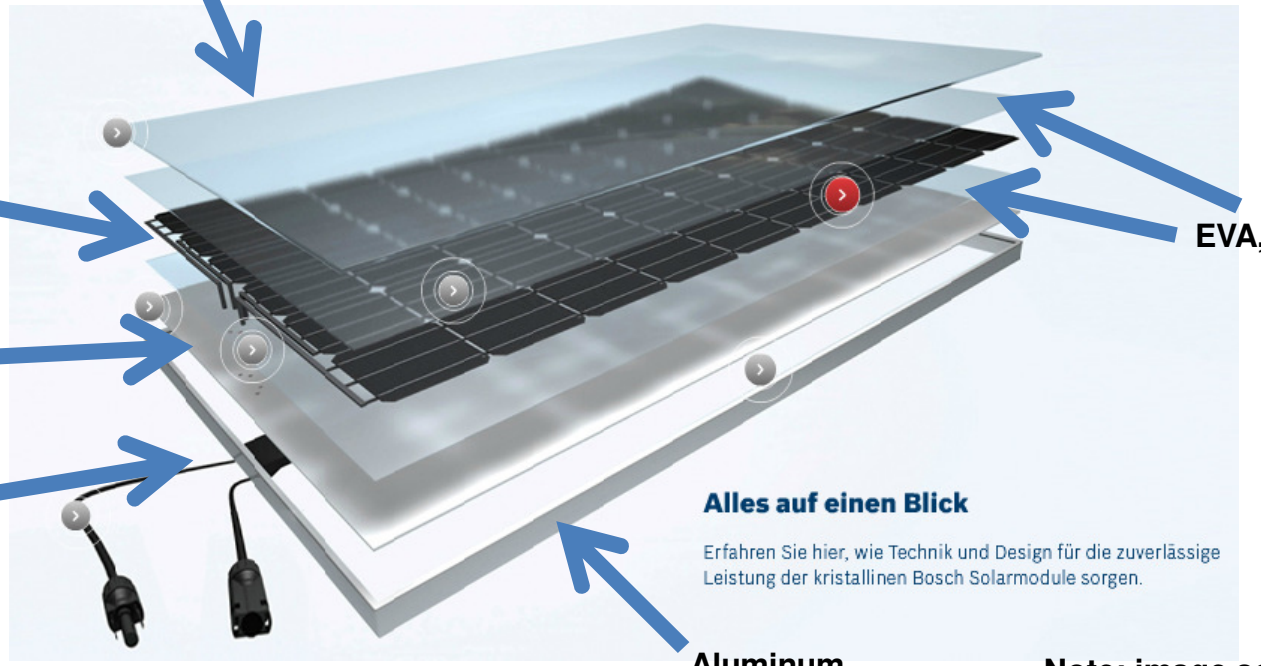
Standard Modules **Custom Modules**

- Ability to generate right power (voltage and amperage) from cell circuits
- Good mechanical support
- Water moisture barrier
- Anti oxidation and other chemical corrosion protection
- Good electrical insulation for solar cells
- UV aging resistance
- Longevity

Standard Modules VS Custom

Typical Glass PV Module Encapsulation / Construction

Low iron, ultra white, tempered glass, 3.2 mm



Solar cell string

EVA, 0.45 mm

TPT, TPE Backsheet

Junction box attached to backsheet with PV804, with MC4 connectors

Aluminum frame

Note: image source is Bosch Solar

Standard Modules VS Custom

Custom PV Module Requirements Due to Special Usage

Examples of Primary Considerations

- Simplicity and aesthetic appeal – personal solar charger – SolarJoose
- Portability, ample power, low profile – mobile solar suitcase – We Care Solar
- Highest efficiency, extremely sturdy, light weight, buoyancy – Undisclosed
- Custom shapes and polymer encapsulation materials – Cal Poly Pomona
- Extreme light weight panel for space junk cleaning – Tether Applications
- Lowest temperature coefficient CPV receiver – Undisclosed
- Conformable solar panels for bus stops' curved glass roof – Undisclosed
- Shade resistant / optimized due to unavoidable shading – Undisclosed
- 6 and 12 Cell Panels for Modular Applications
- BIPV and Other Innovative Crystalline PV Modules – non Everbright products

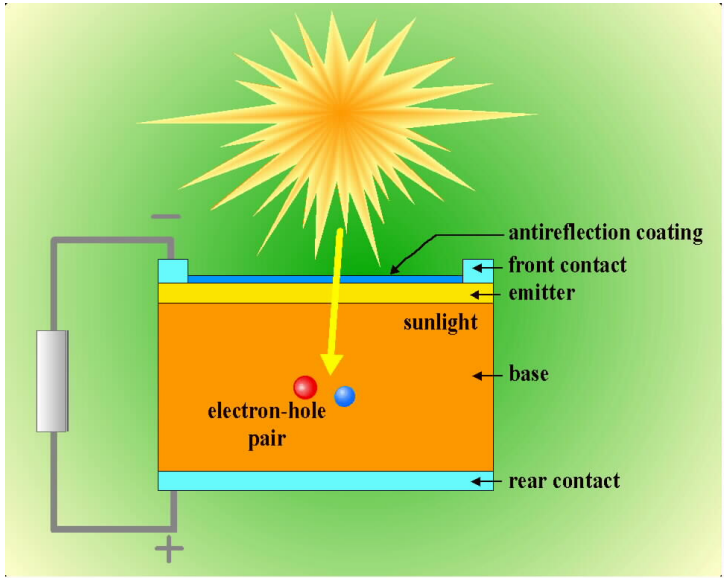
Solar Cell Basics

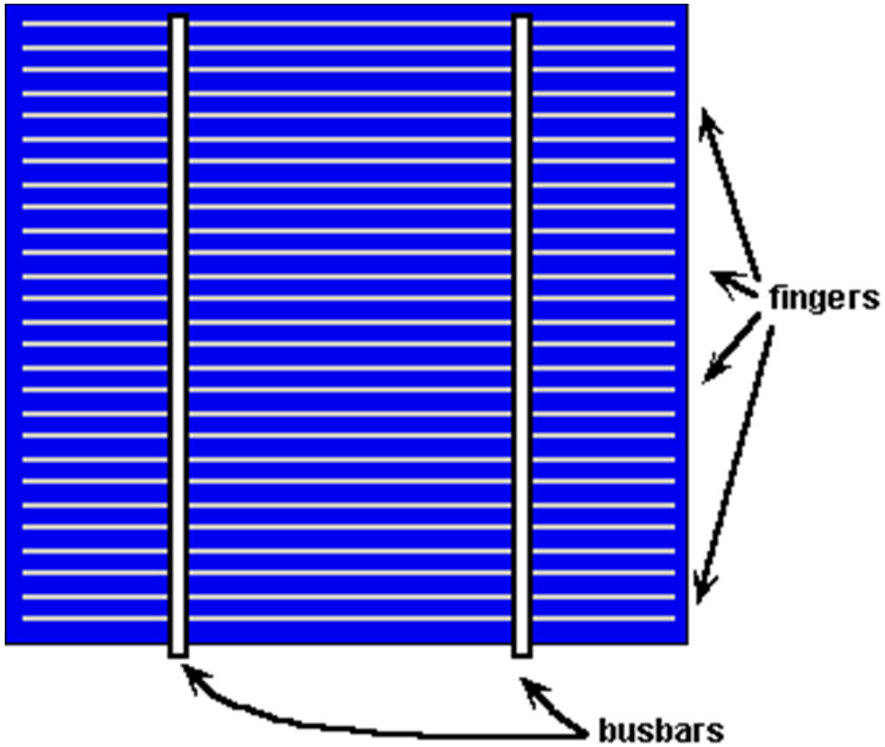
A solar cell is a diode that converts light energy into electricity

It is the opposite (approximately) of an LED light. An LED is a diode that converts electricity into light.

Front side (blue, sunny side) is negative -, back side is positive + , usually.

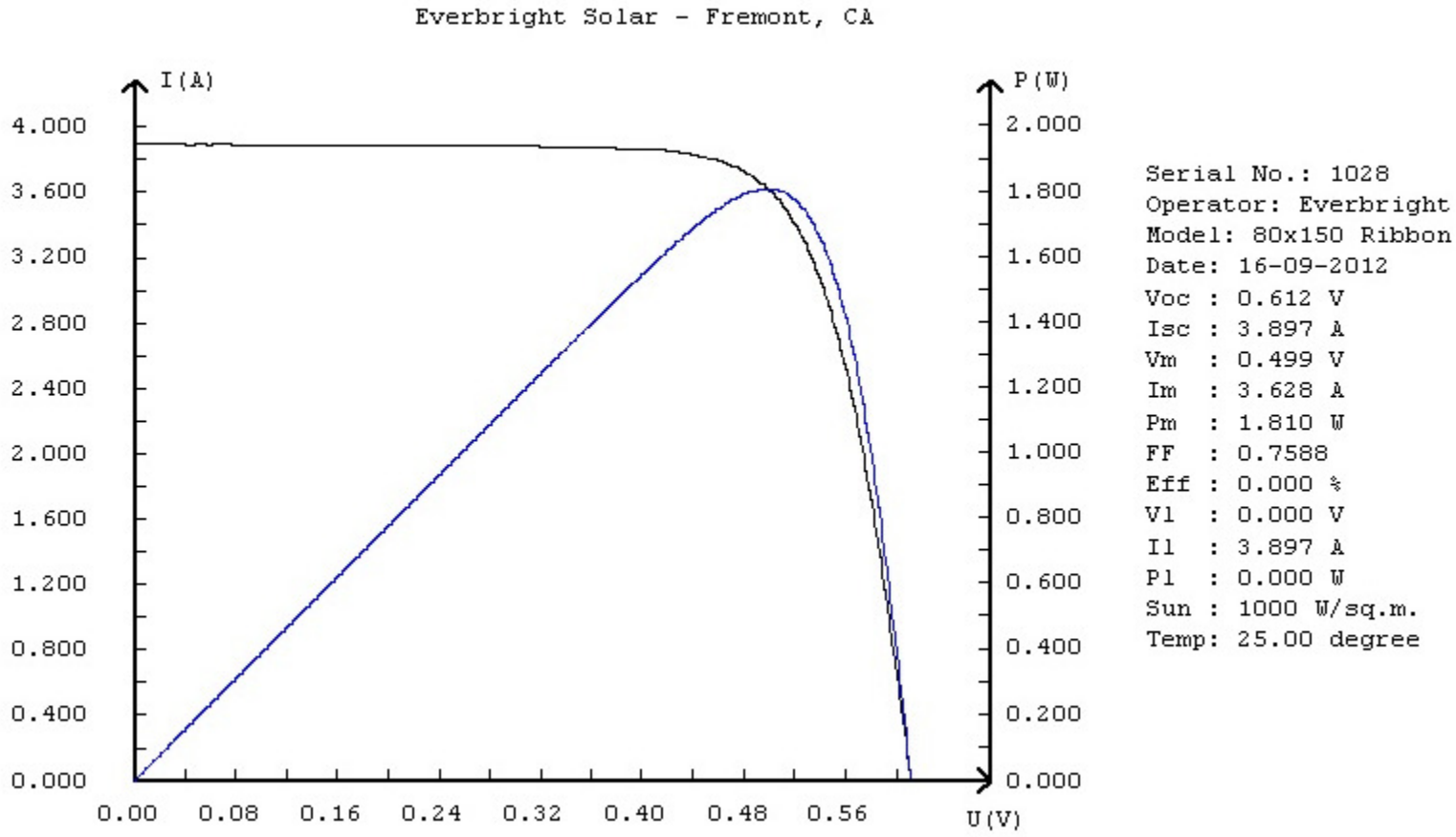
Both the front bus bars are the negative electrodes; back side bus bars positive electrodes





Solar Cell Basics

Understanding the cell IV curve is key to understand the panel Specs



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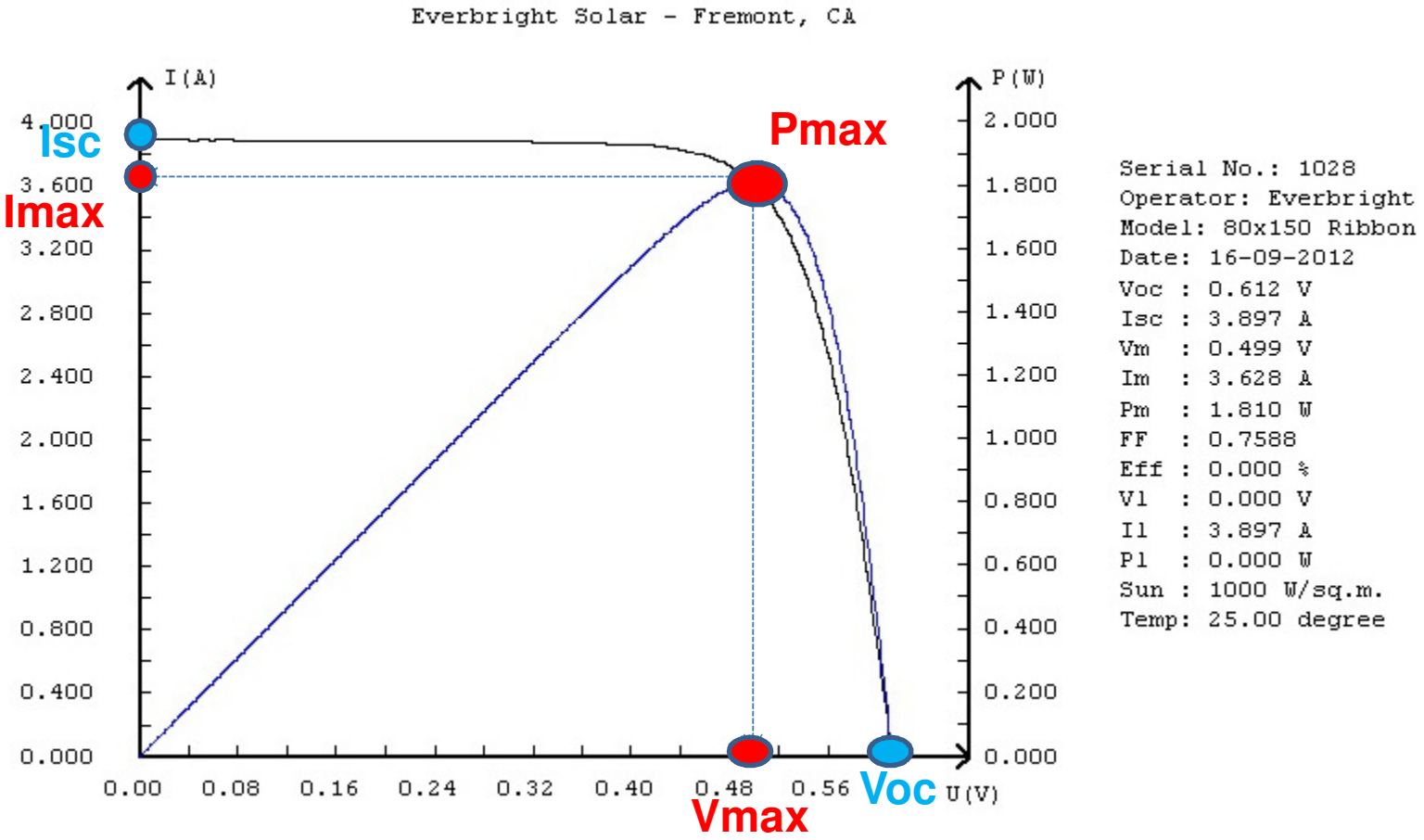
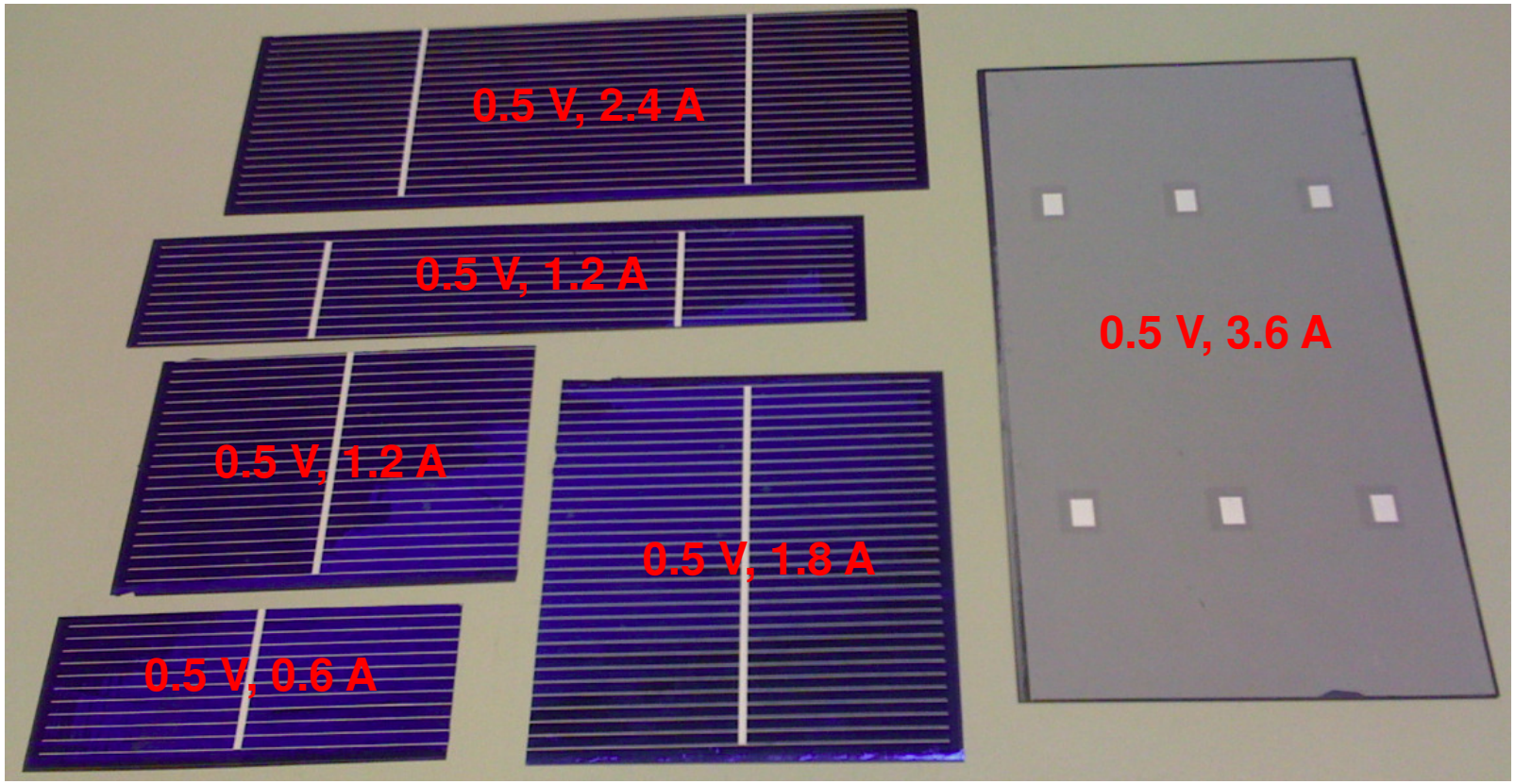


Solar Cell Basics

Each cell's voltage is generally 0.5v, no matter how big or small the cell; Amperage is proportional to cell size – the bigger the cell, the higher the amps.



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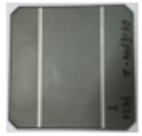
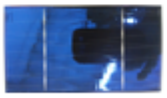
Seven Crystalline Solar Cells for PV Design By Everbright Solar

Type	Front	Back	Base Wafer	Size	Top %	~ Eff	Manufacturer	Availability	Pros	Cons	Comments
Multi / Poly 6 inch			P type multi, 0.5-3 ohm, 180 um +-20 thick	6 in, 156x156 mm	18.4% 4.4w	17-17.5% 4w-4.2w	Many, eg. JA, Qcells, Gintech, SolarWorld	Easy	Inexpensive, good power, full square	Not as efficient as mono	Currently cells of choice. Multiple colors available.
Mono 6 inch			P type mono, 0.5-3 ohm, 180 um +-20 thick	6 in, 156x156 mm Dia 200 mm	19.4% 4.63w	18-18.5% 4.3-4.5w	Many, eg. Suniva, SolarWorld, Bosch, JA, Neo, Motech	Easy	High efficiency / power, all black after encapsulation	Expensive to make	Under pressure from 6 inch multi cells. Qusai mono (cast mono) not catching on.
Back contact Mono			N type mono, 1-11 ohm, 150-180 um +-20 thick	5 inch, 125x125 mm Dia - 160	24% 3.7w	22%, 3.43w	SunPower	Hard, low power, off spec only	Very efficienct, no wires on front of cells/ panel, all black	Highest cost to make	High power cells only for own modules, off specs cells to 3rd party
Hetero-junction Mono (HIT)			N type mono, 1-3 ohm, 180 um +-20 thick	5 inch, 125x125 mm Dia - 165	21%, Road map - 24%	19.5-20% 3w	Silevo (Sanyo cells not for sale, not listed here)	New to market, Everbright beta user	Best temperature coeffient on the market	Limited production, high cost	High power cells only for own modules, bifacial as well
Mono 5 Inch			P type mono, 0.5-3 ohm, 180 um +-20 thick	5 inch, 125x125 mm Dia - 165	19.4% 3w	17% 2.8w	Chinese makers only, mostly stopped	Getting harder, existing inventory	High efficiency, compact panel size for off grid panels	Expensive to make, limited wafer	Being phased out more quickly than thought
String ribbon			P type ribbon wafer 0.5-3 ohm,	80x150 mm	15.8% 1.9w	14.5% 1.75w	Sovello, Evergreen (Both gone)	Off spec left over inventory	Off spec cells cheap to get	No longer in production	Large stock of off spec ribbon cells being depleted
Bifacial Mono 6 inch			N type mono, 1-3 ohm, 180 um +-20 thick	6 in, 156x156 mm	19.4% 4.63w	18.8% 4.5w	PVGS	Moderate	High efficiency, convertion on BOTH sides	Expensive to make	Good to use in BIPV, would like more suppliers

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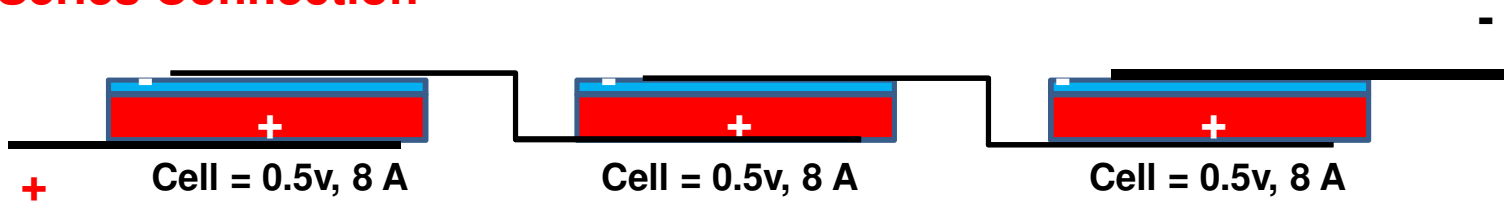
Solar Cell Circuit Design

Series and Parallel Connections of Solar Cells

Most solar panels' cells are connected only in series, consist of only one string.

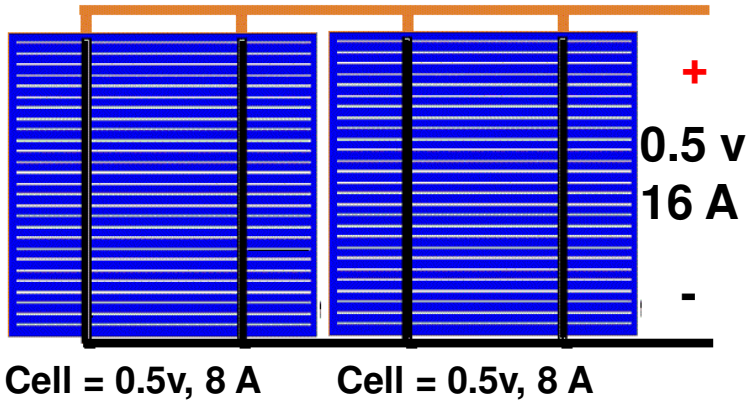
Series Connection



- Solar cells are connected in a single path, positive electrode is connected to the negative electrode of the next cell, daisy chaining, forming a **string**. (Christmas lights)
- Voltage increases by ~0.5v for each cell added to the string, while amperage stays the same.

Parallel Connection

- Solar cells are connected in a way that positive electrode is connected to the positive electrode of the next cell, the same for negative electrodes.
- Total Amperage increases by the amperage of the cell for each added to the circuit, while voltage stays the same.



Solar Cell Circuit Design

Series Solar Cells Interconnect – Auto VS Manual

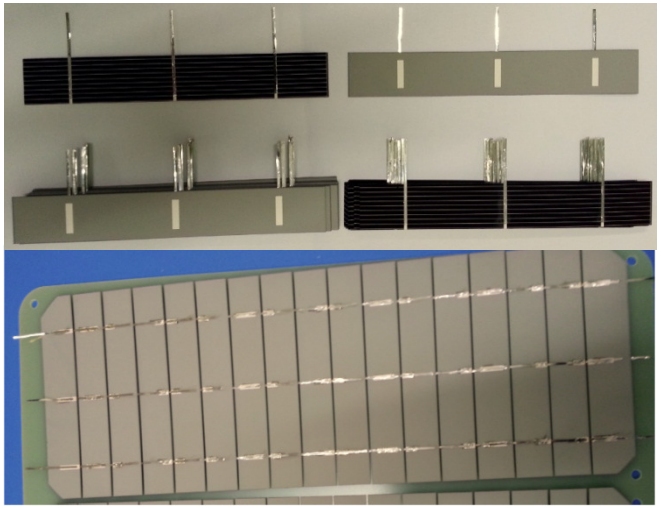
Most solar panels made in China were soldered by hand, Western – tabber / stringer.

Series Connection – by tabber / stringer

- Solar cells are tabbed and put on a string evenly and consistently by machine
- High output, two to three times of human
- Strict requirements on solar cells size consistency, bus bar positioning etc, breakage and yield loss can be high.
- Takes a lot of fine tuning.

Manual Series Connection – by hand

- Manually cut ribbon into about two times the length of bus bar
- Solder ribbon onto front side bus bars for all
- Flip tabbed cells over, place tabbed cells on a jig for consistent spacing for solar cells string, and then solder the tabbing wires to back contact of the adjacent cell
- Slower than machine, could be less consistent, but yields could be higher.

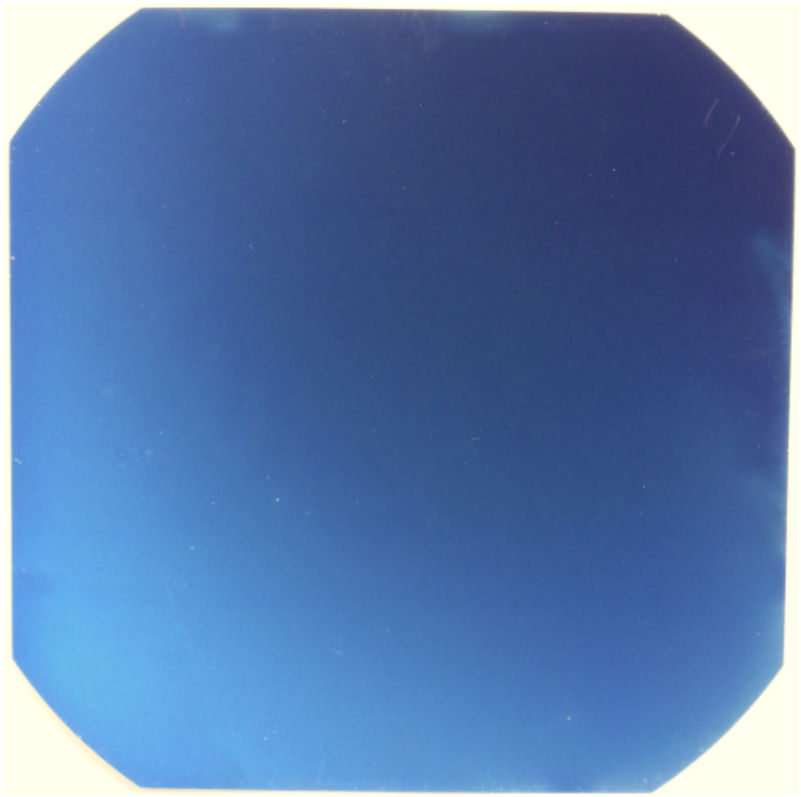


Solar Cell Circuit Design

Non-Conventional Solar Cells Connection Schemes

Back contact solar cells

Both + and – on back (interdigitated), makes series easy, panel clean looking



Front side

Solar Cell Circuit Design

Non-Conventional Solar Cells Connection Schemes

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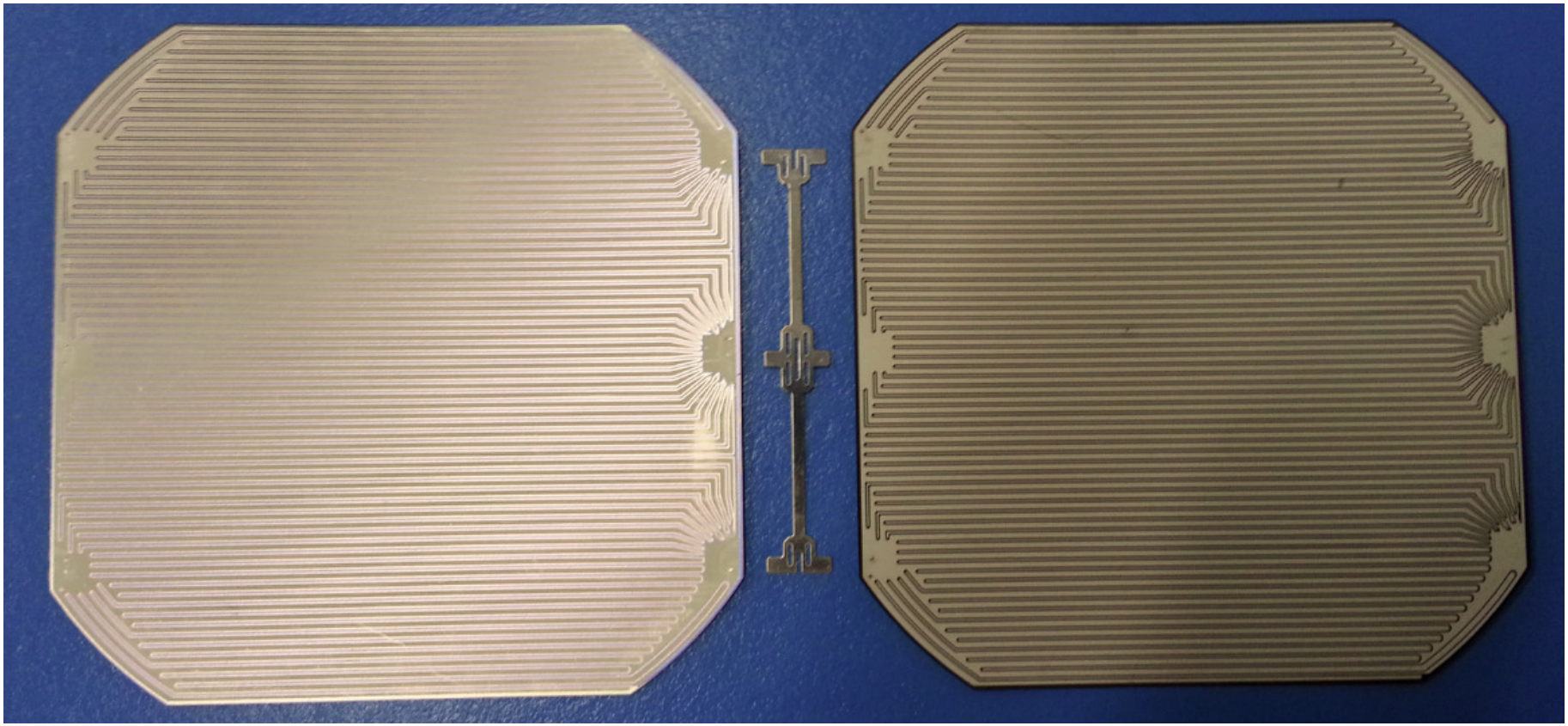

Solar Cell Circuit Design

Non-Conventional Solar Cells Connection Schemes

Back contact solar cells

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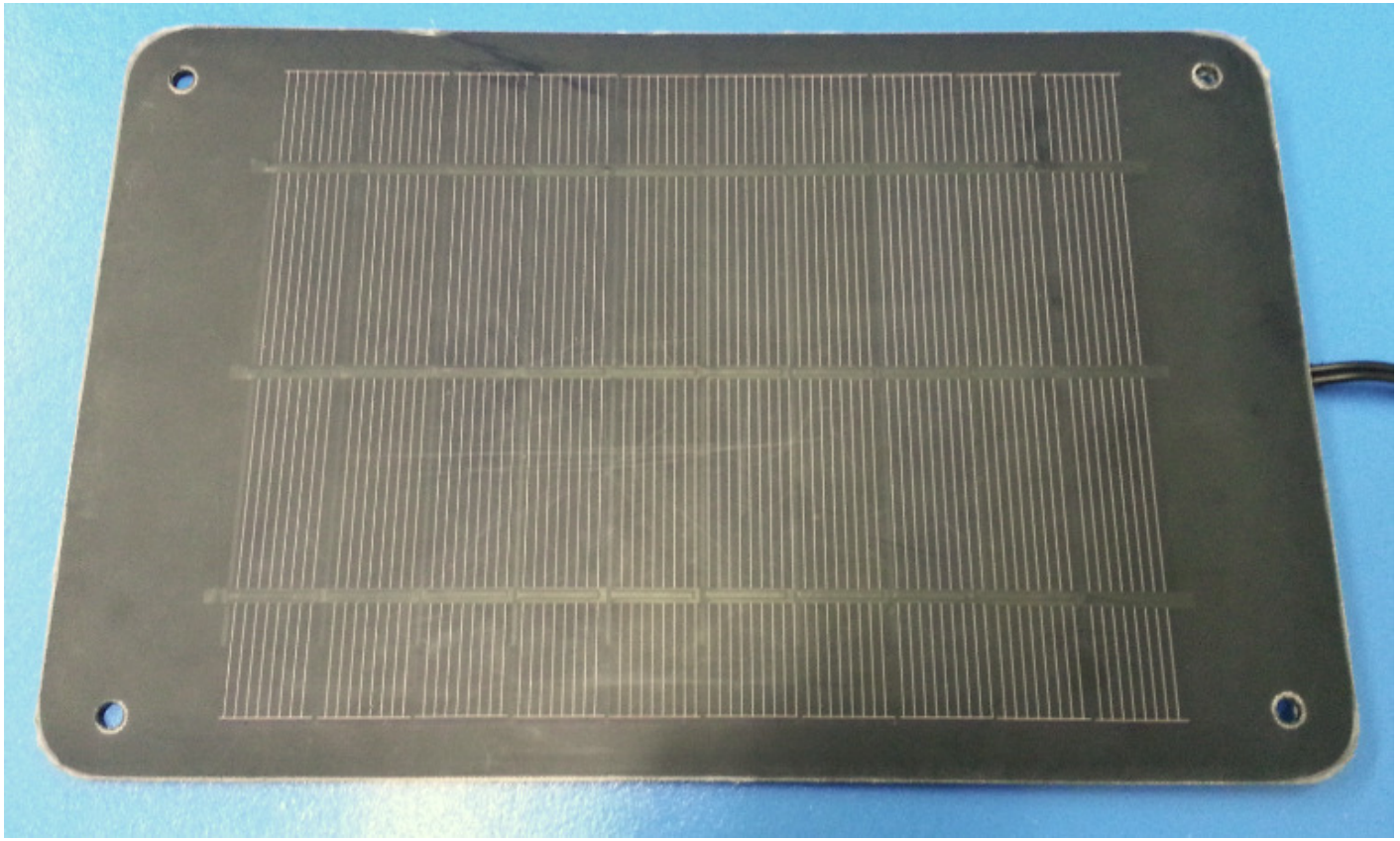
Solar Cell Circuit Design

Back Contact Solar Cell's Clean Panel Looks Can Be Simulated

Using black substrate and regular mono solar cells, panels turn dark after encapsulation. Picture below shows an Everbright Solar's battery-less iPhone solar charger prototype.



Solar Cell Circuit Design

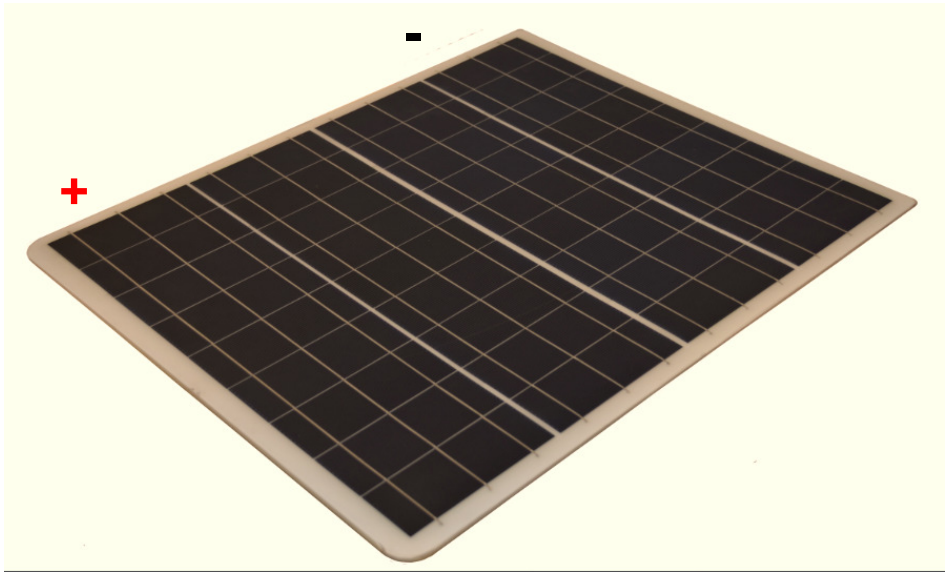
How Many Cells Per Panel? Why? All in Series, Usually

Grid Tied Standard Modules

- 60, 72 cells Most Common
- Even number of columns of cells

Custom Modules (Off Grid)

- Usually 32-36 cells, voltage
- Can be lower number for very small solar panels, ie for solar garden lights.



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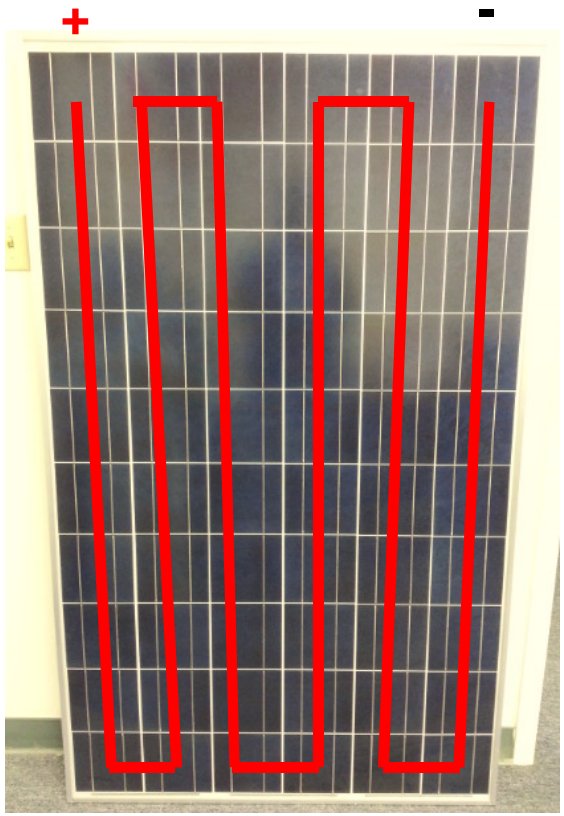

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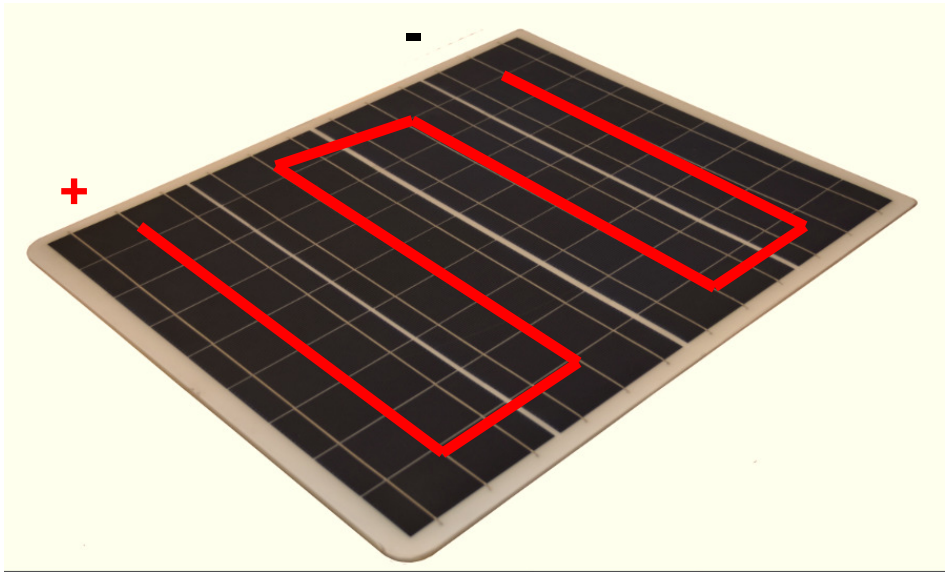


Solar Cell Circuit Design

Review of a standard grid tie solar panel – 60 cells in series

6 inch Mono Cell

Power: 4.16 W **X60 =**
Isc: 8.28 A **=**
Voc: 0.63 V **X60 =**
Imax: 8.05 A **=**
Vmax: 0.51 V **X60 =**

Module

Power: 250W
Isc: 8.28 A
Voc: 37.8 V
Imax: 8.05 A
Vmax:31.1 V
Cell count: 60

Points of using 60 Cells:

- Voltage increases for string inverters, which typically need 200v to start
- Compatible with micro-inverters
- 6x10 cell arrangement makes sure that there are even number of column of cells, so that the positive and negative electrodes of the string will end up on the same side for easy junction box attachment
- 1 bypass diode for every 20 cells or less.
- Final panel side not too bulky, manageable by 1 person on rooftop.
- 72-cell and larger panels good for utility scale solar farms
- For high wattage off grid installation, limited to 3 solar panels per series string, to avoid VOC going over 150 V upper limit by most charge controllers, in very cold conditions.

Solar Cell Circuit Design

Review of Uncommon Grid Tie Solar Panel – 50 cells BP SX195B

Pros of 50 Cells:

- Voltage increases for string inverters, can put more panels on single string without risk of going over 600 V
- Panel easy to handle due to smaller size.

Cons of 50 Cells:

- Not compatible with many micro-inverters
- 5x10 cell layout makes positive and negative leads on opposite ends of solar panel, very difficult to series connect on rooftop after being fastened to rail. Remedy: Rotate panel 180 degrees every other panel.
- Two single lead junction boxes to attach. More work during production.
- Remedy: extend bus wires of solar cells and bring the lead to the same side of panel, **but the extra length of bus wire increases resistance therefore power loss. Also increases risks of lamination defects and costs.**

Solar Cell Circuit Design

Odd Number of Columns Not as Big an Issue with Off Grid Panels

Any No. of Columns

- Off grid panels come in a variety of form factors due to special demands
- Power loss due to longer bus wires to junction box not as significant due to much smaller size.
- In fact it may be desirable to have odd number columns of cells.
- Balance of power specs and looks

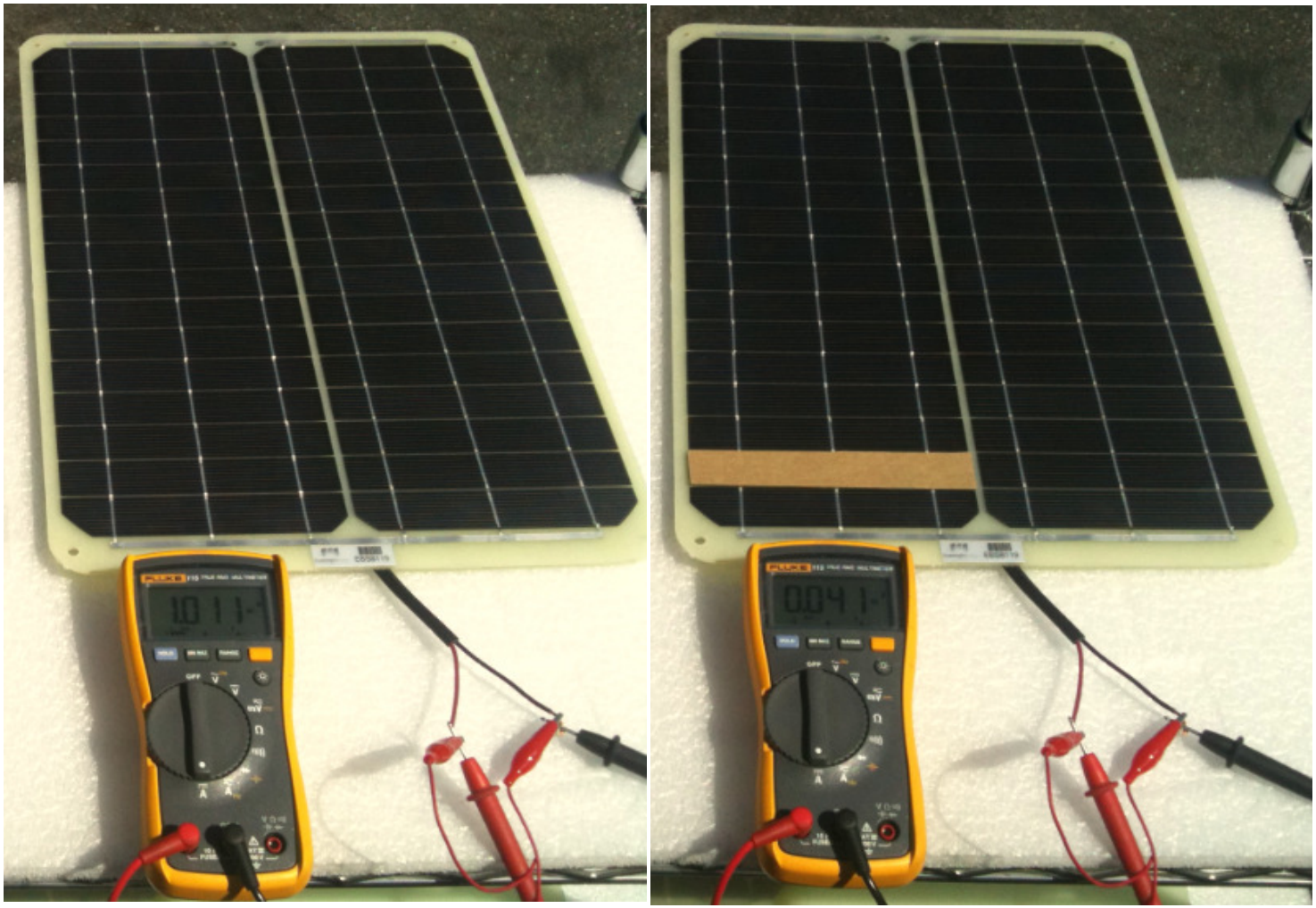
Cell Layout Schemes

- 1x36, 35, 34, 33, 32, 12,11, 9,8,6….
- 2x18
- 2x17
- 2x16
- 3x12
- 3x11
- 4x9
- 4x8
- 5x8
- 5x7
- 6x6

Cell Circuit Design and Operation

Series Connection and the Impact of Shading

A cell loses most of its current when even one cell is shaded. In a series cell string (panel), any single cell can restrict the current flow of the entire string (panel) - the effect of 'pinching the water hose'.

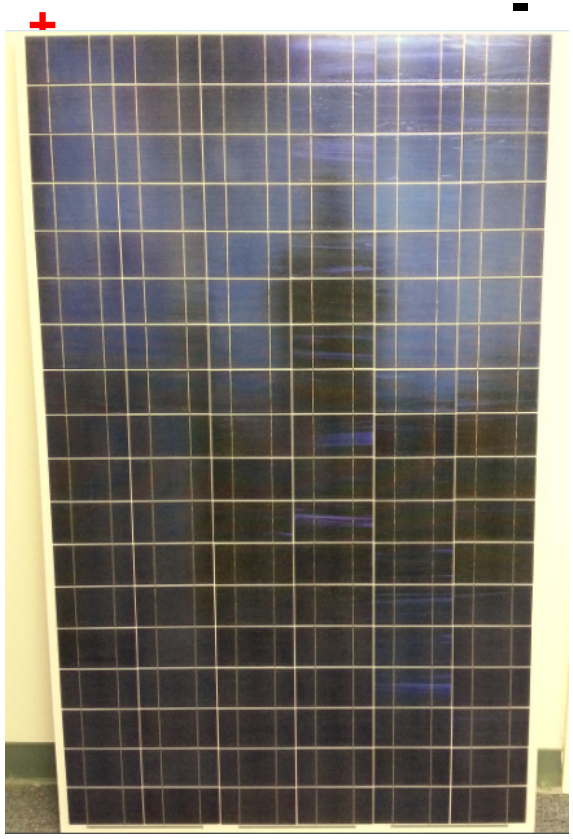


Solar Cell Circuit Design

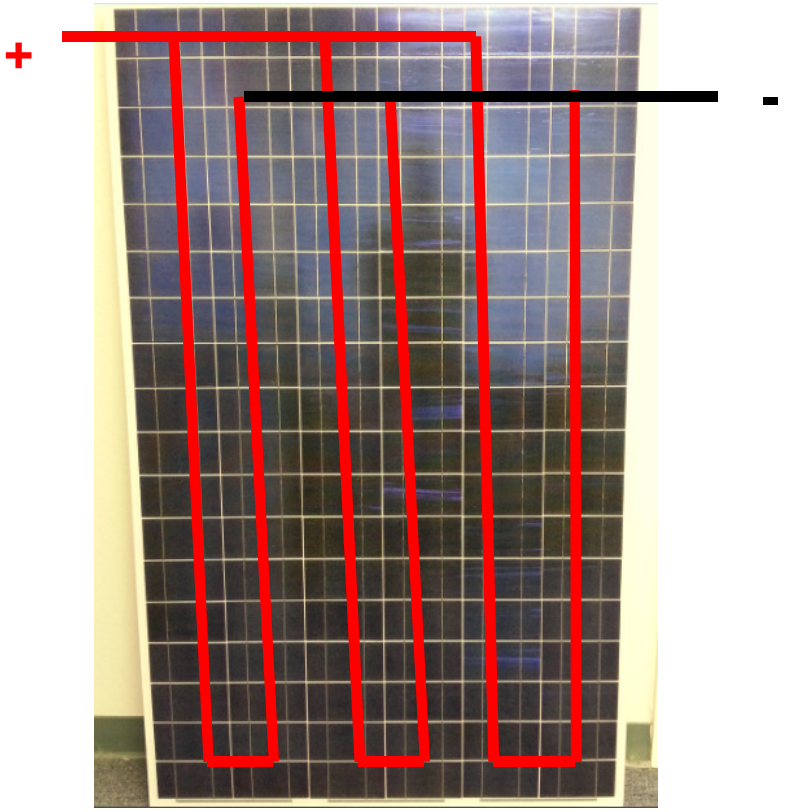
Series and Parallel Combo Design Solar Panels

Low V / High Amp Design, 18V, 11.8 A

- 108 3x6 Evergreen Solar cells (Small cells)
- 3 strings (panels) connected in parallel



- Can put more panels on one string without going over 600V
- Can be used in off grid system without expensive MTTP charge controller



Solar Cell Circuit Design

Series and Parallel Combo Design Solar Panels

Unique Design from TenK Solar

- Use smaller cells as well
- Solar cells connected in parallel

- Integrated electronics at junction box with solar panel
- Reflector sends additional absorbable wave lengths to solar panel and let heat generating rays pass through. Nice!
- Cons: Voltage boost relies on built-in electronics which have shorter life span than vanilla solar panels
- Some shading loss during winter months due to Sun at lower positions.

tenK panels are wired in parallel.
Current will always flow in any uneven light.

Sources: TenK Solar web site

Custom PV Module Requirements Due to Special Usage

Examples of Primary Considerations – Everbright Solar Implementations:

- Simplicity and aesthetic appeal – personal solar charger – SolarJoose
- Portability, ample power, low profile – mobile solar suitcase – We Care Solar
- Highest power, extremely sturdy, light weight, buoyancy – Undisclosed
- Custom shapes due to solar / wind device and solar boat – Cal Poly Pomona
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- Conformable solar panels for bus stops' curved glass roof – Undisclosed
- Shade resistant / optimized due to robotic ships masts – Undisclosed
- Solar window with green color solar cells – Undisclosed
- 6 and 12 cell high power panels for modular voltage adjustment
- BIPV and Other Innovative Crystalline PV Modules – non Everbright products
- Frameless solar panels and AC panels with micro inverters

Custom PV Module Design and Operation

Simplicity and Aesthetic Appeal – Single Cell Solar Charger

Pros:

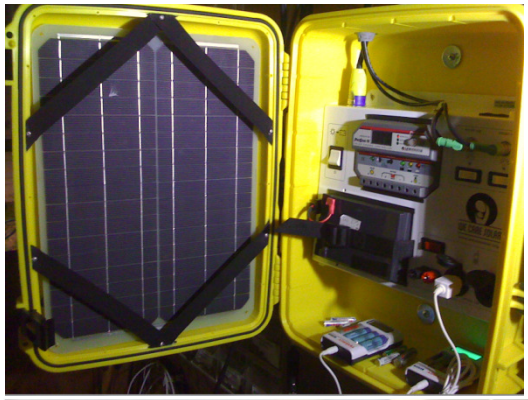
- SolarJoos iPhone charger has only one single cell. It looks clean and elegant with great aesthetic appeal.
- Simple and elegant design also minimize shading impact that would have had a much larger effect on other similar size personal charger with smaller cells wired in series.

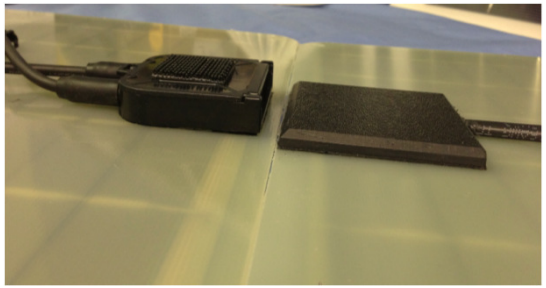
Cons:

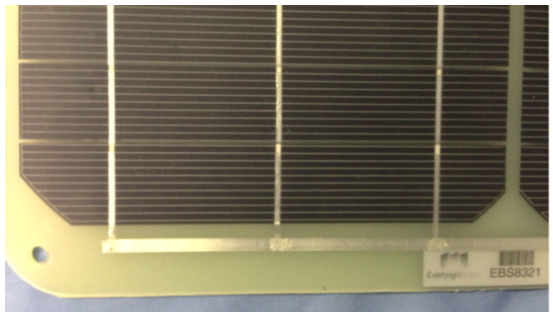
- Voltage boost circuit is required to charge built-in battery. Electronic components fail more easily than solar cells. If boost circuitry fails than the device is useless.
- Single cell design dependent on availability of one cell size, 125x125mm cell with diameter of 150 mm, which is no longer being made.

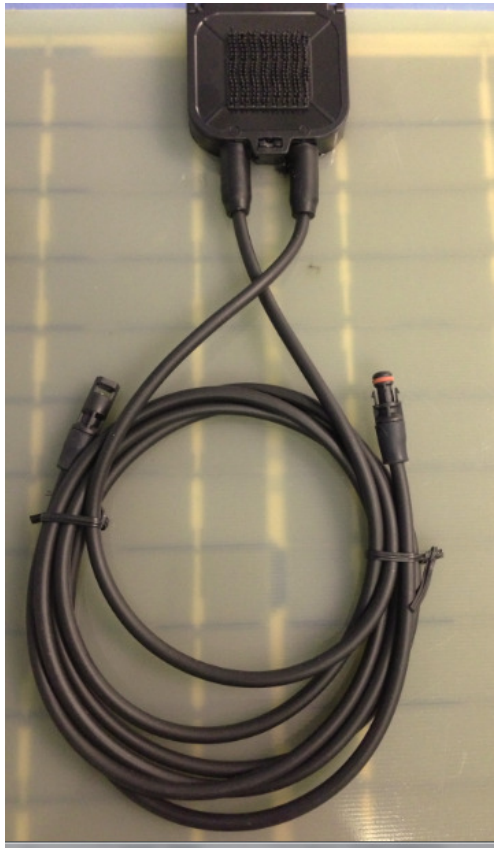
Custom PV Module Design and Operation

Portability, High Power, Low Side Profile – Mobile Solar Suitcase – We Care Solar









Pros:

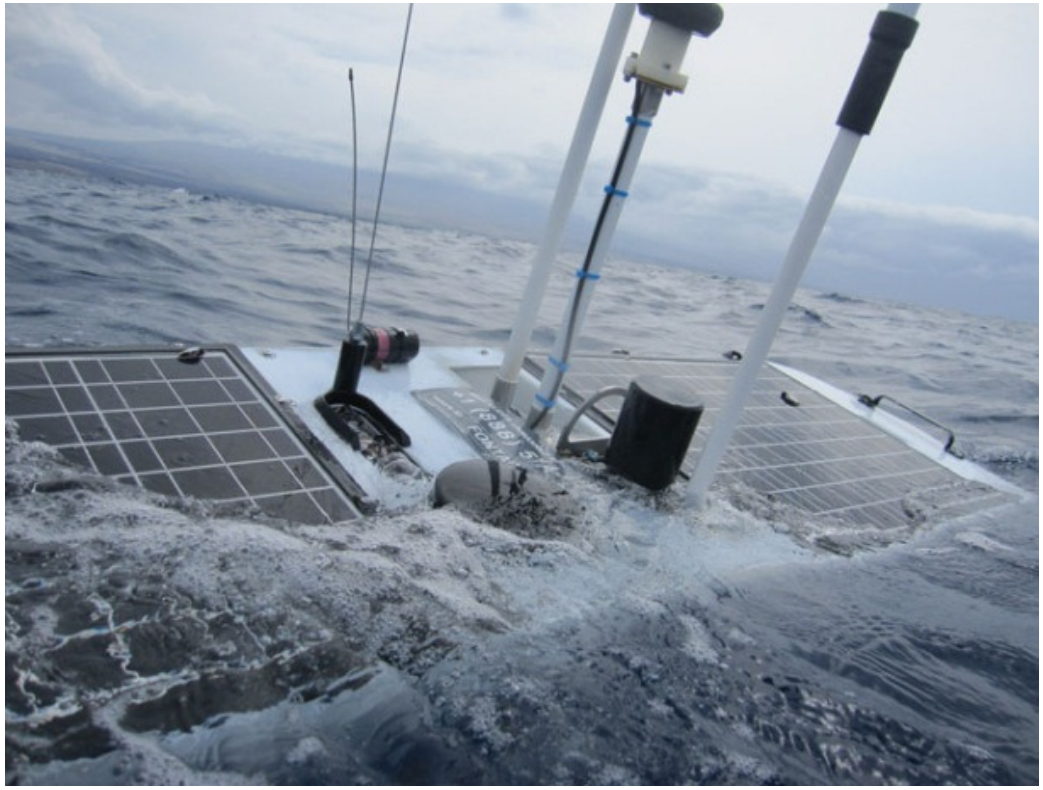
- Custom size panel to fit in the inside lid of Palican suitcase – highly portable
- Ultra thin junction box along with thin fiberglass back board allows multiple panels to be fit in
- Consistent current output from each cell – round corner cells are slightly wider than the full square corner cells
- Anti-reflective matt finish front sheet increases power by 3%
- Durable fluoropolymer front sheet is UV rated for 20 years and the panel is shatter resistant
- Compact and water resistant custom ‘mini MC4’ connectors are used
- Frameless design – total thickness include Jbox – 0.42 in.

Cons:

- Cost more than glass panels

Custom PV Module Design and Operation

Challenge: Highest Power Density, Sturdy, Light Weight, Buoyant – Undisclosed



Picture from customer company web site

Everbright Solution:

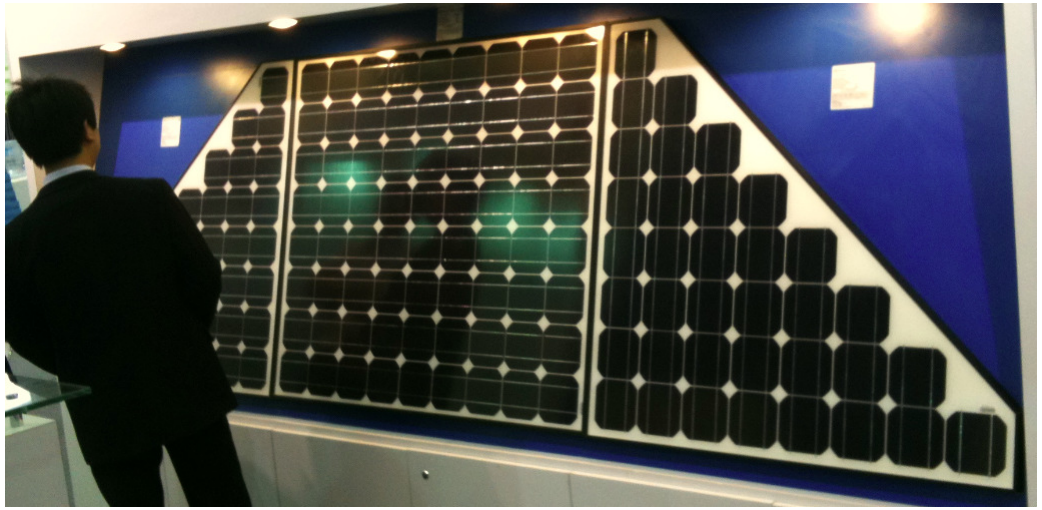
- Custom size solar panel that fits on the ocean faring robotics
- No metal parts that may be corroded by salty liquid
- Highest efficient mono solar cells cut size to maximize real estate utilization. Bus bars all folded to the backside of solar cells maximize cell size.
- Anti-reflective front sheet increases power by 3%
- Durable fluoropolymer front sheet is UV rated for 20 years and the panel is shatter resistant – no glass used
- Custom engineered backboard provides ultra strong rigid mechanical support and buoyancy
- Special wiring and electronics provide shade resistance

Cons:

- Higher cost than other panels

Custom PV Module Design and Operation

Custom Shapes For Solar / Wind Combo – Undisclosed



Pros:

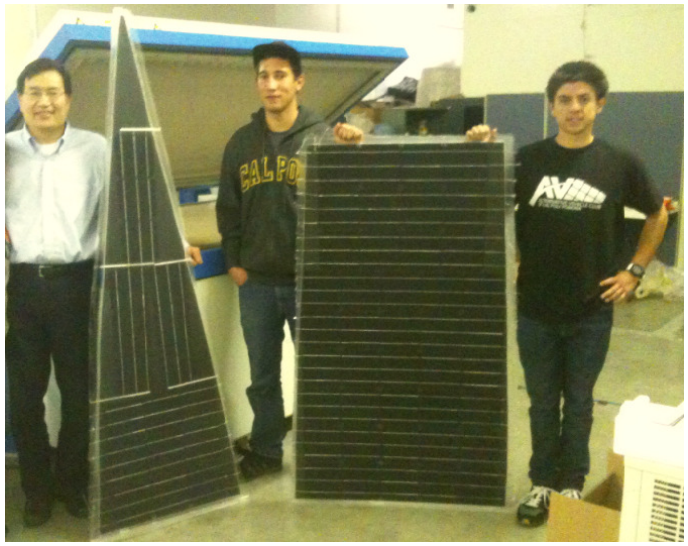
- Round / oval shape is the primary design consideration.
- Cells were cut to the right equal sizes to maximize real estate utilization.
- White spaces could be filled with mockup decoy cells that are not connected to the string
- Panel was split to two half circle shape for easier handling.
- Parallel connectors and wiring were provided
- Two triangular shape panels connected in series equal to the 72 cell panel in the middle. Maximize utilization of triangular shape roof top. (non Everbright product but can be easily made)

Cons:

- Higher cost than rectangular shape panels.

Custom PV Module Design and Operation

Custom Shape / Light Weight Design For Solar Boat Race – Cal Poly Pomona

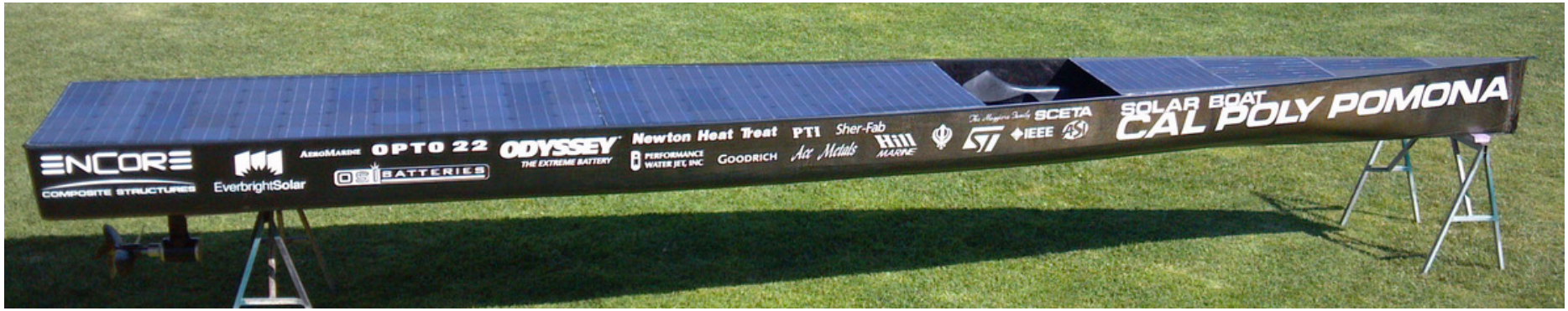


Challenge:

- Students need custom shape, light weight and high efficiency solar panels to fit on race boat, but have very limited budget and need help perfecting solar panel design & manufacturing.

Solution:

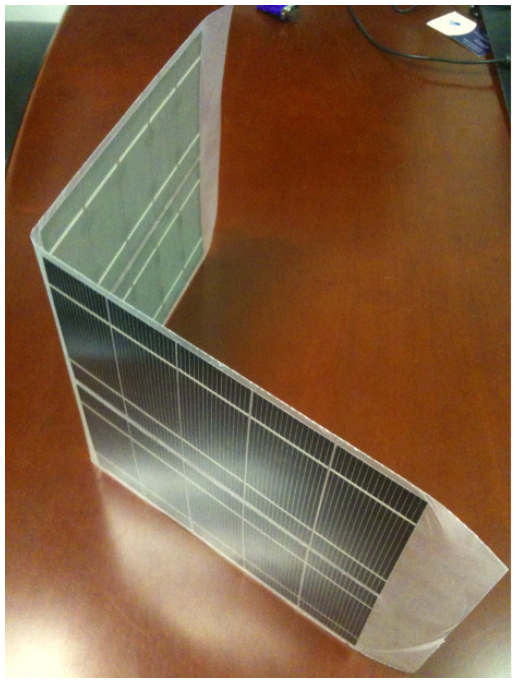
- Everbright donated cell materials, custom laser cutting and shaping of solar cells, bus wire sizing adjustments, super light weight and durable encapsulation materials, on site equipment usage and lamination training for the Cal Poly Pomona solar boat race team, free. Free lunch and dinner provided to the visiting students as well. ☺



Boat picture courtesy of Cal Poly Pomona Solar Boat Team

Custom PV Module Design and Operation

Extreme light weight panel for space junk cleaning – Tether Applications



Everbright Implementation:

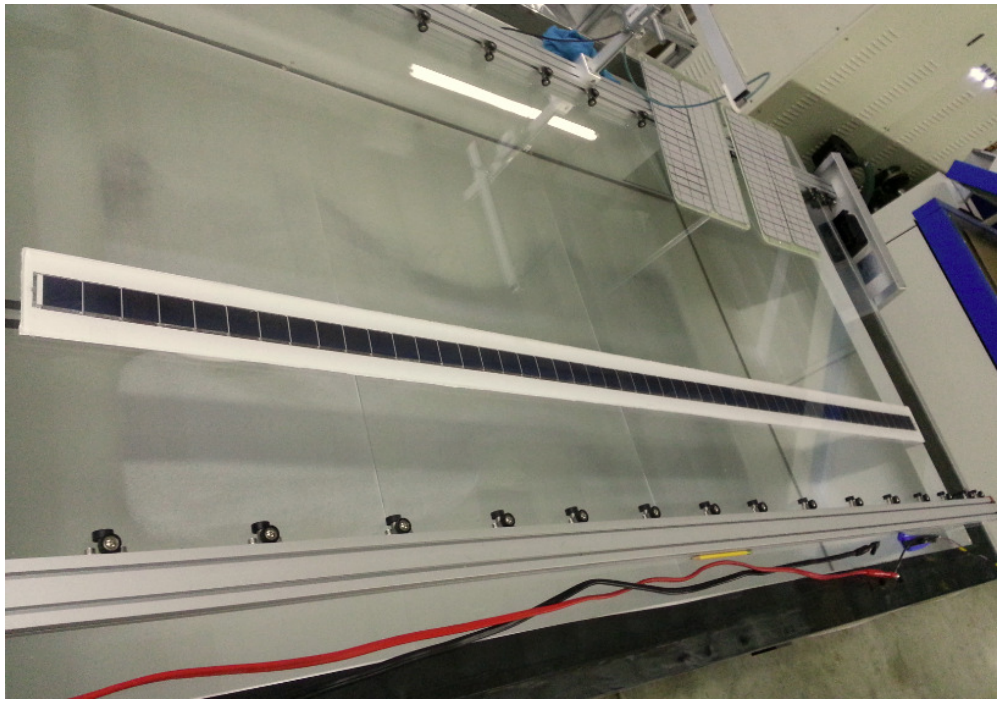
- The lightest crystalline solar panel in the world.
- Special encapsulation film provides adequate protection of cells.
- Cells changed from one bus bar to two bus bar custom cut cells for better reliability

Cons:

- Need more cracks compensation wiring

Custom PV Module Design and Operation

Challenge: Lowest temperature coefficient CPV receiver – Undisclosed



Problem:

- Low ratio CPV receiver relies on convection cooling, and it uses low cost single junction silicon based solar cells.

Solution:

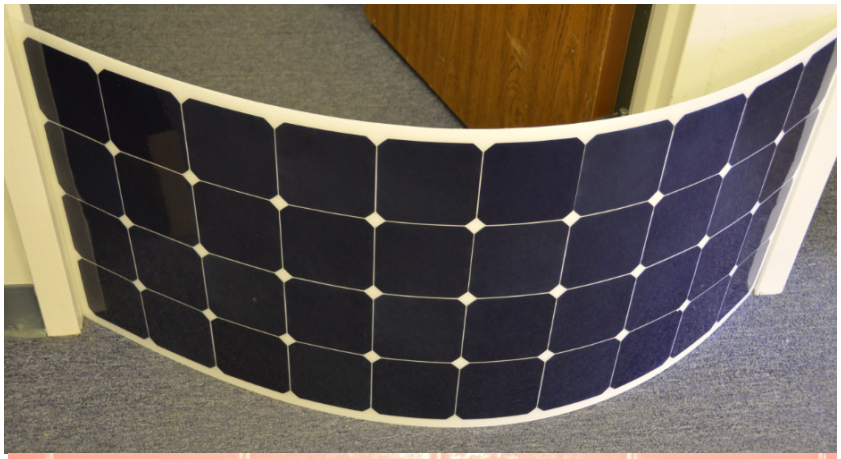
- Use Silevo solar cells that have the best temperature coefficient for mono crystalline solar cells
- Next experiment will be done to compare its performance with regular diffusion solar cells that have special print pattern.

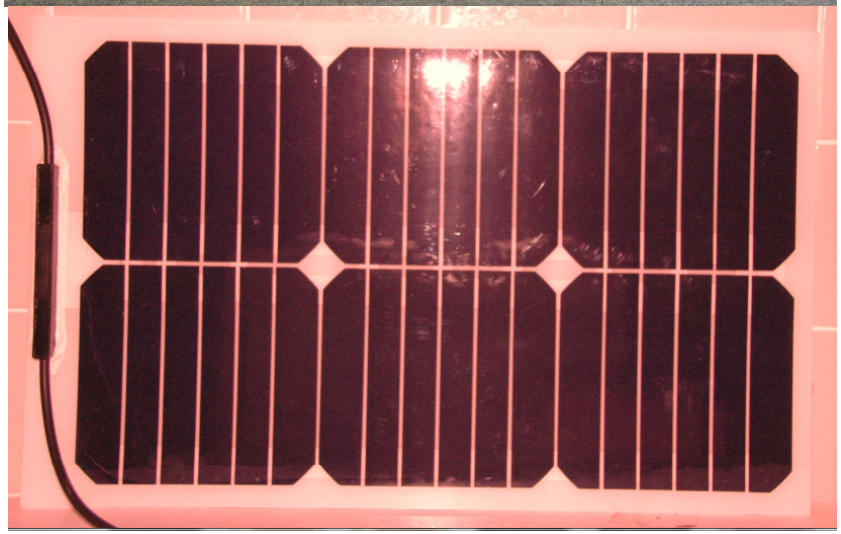
Cons:

- Solution is not cheap

Custom PV Module Design and Operation

Conformable solar panels for bus stops' curved glass roof – Undisclosed





Problem

- Some surfaces are curved, and certain flexibility in solar panels is desired.

Solution:

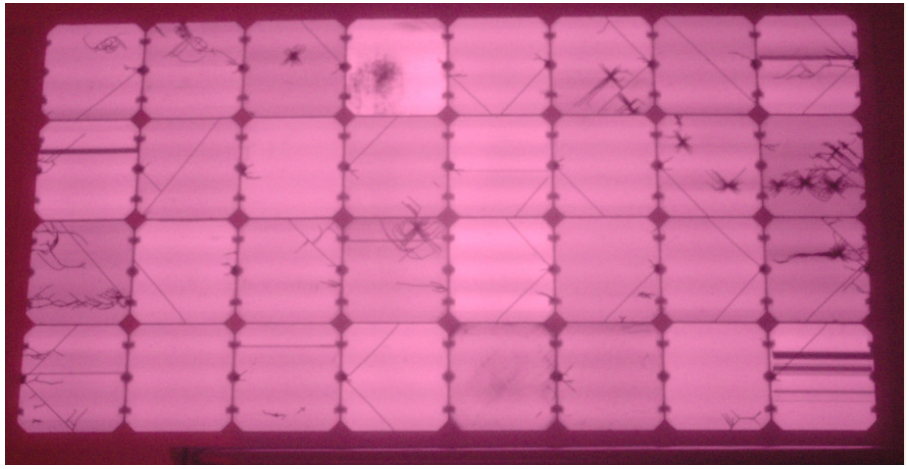
- Created semi-flexible / conformable solar panels
- No frames and only polymer materials are used
- Recommended to be used as 'solar skin', mounted on rigid substrate.

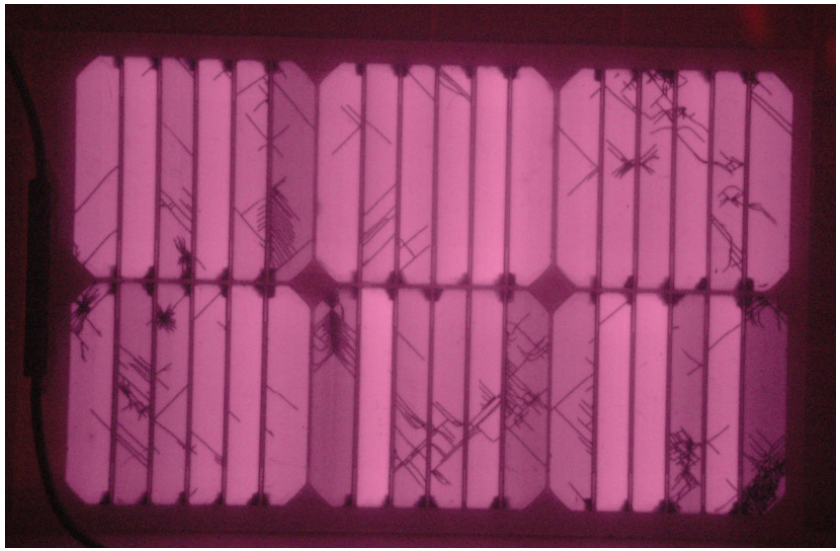
Cons:

- Crystalline solar cells cracks hard to avoid.
- Not recommended for high reliability and longevity applications.
- Should keep system voltage low
- See electroluminscence pictures in next page.

Custom PV Module Design and Operation

Conformable / Flexible Solar Panels – Issues!



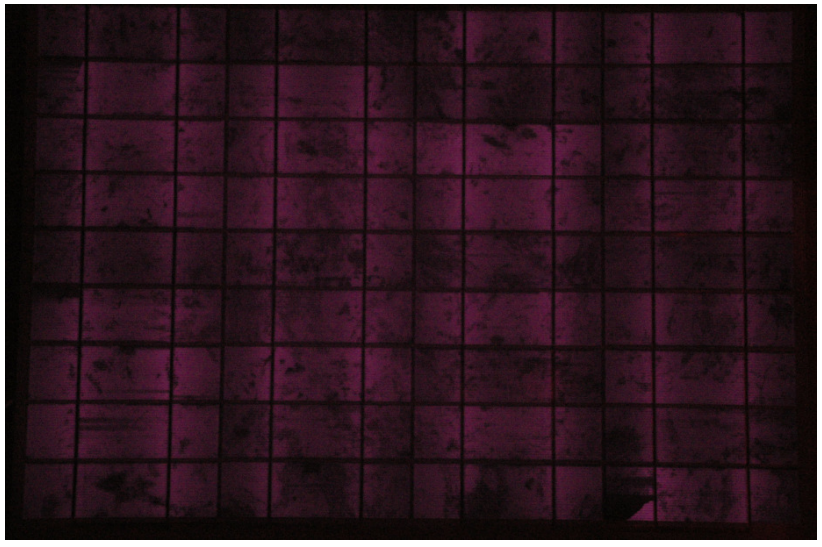


Problem with flexible solar panels

- Today's crystalline based solar cells are all at least 50 microns thick, therefore not flexible, and they will crack without sturdy substrate mechanical support
- Long term reliability concerns.

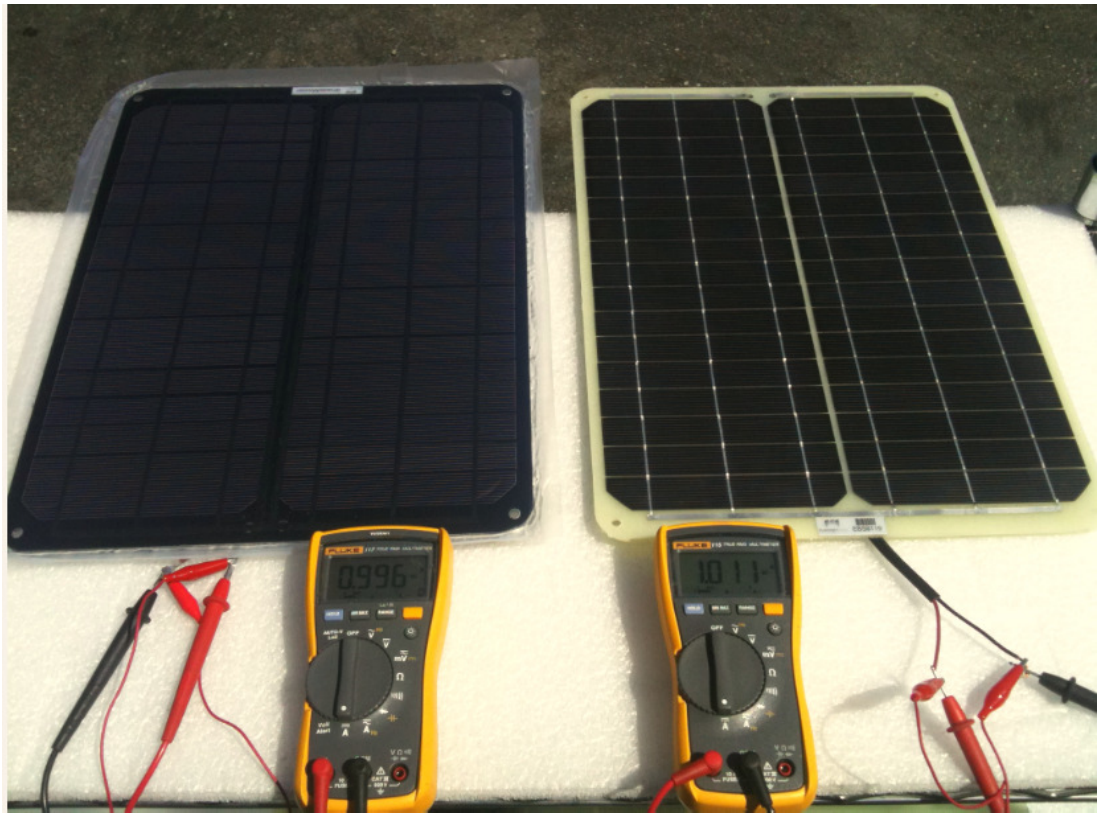
Electroluminescence Images:

- Cracks are extensive under EL, not obvious with naked eye inspection.
- Brighter cells indicate higher efficiency of cells
- Darker spots below show multi crystalline wafers with lower purity silicon, lower consistency.



Custom PV Module Design and Operation

Two Equal Size and Evenly Illuminated Panels Show Same Current & Power



Picture shows Everbright Solar ShadeMaster panel (black) and the regular 'SunSoaker' series solar panel (Green back board) have about equal size and same thickness, produce equal current, under one sun, unshaded illumination.

Problem:

- Sometimes shading is unavoidable due to obstruction devices that must coexist with solar panels in tight spaces.

Solution:

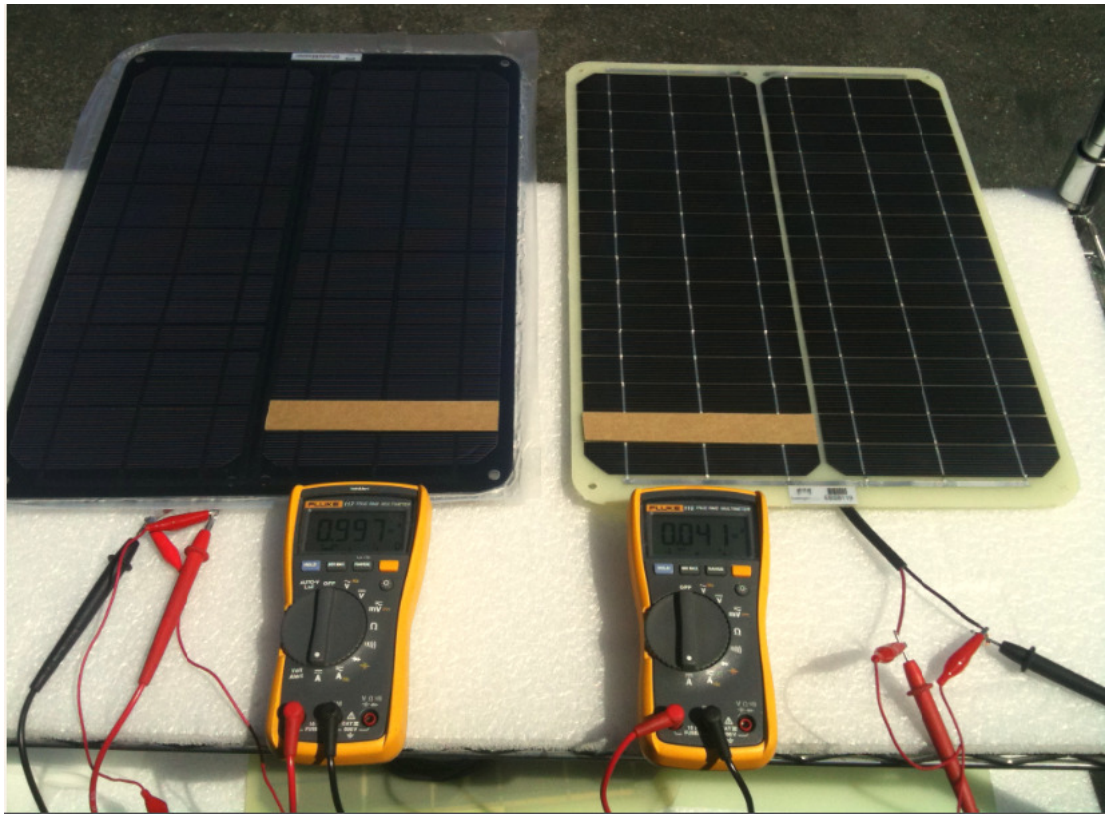
- To minimize shading impact, one can divide the solar panels into smaller panels / strings and connect the strings in parallel
- Other special wiring schemes can be used
- Bypass diodes can be applied in smaller granularity

Constraints:

- Need to reach happy medium between cells size and panel size
- Need to strike balance between reliability of solar panel and the risks introduced when more electronic components are used in a solar panel that's very simple.

Custom PV Module Design and Operation

Everbright Solar ShadeMaster Panels Reduce Shading Impact



Picture shows that when one or more cells are completely shaded, the regular solar panel loses most of its current, while the Everbright Solar ShadeMaster panel can maintain its current level. The two solar panels have about the same form factor, all equal thickness!

Problem:

- Sometimes shading is unavoidable due to obstruction devices must coexist with solar panels in tight spaces.

Solution:

- To minimize shading impact, one can divide the solar panels into smaller panels and connect the panels in parallel
- Other special wiring schemes can be used
- Bypass diodes can be applied in smaller granularity

Cons:

- Need to balance happy medium between cells size and panel size
- Need to strike balance between reliability of solar panel and the risks introduced when new electronic components are introduced.

Custom PV Module Design and Operation

Everbright Solar ShadeMaster Panels Reduce Shading Impact (Zoom In)

Picture shows that when one or more cells are completely shaded, the regular solar panel loses most of its current, while the Everbright Solar ShadeMaster panel can maintain its current level. The two solar panels have about the same form factor, all equal thickness!

Problem:

- Sometimes shading is unavoidable due to obstruction devices must coexist with solar panels in tight spaces.

Solution:

- To minimize shading impact, one can divide the solar panels into smaller panels and connect the panels in parallel
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Cons:

- Need to balance happy medium between cells size and panel size
- Need to strike balance between reliability of solar panel and the risks introduced when new electronic components are introduced.

Custom PV Module Design and Operation

Everbright Solar ShadeMaster Panels Reduce Shading Impact

Custom Solar Panels Trade Show:

- **Live demo of 'ShadeMaster' Series of shade resistant solar panels and other custom solar panels at SPI 2012 Orlando**

Problem:

- Sometimes shading is unavoidable due to obstruction devices must coexist with solar panels in tight spaces.

Solution:

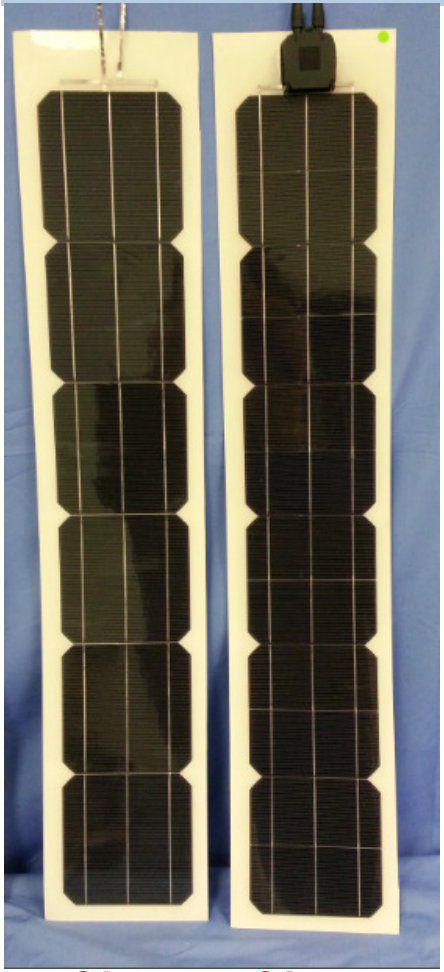
- To minimize shading impact, one can divide the solar panels into smaller panels and connect the panels in parallel
- Other special wiring schemes can be used
- Bypass diodes can be applied in smaller granularity

Cons:

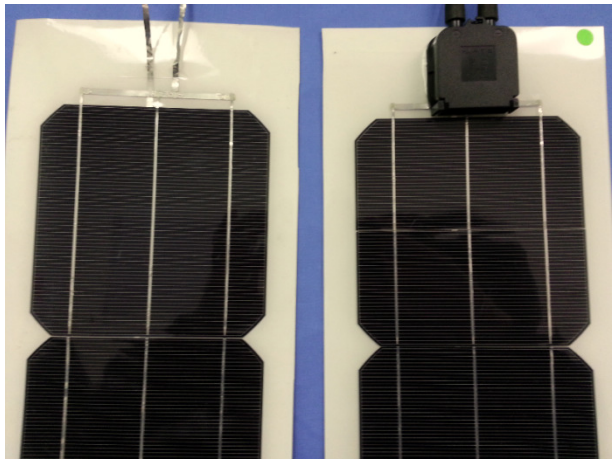
- Need to balance happy medium between cells size and panel size
- Need to strike balance between reliability of solar panel and the risks introduced when new electronic components are used in highly simple and reliable panels.

Custom PV Module Design and Operation

6 and 12 Cell Panels for Modular Applications



24 w 3v,8a **24 w 6v,4a**



Enlarged picture shows that the panel on the right has cells cut in half and all are connected to series to increase voltage, while maintaining the same power and physical dimension.

Usage Scenarios:

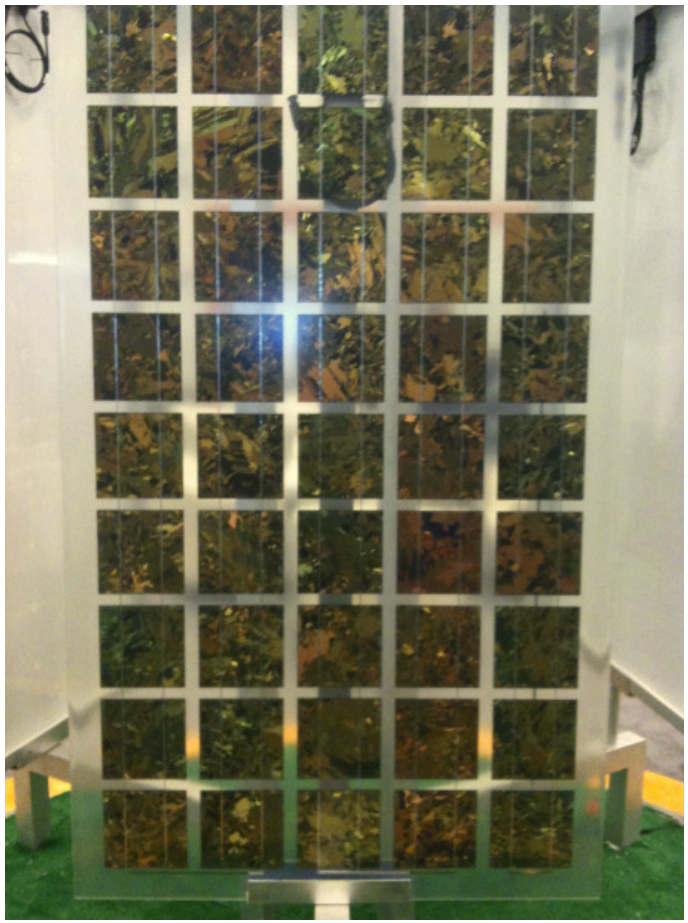
- Sometimes certain applications need to have lower voltage input and flexible configurations.
- By using multiple 3 volt or 6 volt modules in series one can gain the flexibility in power configuration and possibly panel placement due to smaller components. It's similar to 2 volt, 6 volt lead acid batteries giving you more flexibility to configure the batteries in a combination of series and parallel based on specifica needs.

Cons:

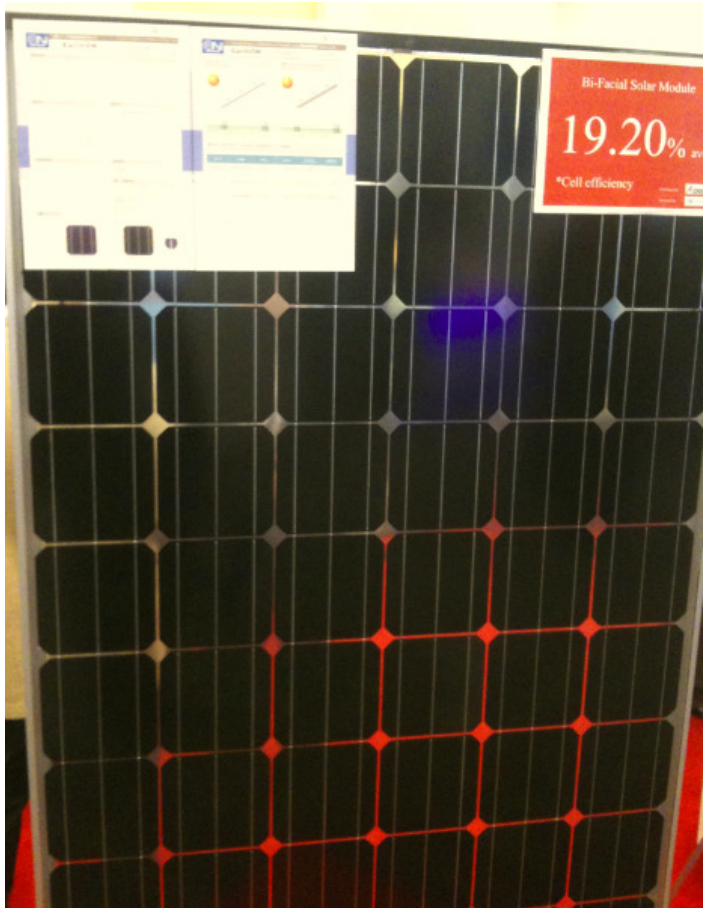
- A bit more work in putting the system together

Custom PV Module Design and Operation

BIPV Benefit from Colorful cells and Bafacial Solar Cells for Better Function and Form



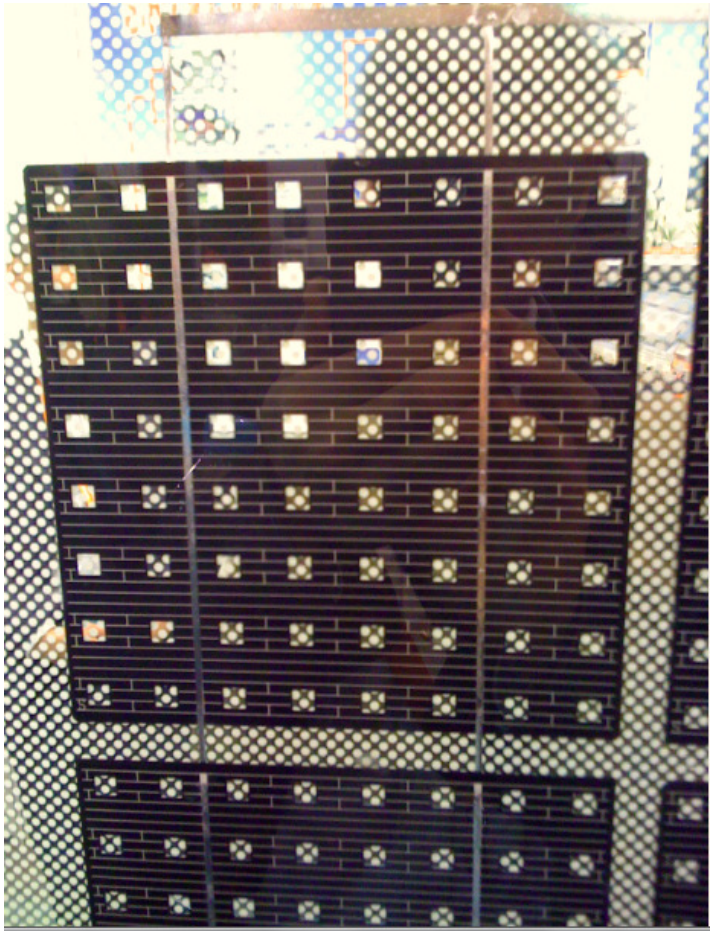
- Colored Solar Panels



- Bifacial Solar Panel

Custom PV Module Design and Operation

BIPV and Other Innovative Crystalline PV Modules



- **Solar cells with laser cut holes to let more light through**

- **A new solar cell layout pattern for solar windows**

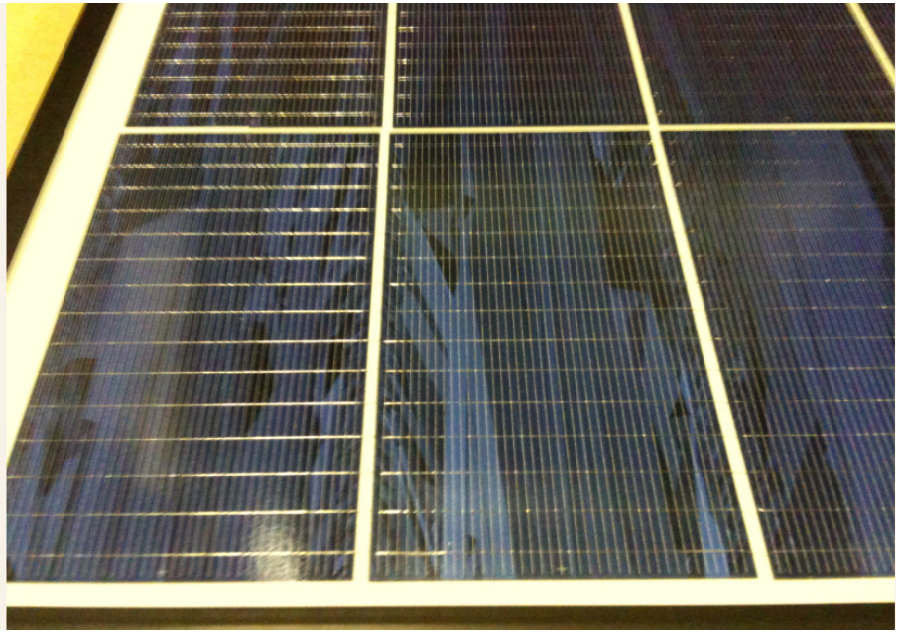
Custom PV Module Design and Operation

BIPV and Other Innovative Crystalline PV Modules

- **2nd Generation BIPV**
- **Glass integrated solar cells / panels**

Custom PV Module Design and Operation

BIPV and Other Innovative Crystalline PV Modules

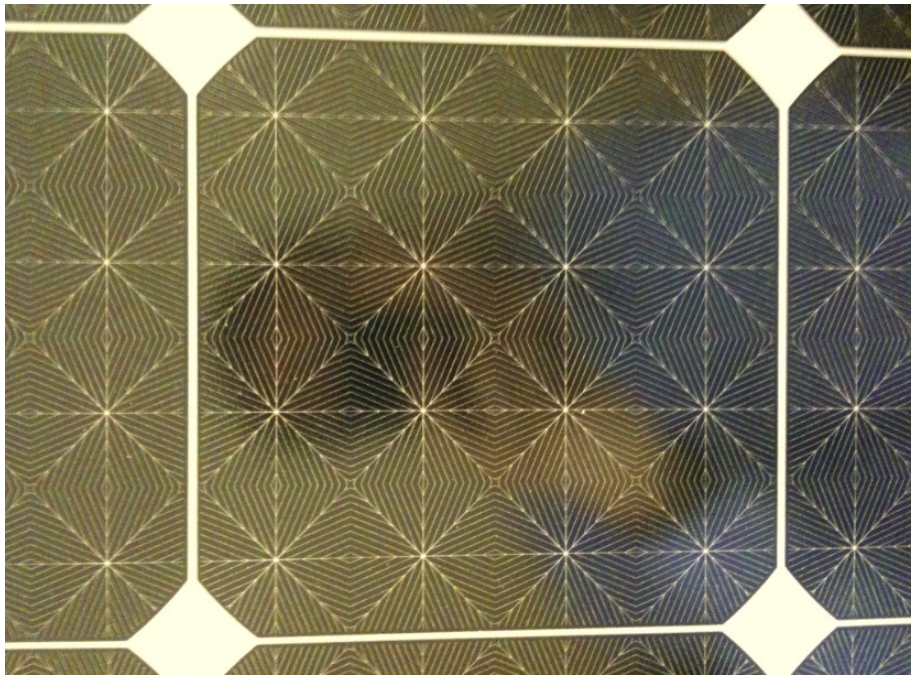


- **Evergreen micro wire solar cells made into panels**

- **Day 4 Energy micro wire solar cells and custom wiring of the cells divide the cells into smaller strings, reducing the impact from shading**

Custom PV Module Design and Operation

BIPV and Other Innovative Crystalline PV Modules

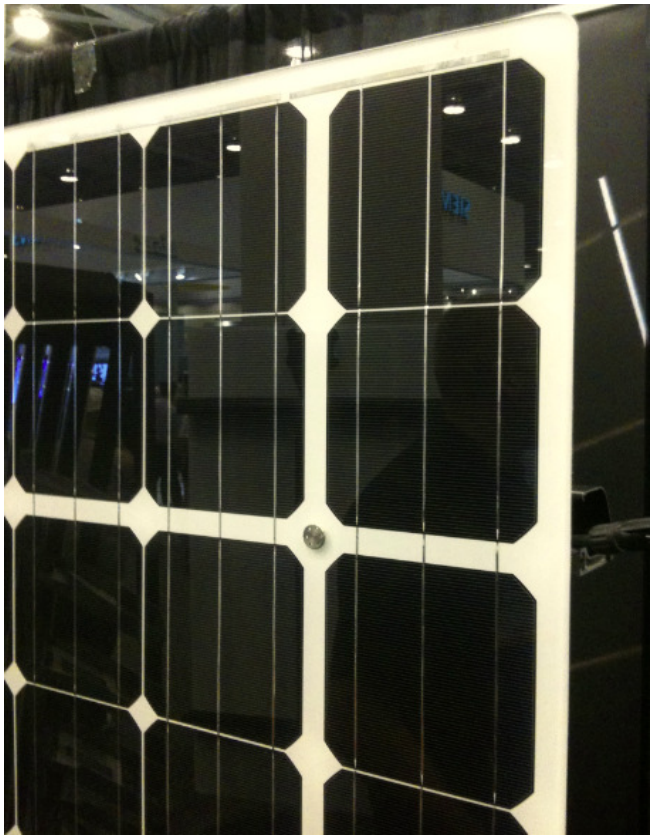


- **Wrap through solar cells**

- **Quasi-Mono solar cells**
- **'Mono Cast' solar cells**

Custom PV Module Design and Operation

Frameless Solar Panel Implementation and Operational Impact



Innovative frameless design with integrated mounting hardware from Lumos.

Regular frameless solar panels (laminates) glued to the flat roof with thick foam glued to the back side of solar panels during installation, with potentially disastrous results over time. Water and dirt get trapped beneath / between solar panels and the foams, promoting vegetation growth. Maintenance is hard due to panel damage risk since the panels have no frames. Picture taken by Charles Liu Everbright in Dec 2012, after a prospect called for help to troubleshoot their failed solar system.

Custom PV Module Design and Operation

AC Solar Panels with One Micro inverter Per Panel

'AC Panel' with attached Micro Inverter

Usage Scenarios:

- Micro inverters allow more panel placement flexibility
- More energy harvest per panel vs string inverter in shaded situations.
- Can deal with panel mismatch better
- Lower overall system voltage
- Easier to install for newbies

Cons:

- Electronics placed in hostile environments and expected to last 30 years like the proven panel
- Higher cost than string inverter
- More failure points. Installer could face multiple trips to customer site to fix / replace inverters in the life time of the solar system, each time going up on the roof. Each trip is costly. String inverters may mean only one trip to the ground level / garage to fix / replace typically one failed inverter in 10 or 20 years, during warranty period.
- Unable to monitor performance without Internet, whereas most string inverters have performance stats right on the ground level inverter LCD screen.
- Could be perceived as the solar panel manufacturer's failure when it's the inverter's failure

Questions And Answers.

You are welcome to send questions, feedback,
Your future development requests to:

Charles Liu

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