

Energy Instructor

Steve Geiger

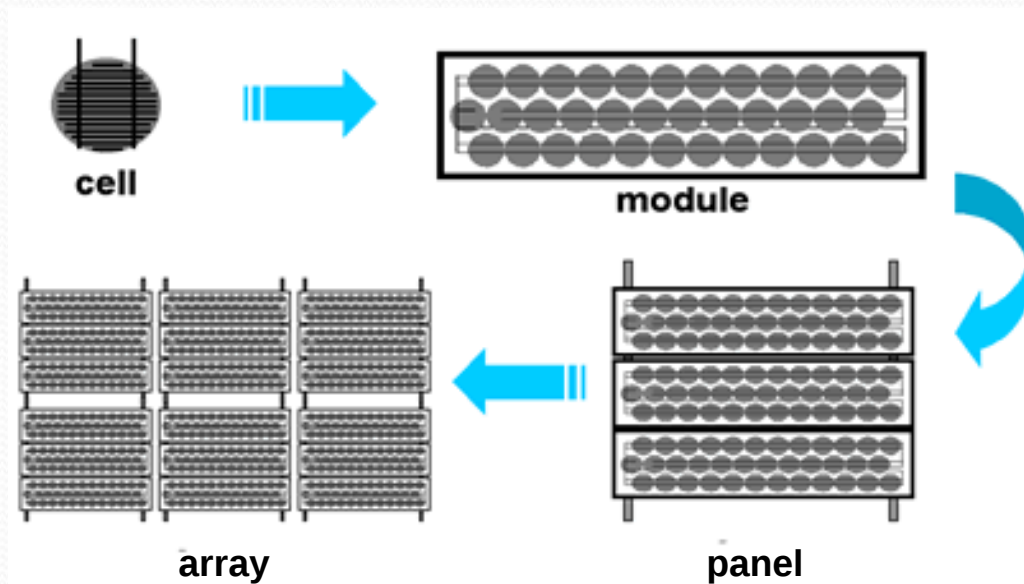
Photovoltaic Modules



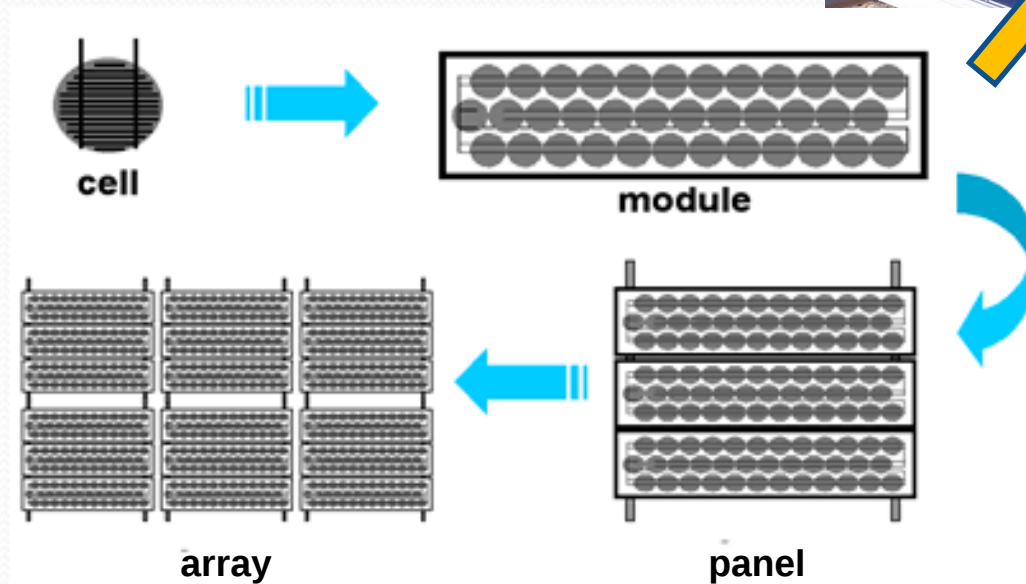
Topics

- Module Basics
 - Structure
 - Module Brands and Types
 - Efficiencies
- The Photovoltaic Effect/Reaction
- Measuring Module Performance
- Factors that Affect Module Performance

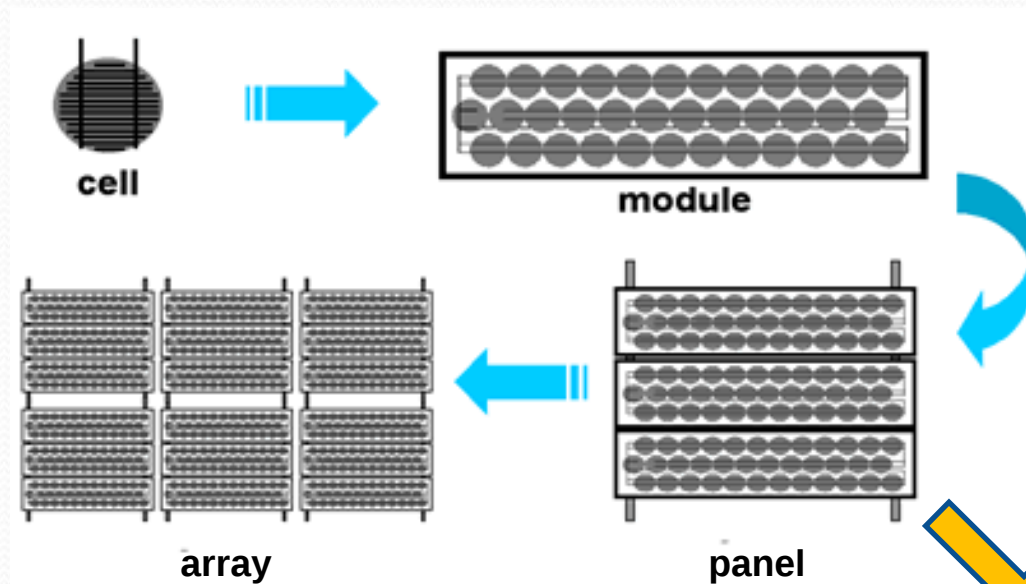
Photovoltaic Array Structure



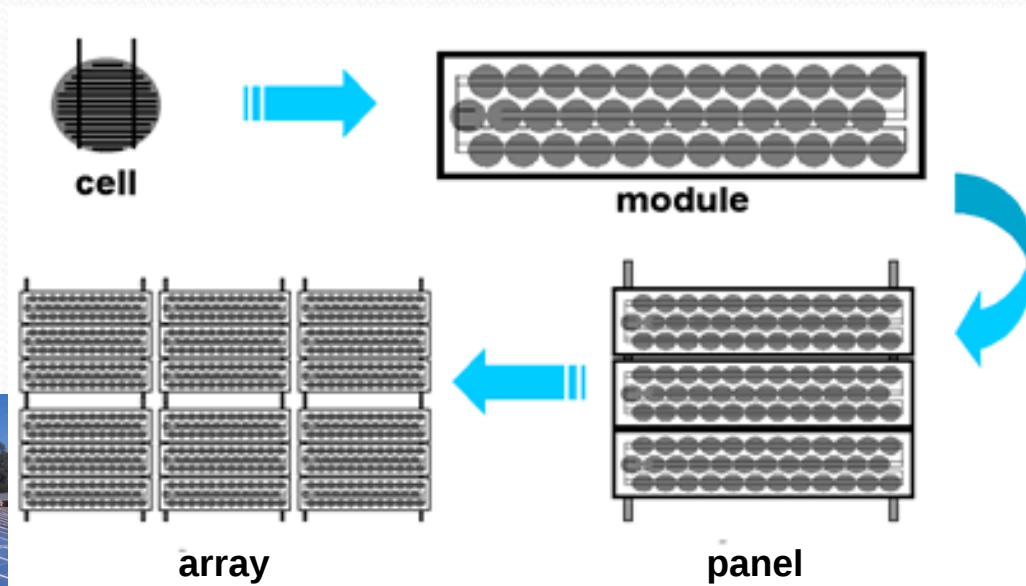
Photovoltaic Array Structure



Photovoltaic Array Structure



Photovoltaic Array Structure



Module Types



 **CanadianSolar**

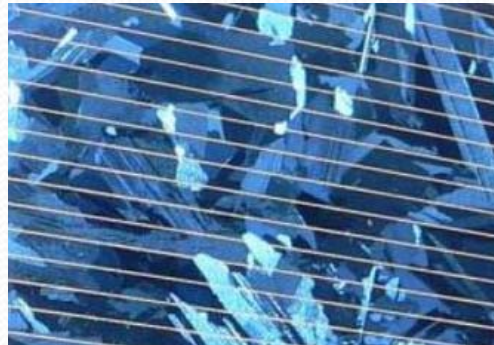
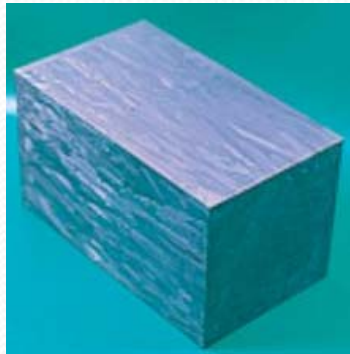


SANYO

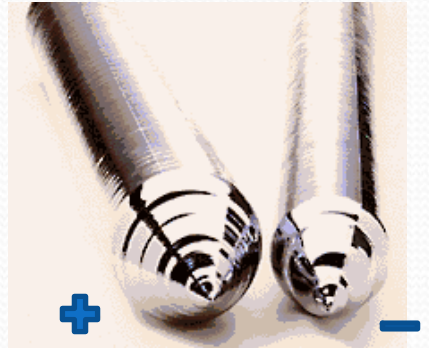
...And many Others

Module Types

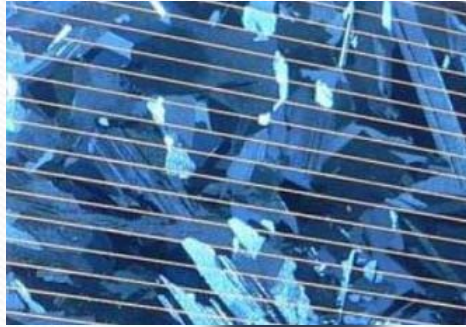
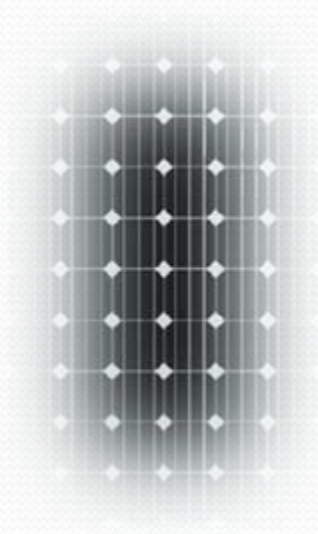
- Mono Crystalline Silicon (most efficient, \$\$\$)
- Poly Crystalline Silicon (next efficient, \$\$)



- Amorphous Thin Film (least efficient, \$)



Module Types



SANYO

...And many Others

- Most Efficient Solar Panels (Updated 5.19.2012 at <http://gosolarcalifornia.org/>)

Manufacturer	ID	STC	Density	Eff.	Tier
<u>Sanyo Electric</u>	<u>HIP-200BA19</u>	200	14.89	17.24%	1
<u>SunPower</u>	SPR-200-WHT-U	200	13.55	16.08%	1
Canadian Solar	CS5A-200M	200	13.29	15.66%	2
<u>Suntech Power</u>	<u>PLUTO200-Ada</u>	200	13.28	15.66%	2
<u>Trina Solar</u>	<u>TSM-200DA01A</u>	200	13.12	15.64%	2
<u>Kyocera Solar</u>	<u>KC200GT</u>	200	12.03	14.74%	3
<u>Schuco USA</u>	SPV 200 SMAU-1	200	11.82	14.21%	3
BP Solar	<u>SX3200B</u>	200	11.52	14.17%	3
<u>Yingli Green Energy</u>	YL200P-26b	200	11.26	13.65%	4
ET Solar Industry	ET-P654200	200	11.18	13.61%	4
Evergreen Solar	ES-200-RL	200	10.69	13.40%	4
Sharp	ND-200U1	200	9.86	12.27%	5

Quick Efficiency Reference

- **Module efficiency** = conversion efficiency.
If the Sun dumps 100 Watts of energy onto the module and the module spits out 15 Watts, then the module is said to have 15% module efficiency ($15 \text{ W} / 100 \text{ W} = 0.15 = 15\%$).
- **Area efficiency (aka Density)** = production in a given area.
It's Watts per square foot, so the more Watts, the more energy you'll get from a specific area. So if a module spits out 210 Watts in 15 square feet, it's density is 14 W/sq ft ($= 210 \text{ W} / 15 \text{ sq ft}$).
- **Cell efficiency** is measured the same way as module efficiency, but only with a single cell.

The Photovoltaic Effect

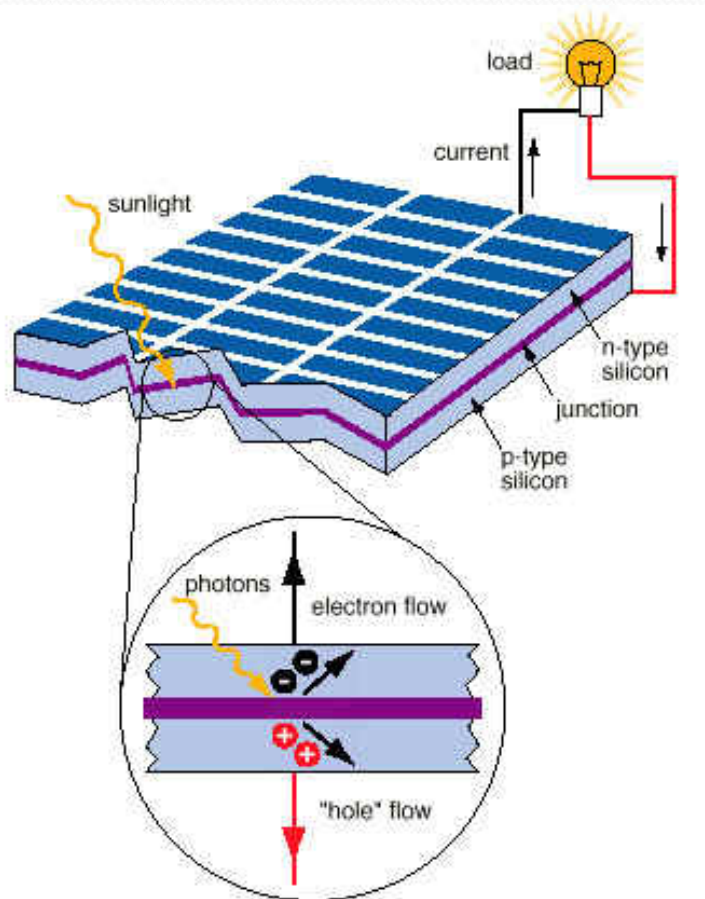
- 1839 French scientist named Alexandre-Edmond Becquerel first observed the phenomenon
- Discovered in 1873 by British scientist Willoughby Smith (Selenium sensitive to light).
- In 1880 Charles Fritts developed the first Selenium-based solar cell.
- 1923 Einstein won Noble Prize for photovoltaic effect paper
- 1950s Bell Labs discovered that Silicon was able to create a photovoltaic reaction.
- 1954 Bell created first modern cell w/NASA – Still Works!!

The Photovoltaic Effect cont.

1. Sunlight will ionize the atoms (electrons) in the silicon.

p-type doped with Boron (+ side)

n-type doped with Phosphorus (- side)



2. Two layers of silicon produce a positive and negative energy flow, separated by the junction material.
3. Current flows from negative to the positive side of the cell to create electricity.

Measuring Module Performance

STC (Standard Test Conditions) – Common Rating

- 1000 Watts per square meter irradiance at 25°C (77°F) cell temp

PTC (Practical Test Conditions)

- 1000 Watts per square meter irradiance at 20°C (68°F) ambient temp

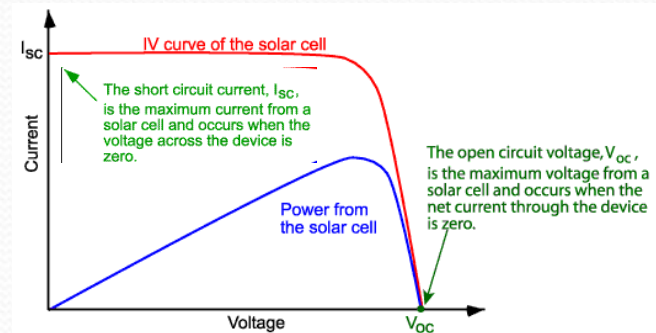
Measuring Module Performance cont.

- ▣ Maximum Power Point: V_{mp} & I_{mp} (max output - STC)
- ▣ Open Circuit Voltage: V_{oc} (no current drawn)
- ▣ Short Circuit Current: I_{sc} (no resistance)

V = Volts

I = Amps

$V \times A$ = Watts



IV curve of a solar cell showing the open-circuit voltage.

- ▣ (See Sanyo Brand PDF – I-V Curve)
- ▣ Panel Testing

Module Label / Junction Box/Backing



Factors that Affect Module Performance

- Cell Material
- Load Resistance
- Sunlight Intensity
- Cell Temperature (mounting)
- Shading (bypass diode)



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Questions???



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Quiz

Quiz

1. Describe the Photovoltaic Array Structure
2. Name the three module types
3. What is Silicon doped with?
4. Name three factors that affect Module Performance



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Quiz Review



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Thank You