

Fundamentals of Solar Photovoltaic Systems

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Electrical Basics

Solar-powered systems are primarily electrical systems.
It is important to understand the three basic terms:

- Current
- Voltage
- Resistance

...And how they are related

Ohm's Law

States the relationship between voltage, current and resistance:

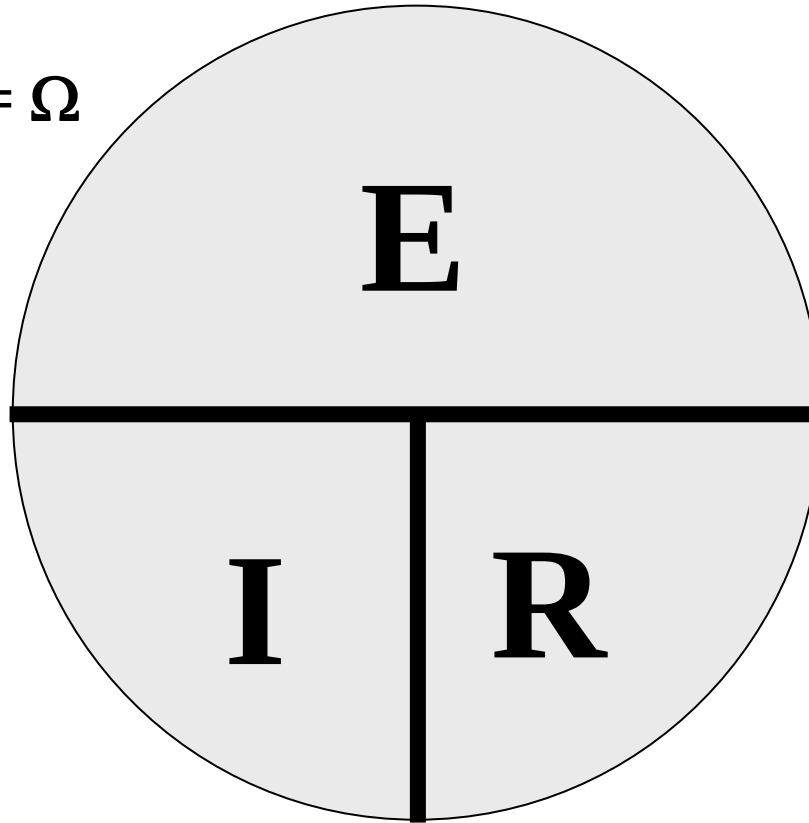
One volt of electromotive force will force one ampere of current to flow through one ohm of resistance

Ohm's Law

$E = \text{Voltage} = V$

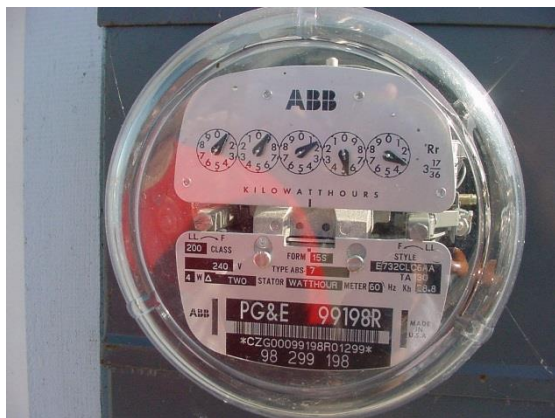
$I = \text{Current} = A$

$R = \text{Resistance} = \Omega$



Power

Horsepower is the unit of measure for mechanical energy



746 Watts = 1 Horsepower (hp)

$$P = E \times I$$

***Power can be measured in
the thousands of watts
consumed per hour***

kilowatt hours = KWH



Photovoltaic Basics



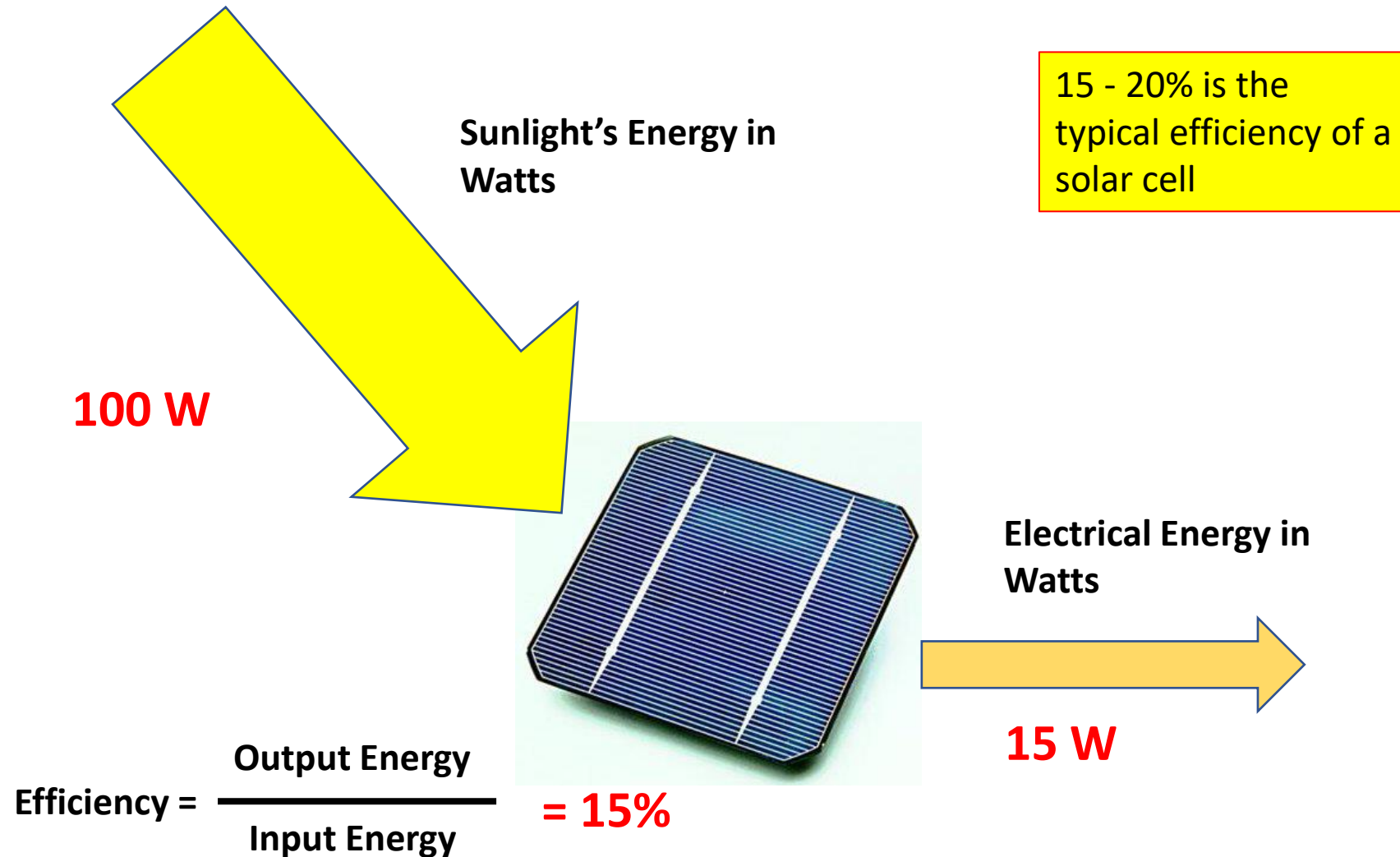
A Single Solar Cell

A typical solar cell can produce about 0.5V

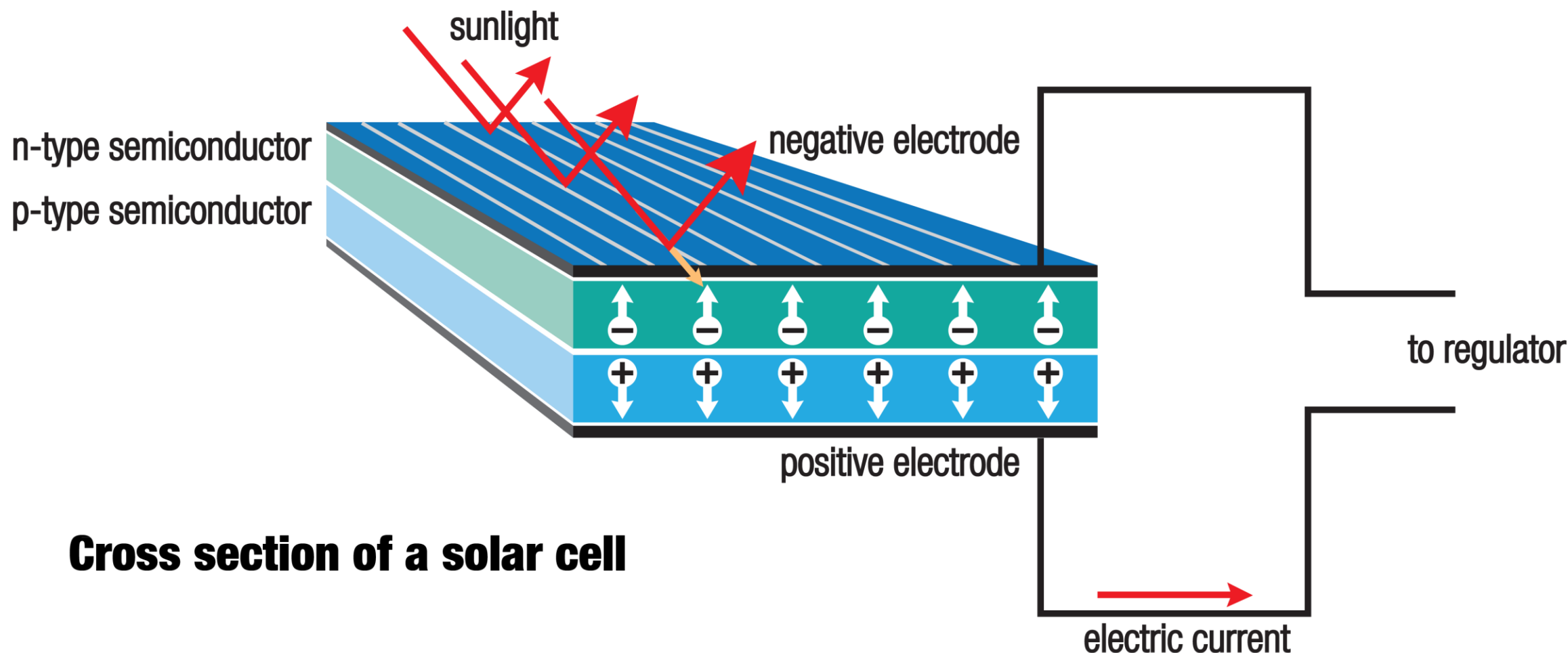


**How do we
get a system
with 120V?**

Energy In vs. Energy Out

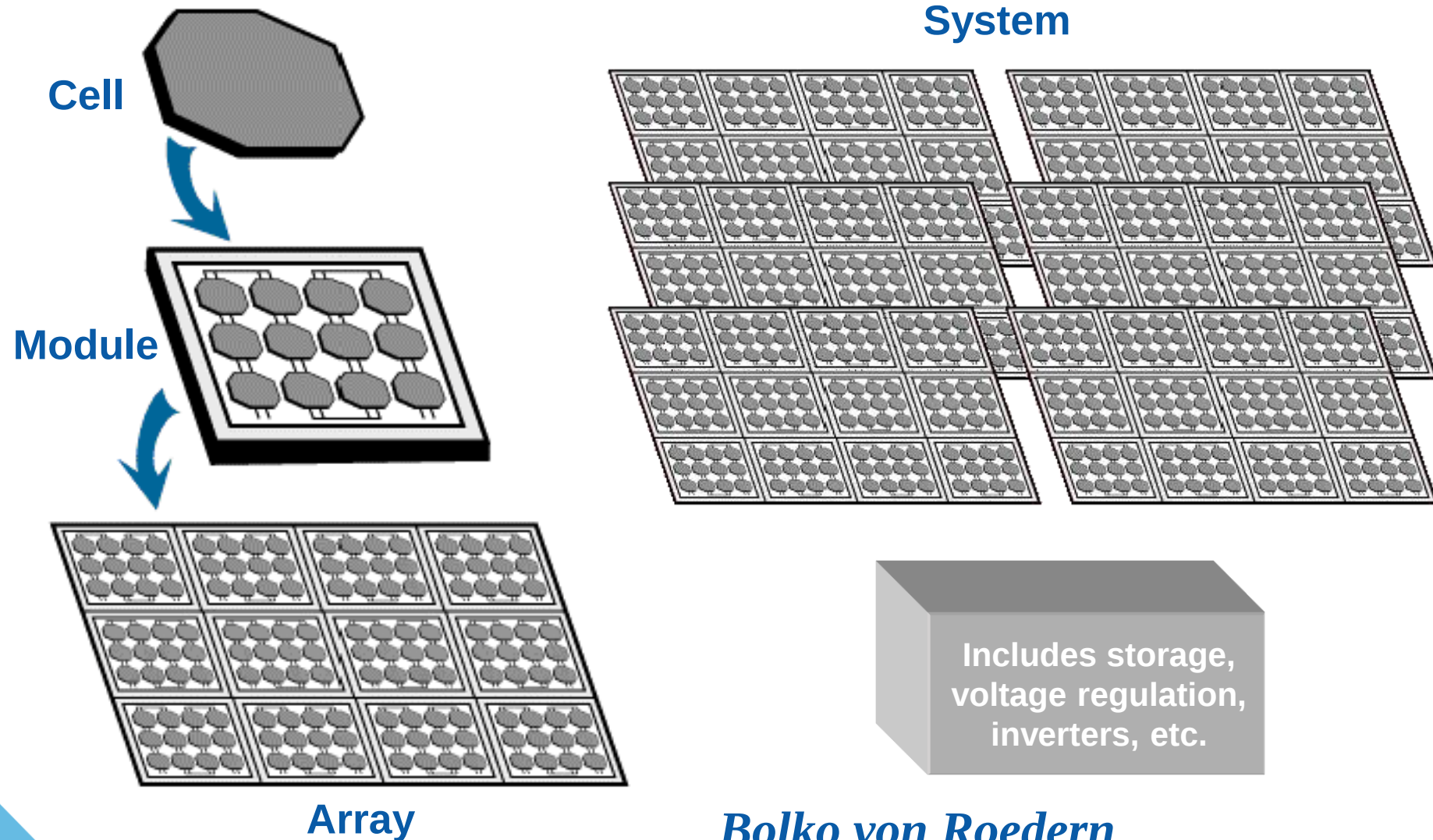


Electron Flow



Cross section of a solar cell

Photovoltaic Building Blocks



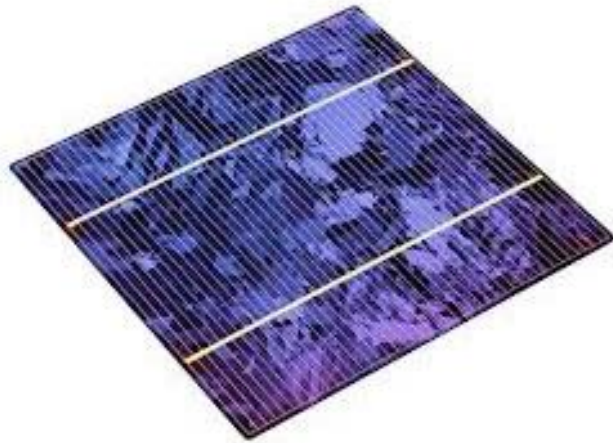
Bolko von Roedern
National Center for Photovoltaics

How do Solar Panels Work?

- PV Panels are made of a semiconductor material
- Examples of semiconductors:
 - Monocrystalline silicon
 - Polycrystalline silicon
 - Amorphous silicon
 - Gallium Arsenide
 - Cadmium Telluride



Polycrystalline vs. Monocrystalline



**Polycrystalline
Solar Cell**



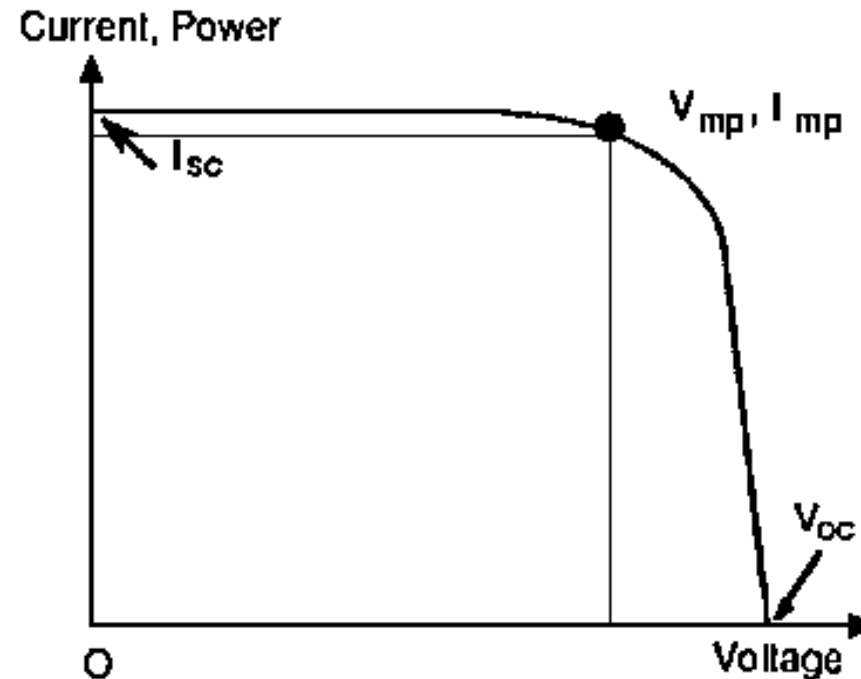
**Monocrystalline
Solar Cell**

Amorphous Silicon – Flexible Thin Film



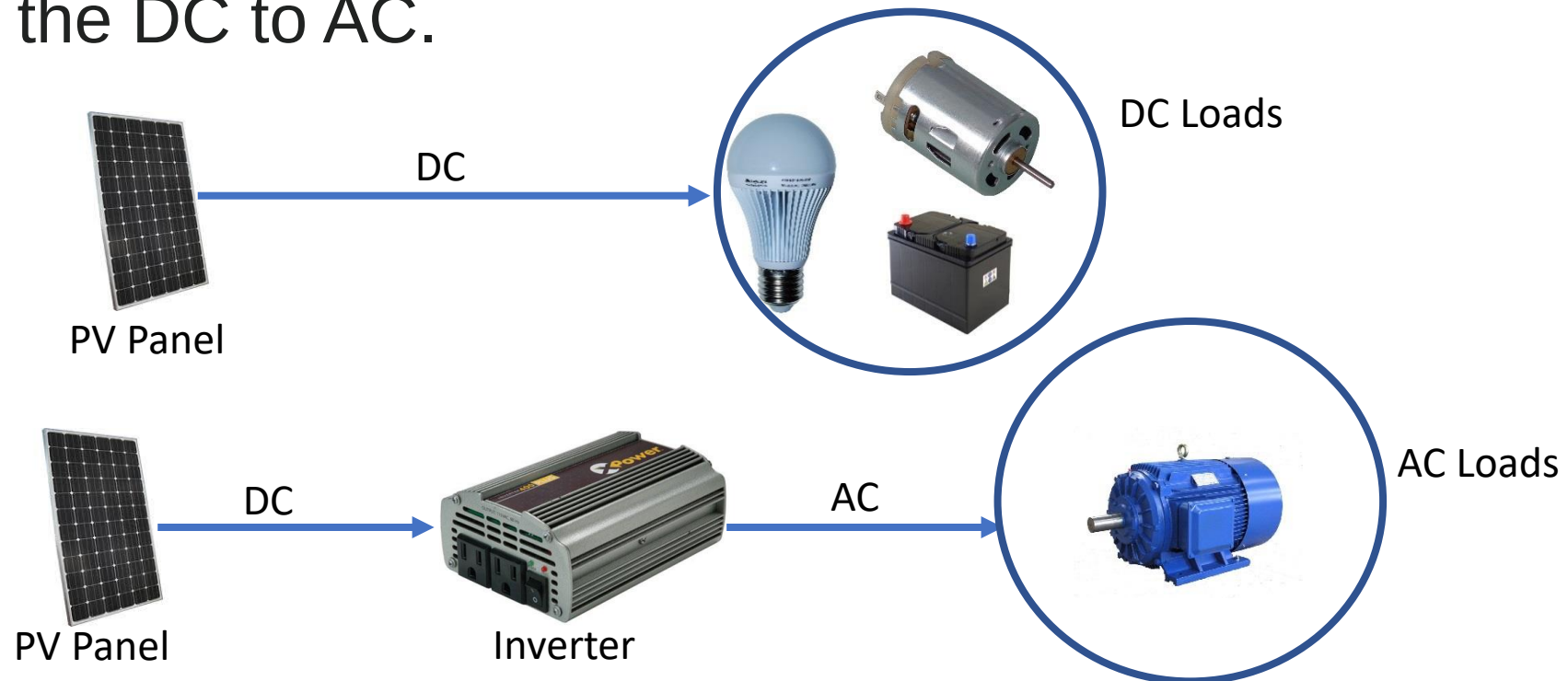
IV Curve of a Solar Cell

- IV Curve → I stands for Current, V stands for Voltage. Shows the relationship of current to voltage in a solar cell



Photovoltaic Facts

- PV Panels produce DC Power
- PV Panels can be used to charge batteries directly
- If AC power is needed, you must use an inverter to convert the DC to AC.





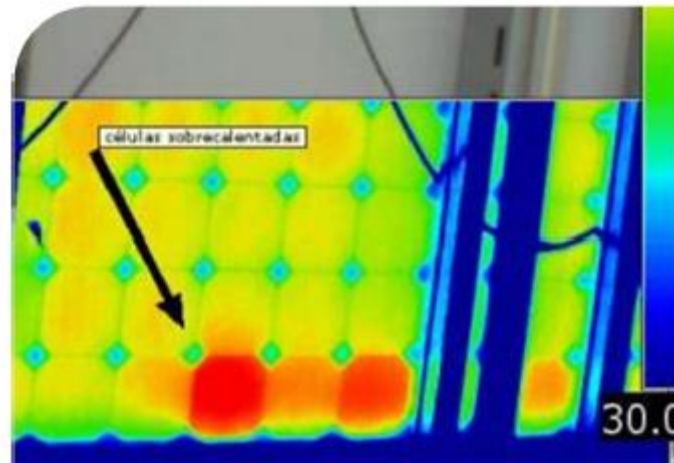
Best Practices for Operation and Maintenance of Photovoltaic and Energy Storage Systems; 3rd Edition

National Renewable Energy Laboratory,
Sandia National Laboratory, SunSpec Alliance,
and the SunShot National Laboratory Multiyear Partnership
(SuNLaMP) PV O&M Best Practices Working Group

PV Module PM Activities

Activity	Interval	Service Provider
Clean PV modules with plain water or mild dishwashing detergent. Do not use hard brushes, any types of solvents, abrasives, or harsh detergents	Condition dependent	Module cleaners
Snow Removal	Condition dependent	Module cleaners
Dust: Agricultural/Industrial/ Pollen cleaning	Condition dependent	Module cleaners
Use infrared camera to inspect for hot spots; bypass diode failure	Annual	PV Module/ Array Specialist

Hot spots may result in a voltage reduction



PV Module PM Activities

Activity	Interval	Service Provider
PV module torque check & visual inspection	5 years	PV Module/ Array Specialist
Racking torque check and inspection	5 years	PV Module/ Array Specialist
Inspection: corrosion and encapsulate yellowing	Annual	PV Module/ Array Specialist
Galvanization inspection	Annual	PV Module/ Array Specialist

Cleaning Panels

- Proper cleaning annually can make panels over 20% more efficient!
- Recommended to use official panel cleaning services

Before



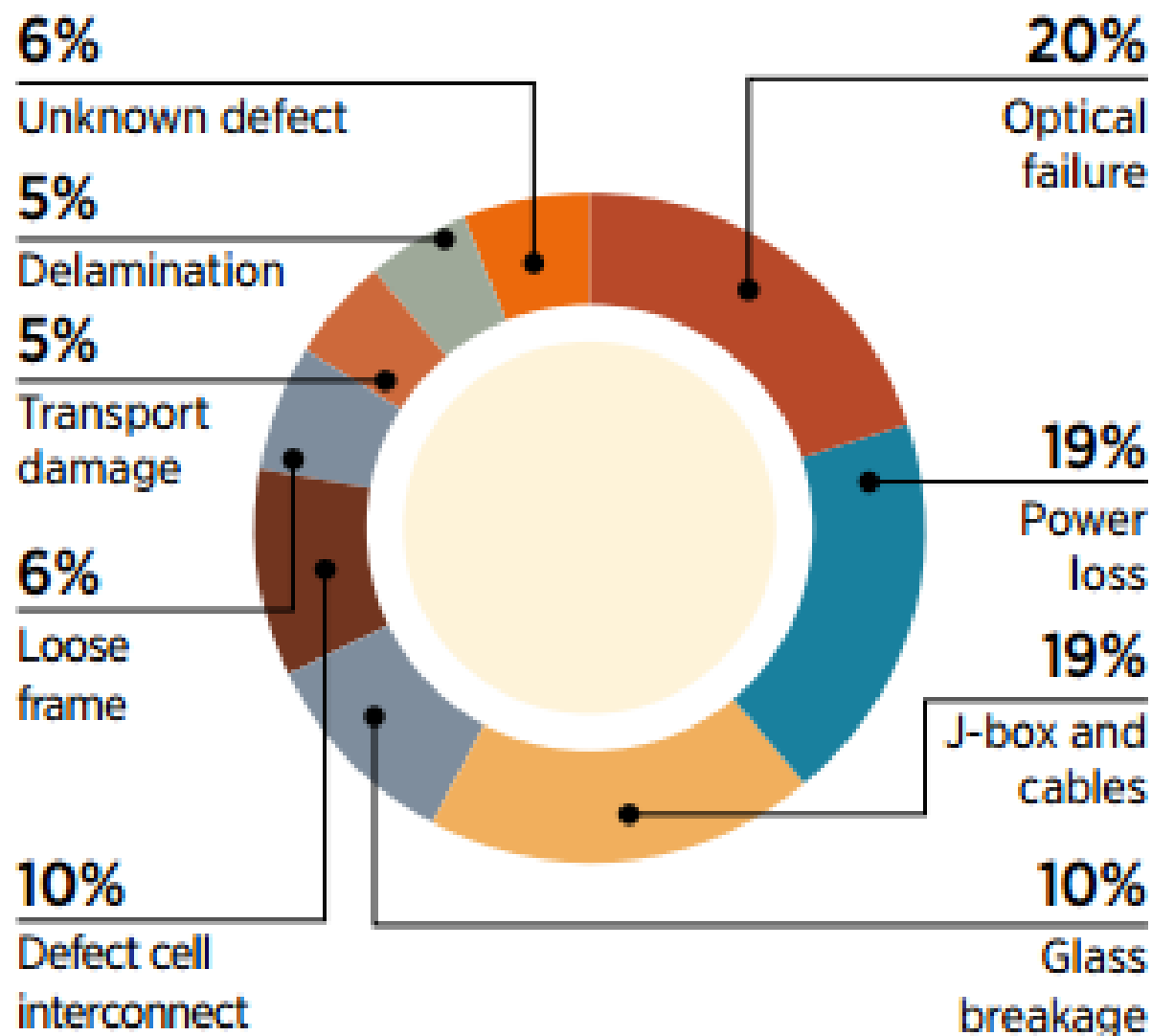
After

Before Installation: Check for Defects

- Manufacturing defects include:
 - Defective frames
 - Yellowing
 - Defective connection boxes
 - Broken glass
 - Water penetration in panel



Failure Rates According to Customer Complaints



Based on IEA-PVPS (2014a)

AC Wiring PM Activities

Activity	Interval	Service Provider
Inspect electrical boxes for corrosion or intrusion of water or insects. Seal boxes if required.	Annual	Electrician
Check position of disconnect switches and breakers.	Annual	Electrician
Exercise operation of all protection devices.	Annual	Electrician
AC disconnect box inspection	Annual	Electrician
Re-torque all electrical connections on AC side of system	Annual	Electrician

PV Array PM Activities

Activity	Interval	Service Provider
Test open circuit voltage of series strings of modules	Annual	Journeyman electrician
Check all hardware for signs of corrosion, and remove rust and repaint if necessary.	Annual	Mechanical Technician
Walk through each row of the PV array and check the PV modules for any damage. Report any damage to rack and damaged modules for warranty replacement. Note location and serial number of questionable modules.	Annual	PV Module/Array Specialist
Inspect ballasted, non-penetrating mounting system for abnormal movement	Annual	Mechanic
Determine if any new objects, such as vegetation growth, are causing shading of the array and move them if possible. Remove any debris from behind collectors and from gutters.	Annual	Tree Trimming

PV Array PM Activities, cont'd

Activity	Interval	Service Provider
Remove bird nests from array and rack area	Annual	Vermin Removal
Nesting vermin removal, nesting vermin prevention	Annual	Vermin Removal



DC Wiring PM Activities

Activity	Interval	Service Provider
Test system grounding with “megger”	Annual	Journeyman Electrician
Scan combiner boxes with infrared camera to identify loose or broken connections	Annual	Electrician
Inspect cabling for signs of cracks, defects, pulling out of connections, overheating, arcing, short or open circuits, and ground faults.	Annual	Electrician
Check proper position of DC disconnect switches.	Annual	Electrician

DC Wiring PM Activities, cont'd

Activity	Interval	Service Provider
Open each combiner box and check that no fuses have blown and that all electrical connections are tight. Check for water incursion and corrosion damage. Use an infrared camera for identifying loose connections because they are warmer than good connections when passing current.	Annual	Journeyman Electrician
Look for any signs of intrusion by pests such as insects and rodents. Remove any nests from electrical boxes (junction boxes, pull boxes, combiner boxes) or around the array. Use safe sanitation practices because pests may carry disease.	Annual	Vermin Removal
Re-torque all electrical connections in combiner box	Annual	Electrician

Roof Mount Considerations

- simple and cheap to install
- offer no flexibility in the orientation of your solar panel
- can only support small photovoltaic units.



Roof Mount Considerations

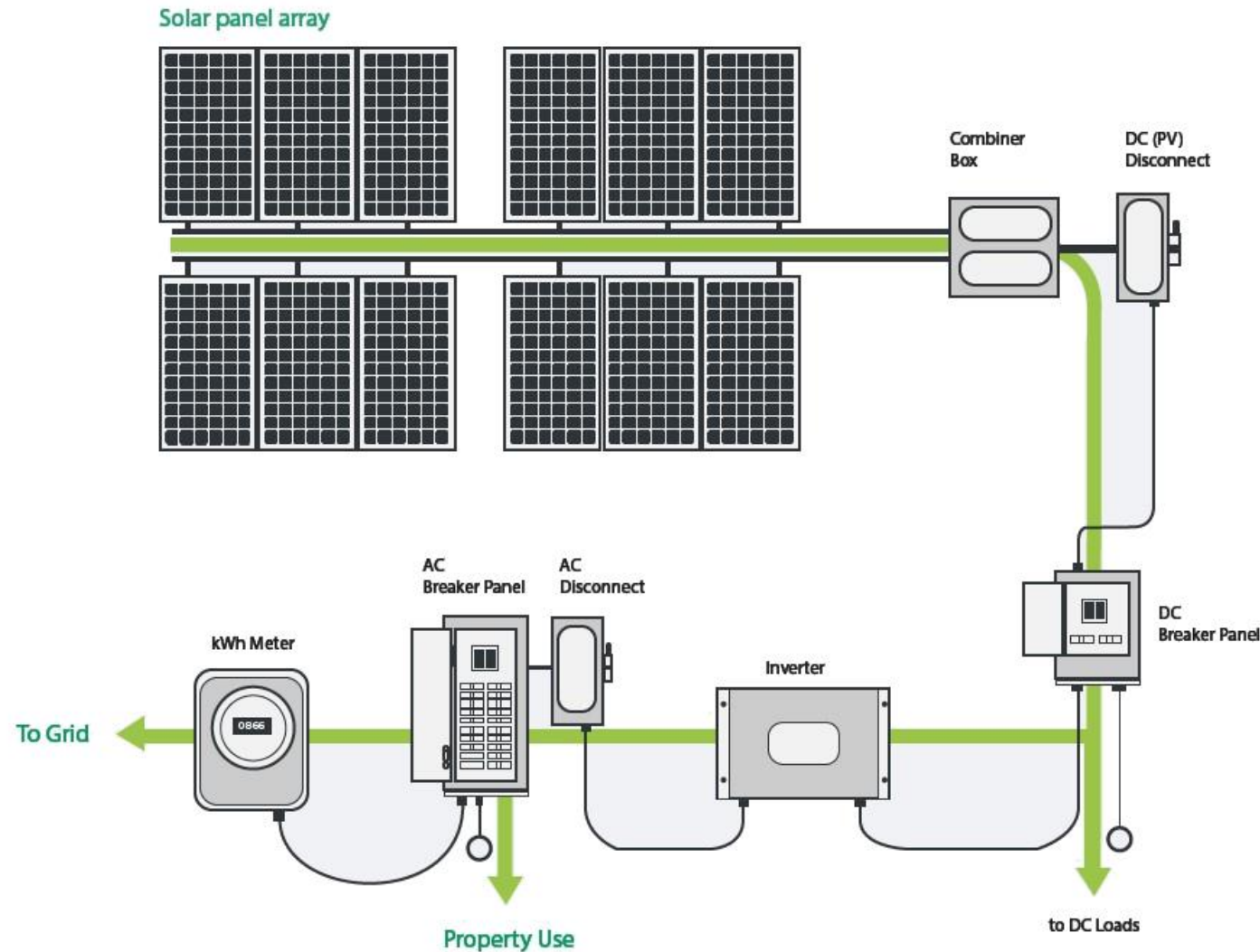
- Penetrate the roof as little as possible
- Weather proof all holes to prevent leaks
 - May require the aid of a professional roofer
- Re-roof before putting modules up
- Leave 4-6" airspace between roof and modules
- On sloped roofs, fasten mounts to rafters not decking

Repair Costs for Different Types of Roofs

Roofing Type	Repair Materials (\$/m ²)	Repair Labor (h/m ²)
Thermoplastic Polyolefin (TPO)	\$20.00	1.0
Ethylene Propylene Diene Monomer (EPDM)	\$20.00	1.0
PolyVinyl Chloride (PVC)	\$20.00	1.0
Built-up, Bituminous	\$15.00	1.5
Styrene-Butadiene-Styrene (SBS)	\$20.00	1.0
Asphalt Shingle	\$15.00	1.0
Composite Shingle	\$25.00	1.0
Wood Shingle	\$40.00	2.0
Slate	\$50.00	1.0
Metal Roof	\$50.00	0.5
Tile	\$50.00	1.0

^a Large variations can exist based on size, site access, location, and labor markets.

The PV System – Other Components to Consider!



Are Your Questions Answered?

If you want to learn more about solar energy and power generation, TPC can help!

Phone: (847) 808-4000

Email: sales@tpctraining.com

Thank You & Work Safely!