



Energi Terbarukan

Pertemuan 2:

Solar PV

Dosen Pengampu:

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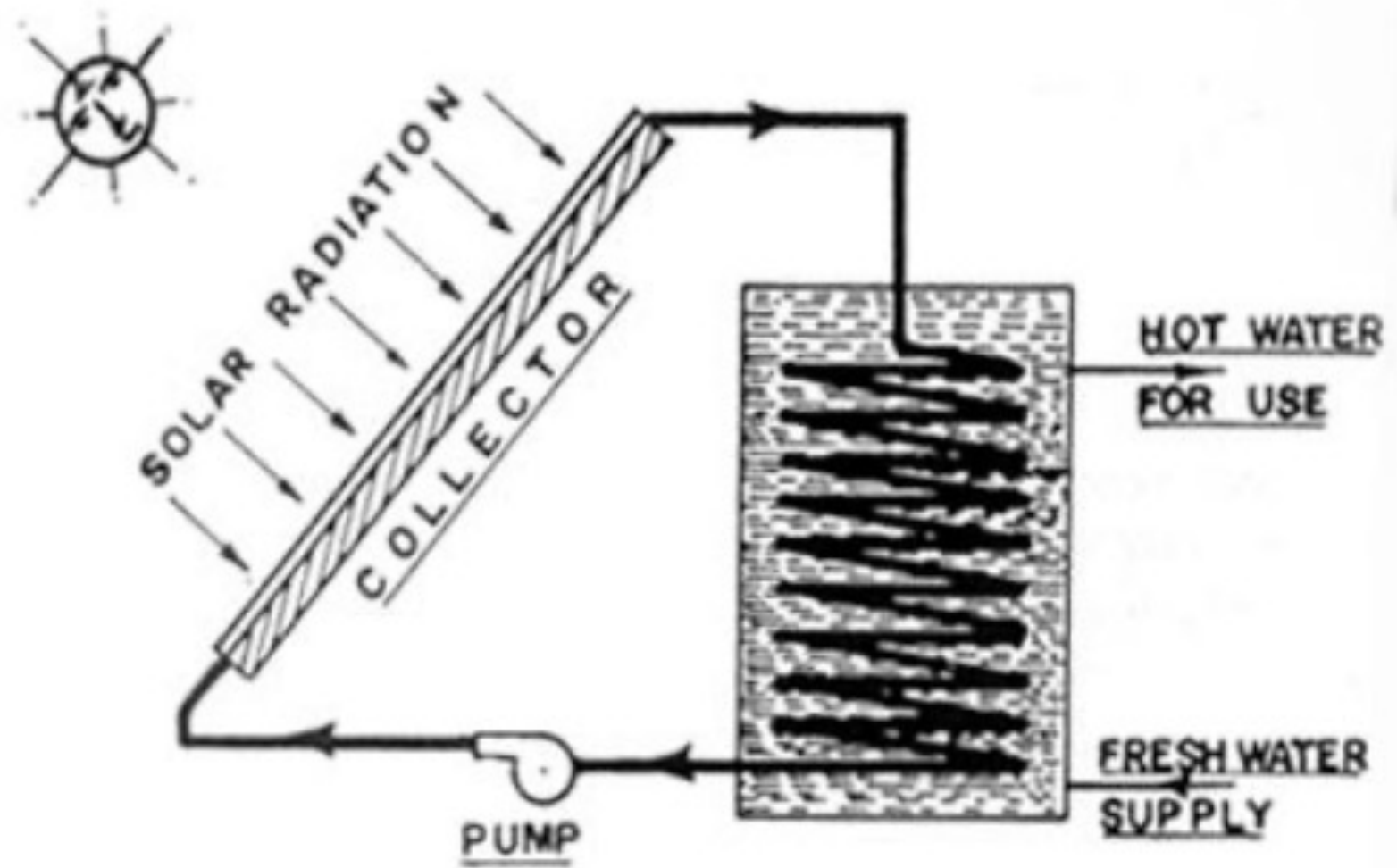
Solar PV

Acquired and Modified from:

Master of Electrical Engineering – UGM

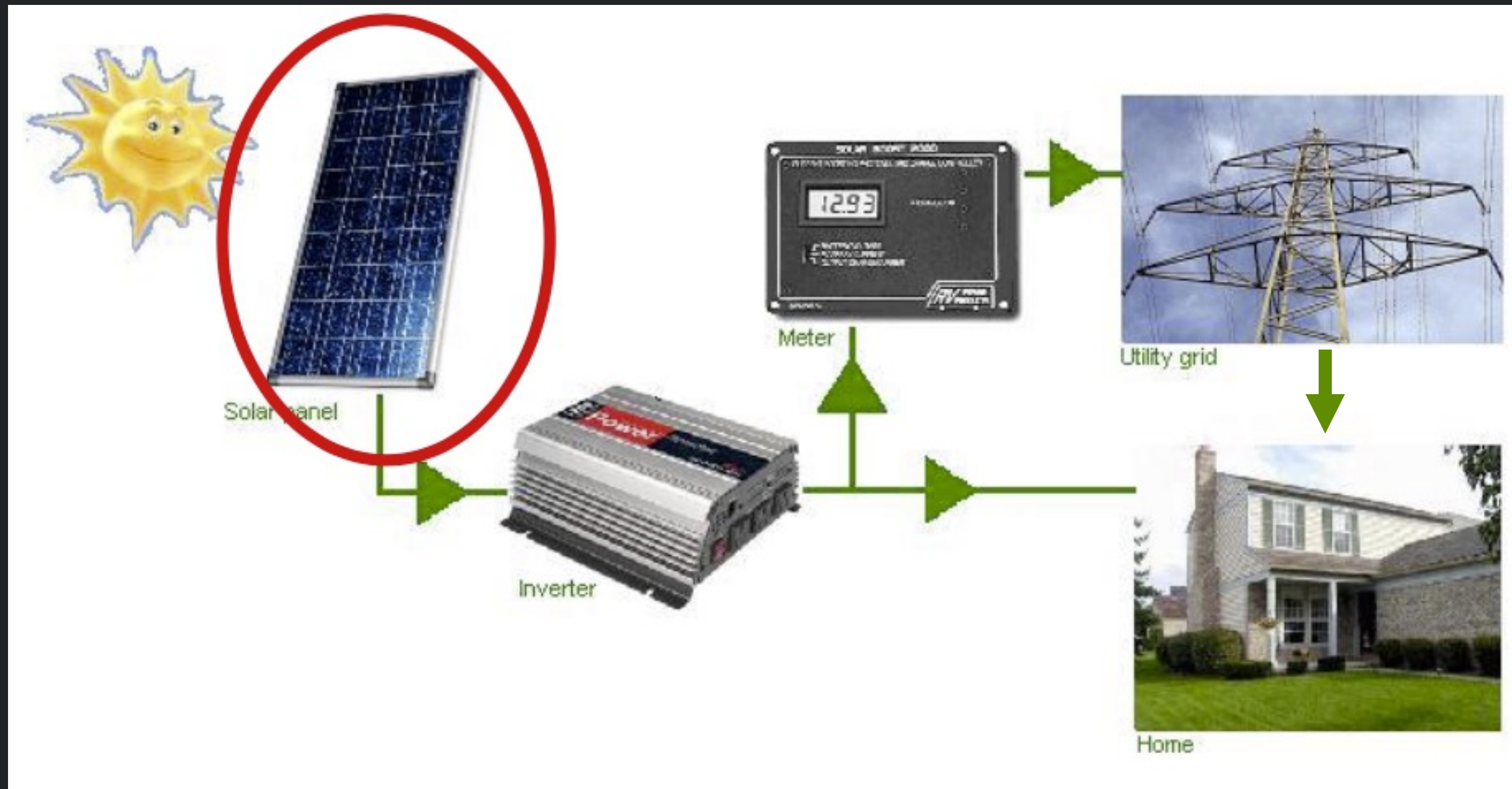
Ir. Lesnanto Multa Putranto, S.T., M.Eng., Ph.D., IPM., SMIEEE.

Solar Domestic Hot Water



Solar water heater with heat exchanger

Solar PV System On Grid



1. Solar PV rooftop
2. Solar PV farm



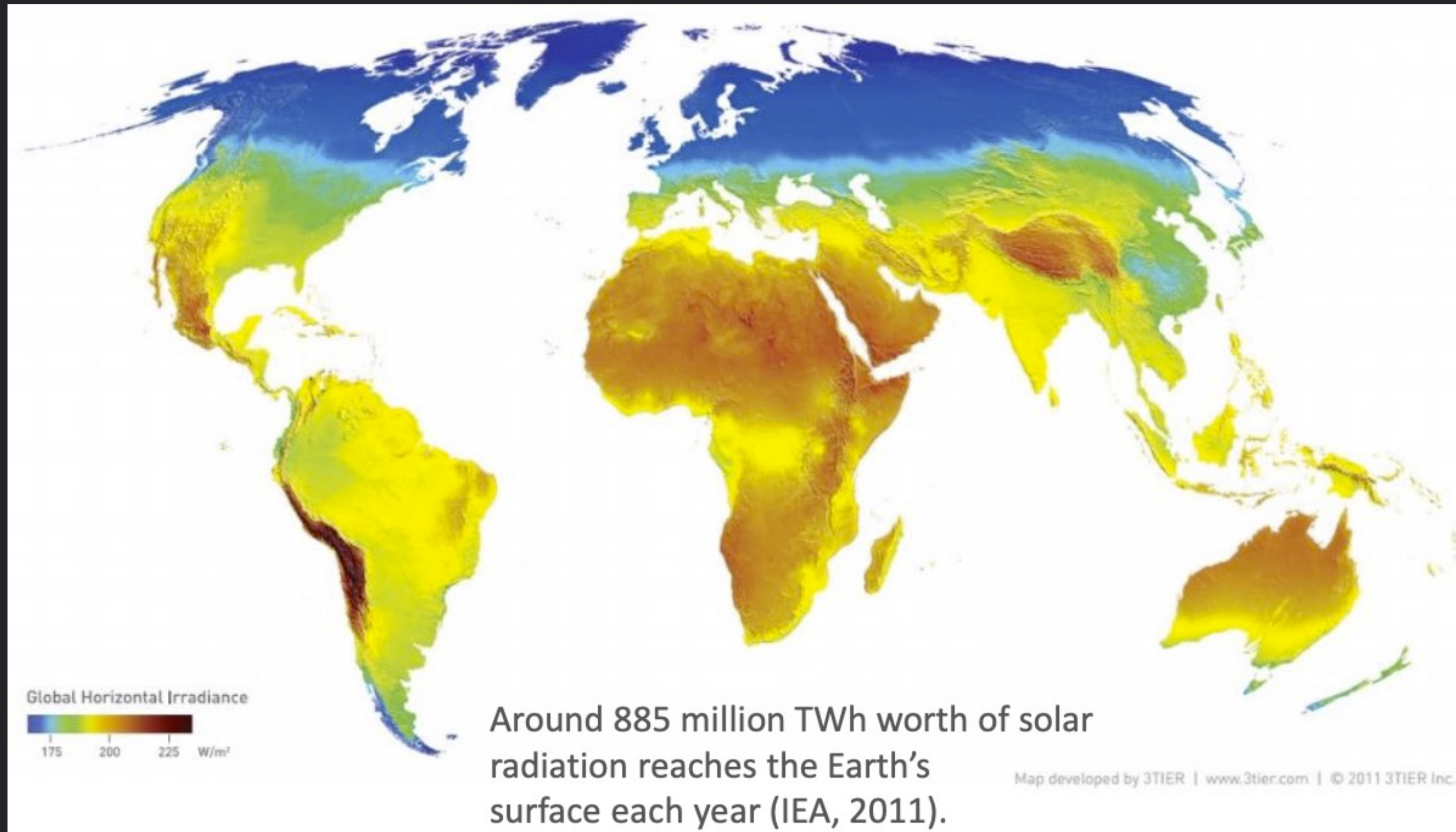
Gonghe Talatan Solar Park stands as the undisputed champion of solar installations worldwide. The site spreads over 609 km² (almost equivalent to Singapore's land area). This massive complex, located in China's Qinghai Province, has been developed in multiple phases since 2011, with continuous expansion pushing its capacity to an astounding 15.6 GW. The facility includes over 7.2 million solar panels and incorporates various panel designs for testing and optimization purposes.



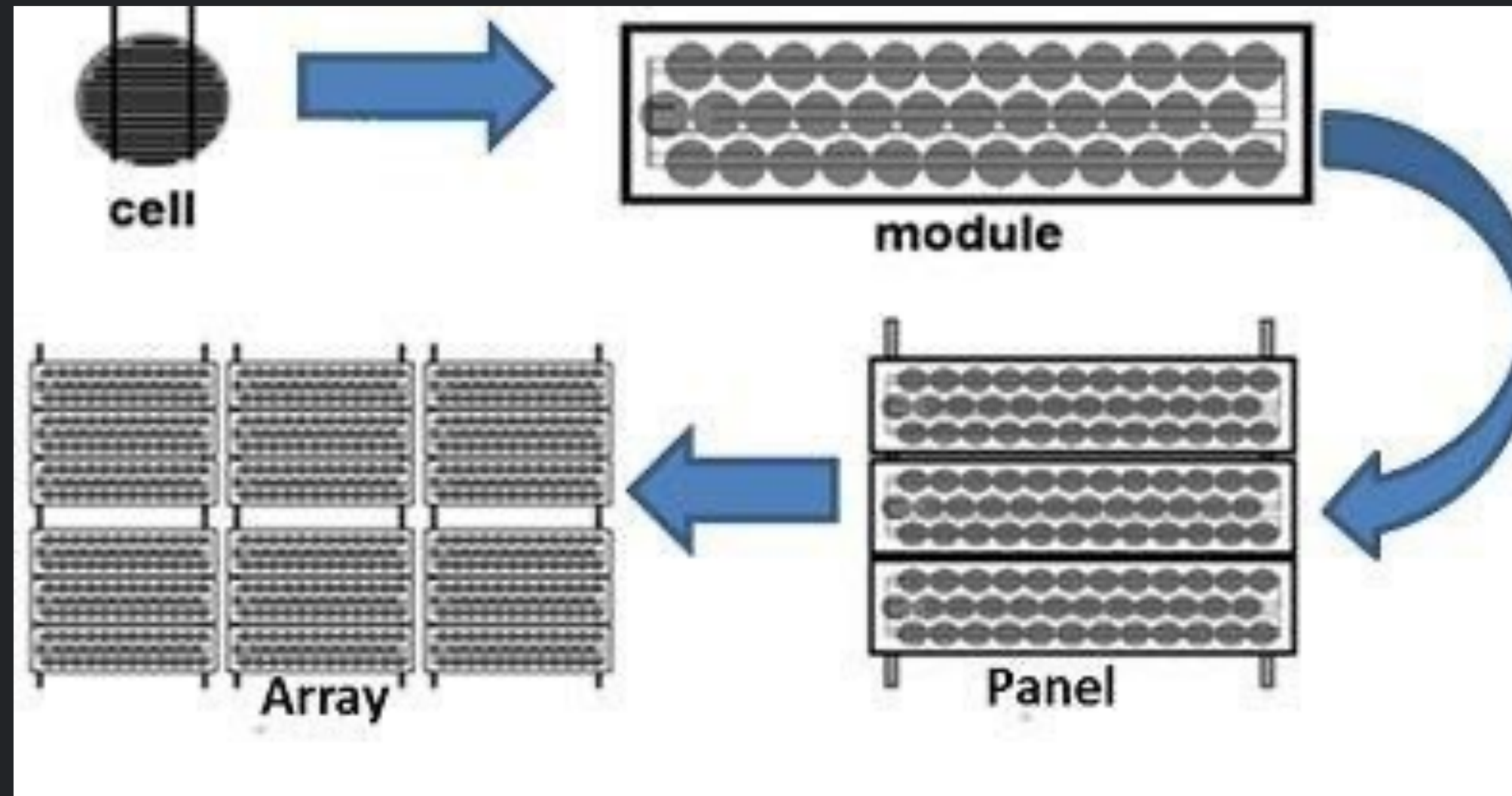
The largest solar power plant in Indonesia is currently the **Cirata Floating Solar Plant** in Purwakarta, West Java. It has an installed capacity of **192 MWp**, occupying about **250 hectares** over the Cirata Reservoir, and is capable of powering over **50,000 households** annually. Developed through a collaboration involving PLN and Masdar, it is also Southeast Asia's largest floating solar plant.

(The Jakarta Post)

Global Mean Solar Irradiance

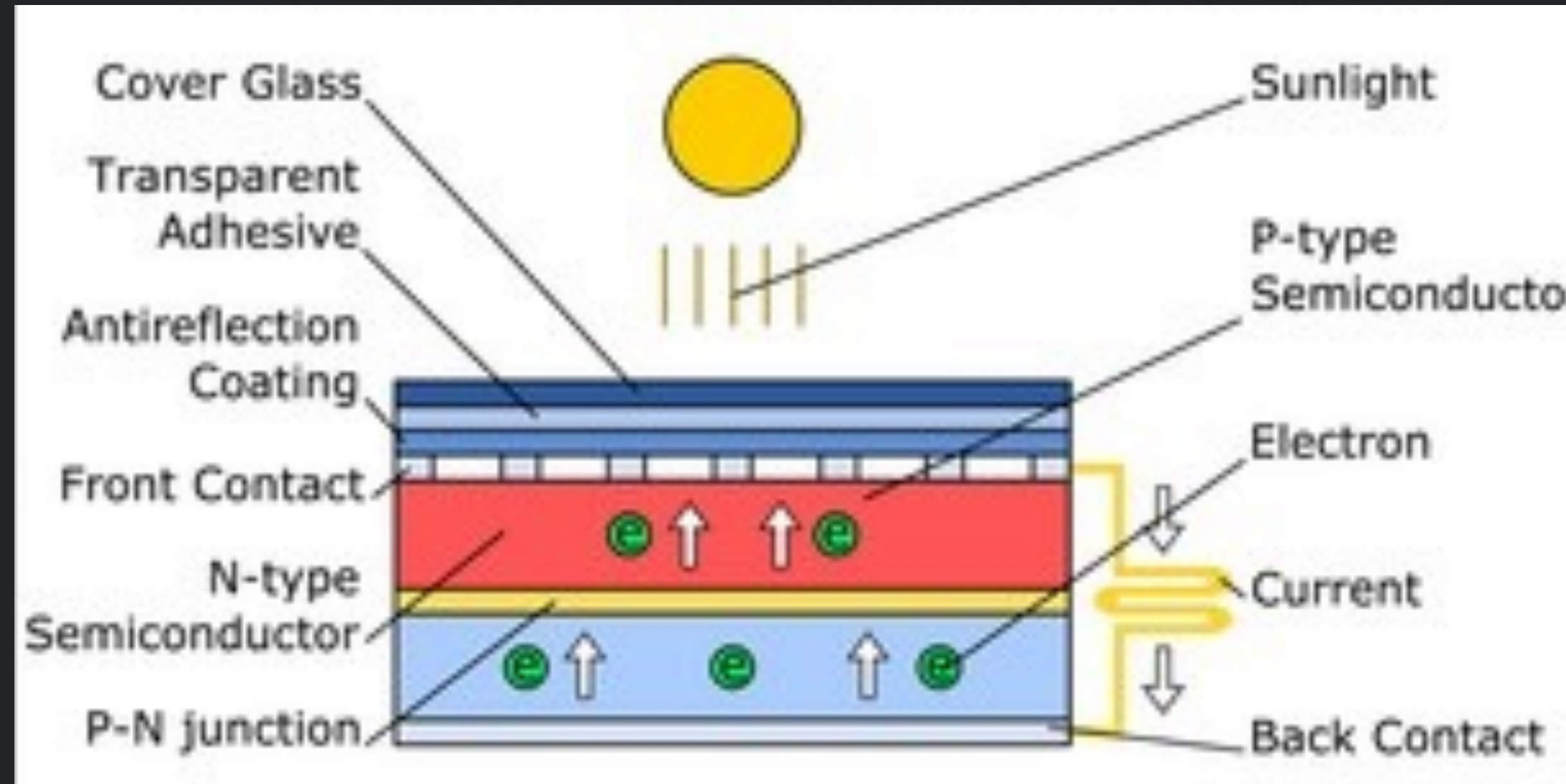


Photovoltaic (PV) Hierarchy



Cell < Module < Panel < Array

Inside of PV Cell



Solar cells consist of two layers of semiconductor material with opposite charges. Sunlight hitting the surface of a cell causes electrons to be knocked loose, which then travel through a circuit from one layer to the other, generating a flow of electricity.

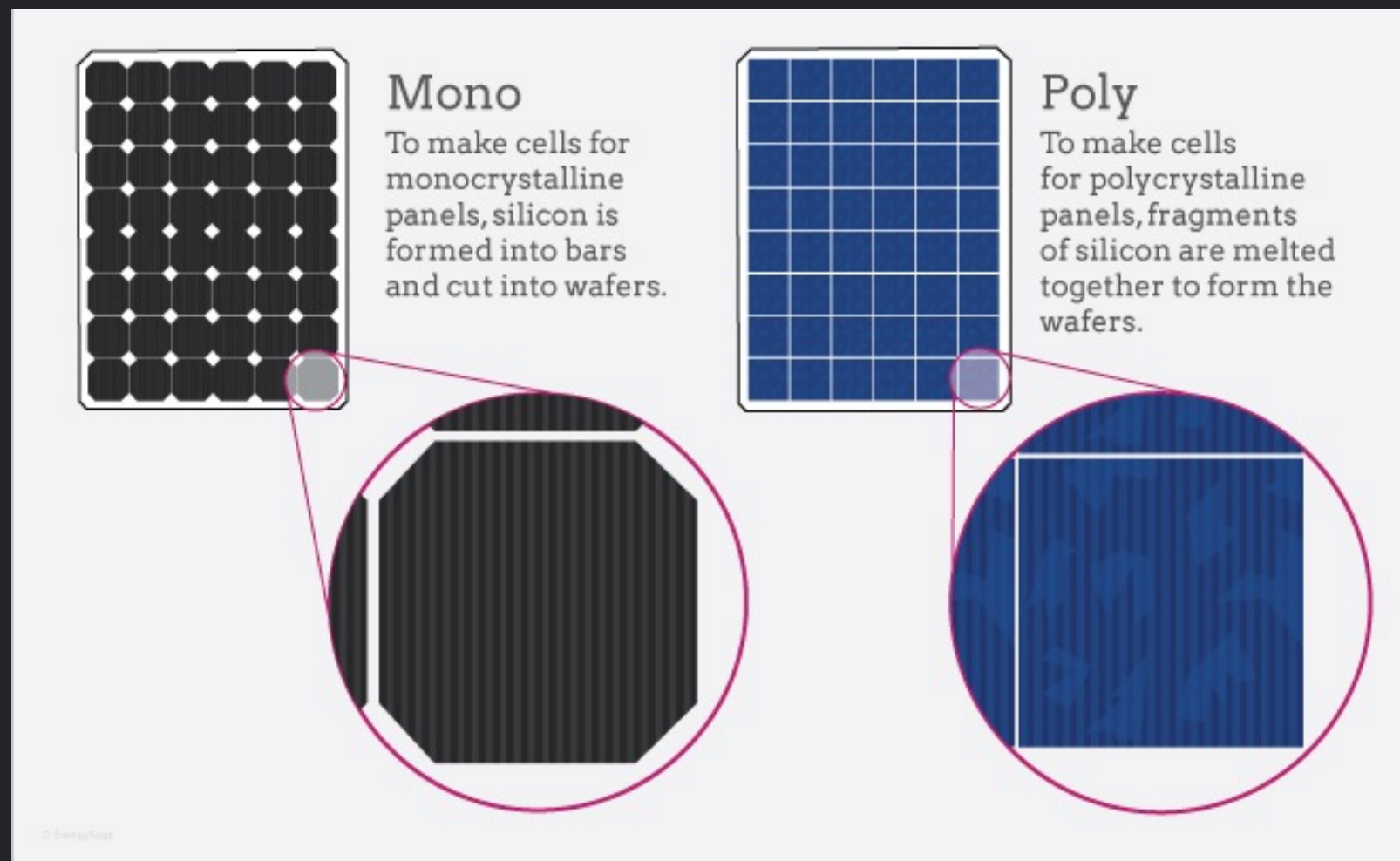


PV SYSTEMS TECHNOLOGIES

PV Systems Technology



1st Generation



Crystalline silicon cells are classified into three main types depending on how the Si wafers are made :

- Monocrystalline (Mono c-Si), sometimes also called single crystalline (sc-Si)
- Polycrystalline (Poly c-Si), sometimes referred to as multi-crystalline (mc-Si)
- EFG ribbon silicon and silicon sheet-defined film growth (EFG ribbon-sheet c-Si)

The manufacturing process of wafer-based silicon PV modules comprises four steps:

Polysilicon production;

1. Polysilicon production;
2. Ingot/wafer production;
3. Cell production; and
4. Module assembly.



Monocrystalline Modules

- Most efficient commercially available module (11% - 14%)
- Most expensive to produce
- Circular (square-round) cell creates wasted space on module.

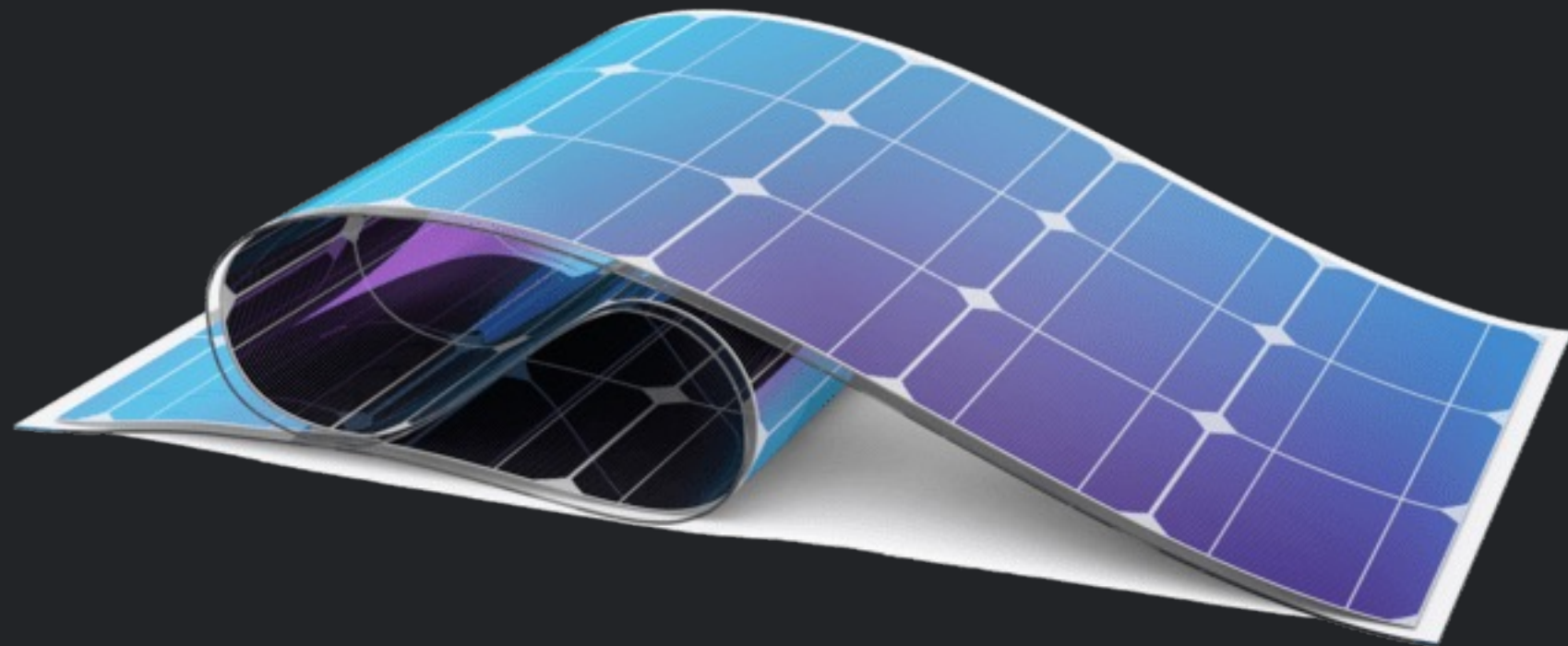
Polycrystalline Silicon Modules

- Less expensive to produce than single crystalline modules.
- Cells are slightly less efficient than single crystalline ones (10% - 12%).
- Square-shaped cells fit into the module efficiently, using the entire space.

PV Systems Technology

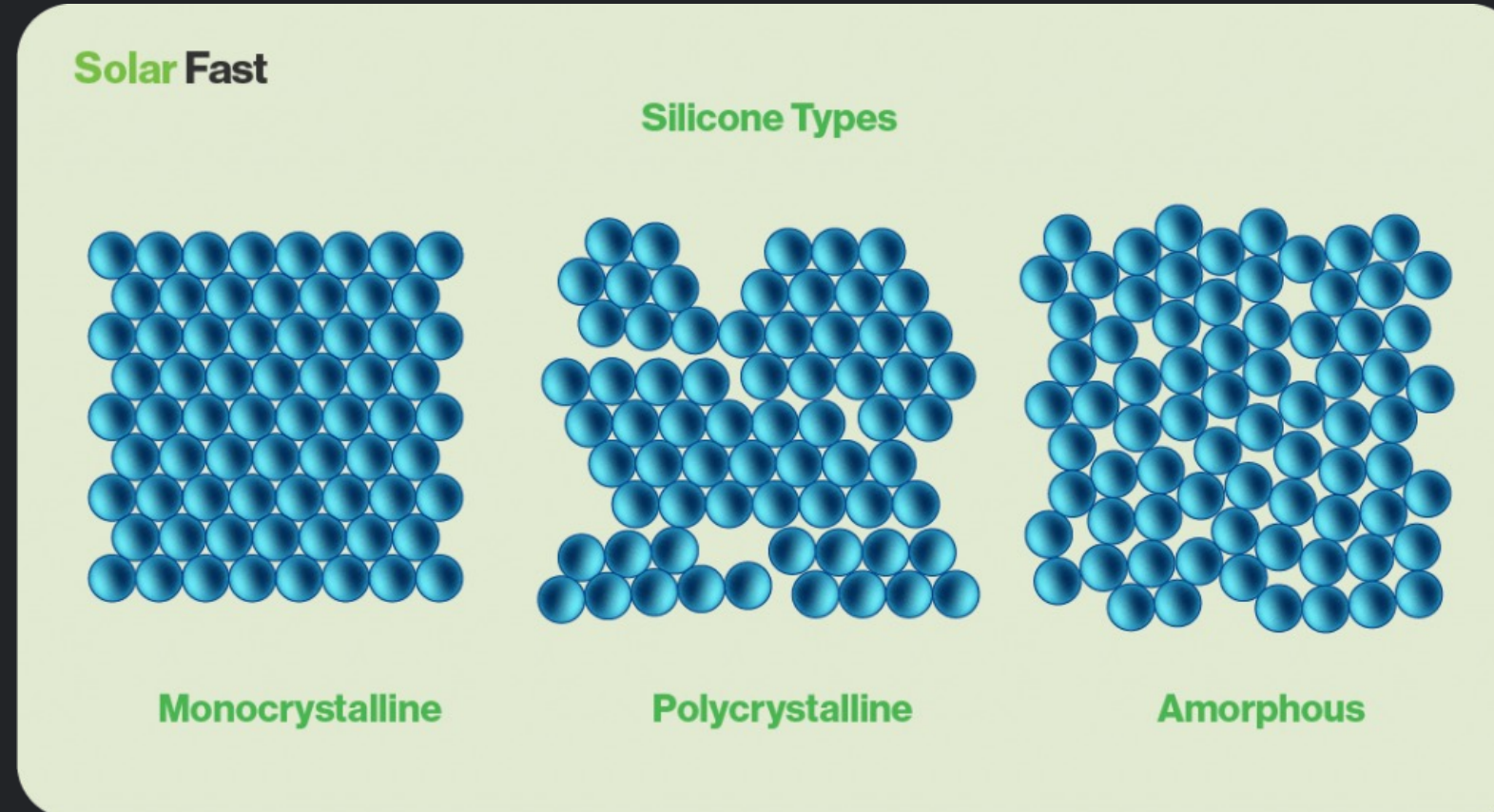


2nd Generation: Thin Film



- Require **a lot less semiconductor material** to manufacture in order to absorb the same amount of sunlight (up to 99% less material than crystalline solar cells).
- Thin films can be packaged into **flexible and lightweight structures**, which can be easily integrated into building components.
- The three primary types of thin-film solar cells that have been commercially developed are:
 1. Amorphous silicon (a-Si and a-Si/ μ c-Si);
 2. Cadmium Telluride (Cd-Te); and
 3. Copper-Indium-Selenide (CIS) and Copper-Indium-Gallium-Diselenide (CIGS).

Amorphous Thin Film



- Most inexpensive technology to produce
- Metal grid replaced with transparent oxides
- Efficiency = 6 – 8 %
- Can be deposited on flexible substrates
- Less susceptible to shading problems
- Better performance in low light conditions than with crystalline modules

PV Systems Technology



3rd Generation

There are four types of third-generation PV technologies:

➤ Concentrating PV (CPV);

- Utilise optical devices, such as lenses or mirrors, to concentrate direct solar radiation onto very small, highly efficient multi-junction solar cells made of a semiconductor material.
- The sunlight concentration factor ranges from 2 to 100 suns (low-to medium-concentration) up to 1000 suns (high concentration).

➤ Dye-sensitized solar cells (DSSC);

- Use photo-electrochemical solar cells, which are based on semiconductor structures formed between a photo-sensitised anode and an electrolyte.
- Use **low-cost materials and are simple** to manufacture.

➤ Organic solar cells;

- composed of organic or polymer materials (such as organic polymers or small organic molecules); inexpensive but not efficient

➤ Novel and emerging solar cell concepts.

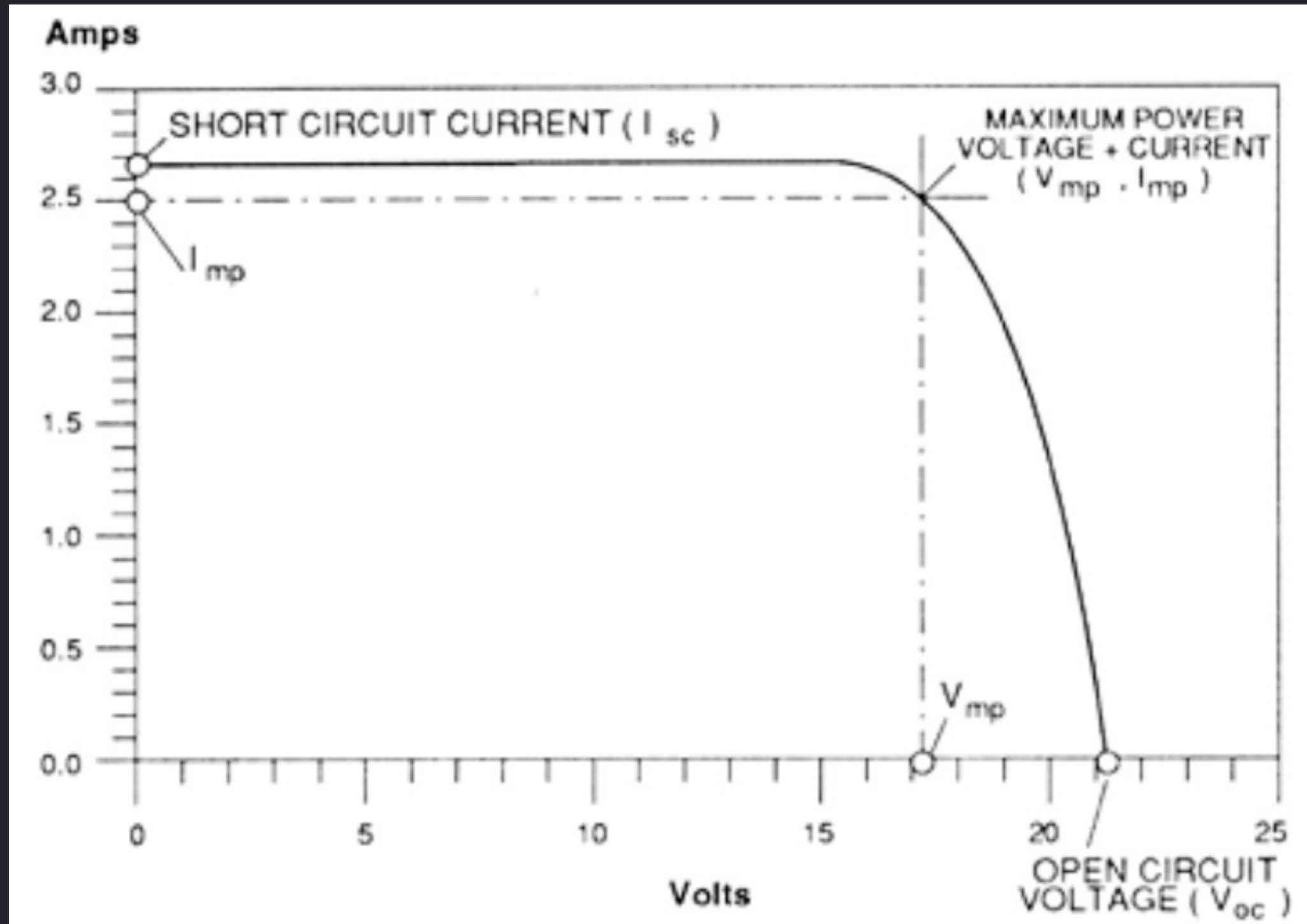
Selecting the Correct Module



Practical Criteria

- Size
- Voltage
- Availability
- Warranty
- Mounting Characteristics
- Cost (per watt)

Current Voltage (I-V) Curve





Current Voltage (I-V) Curve

- I_{sc} (Short Circuit Current)

The point where voltage = 0 (short circuit)

- V_{oc} (Open Circuit Voltage)

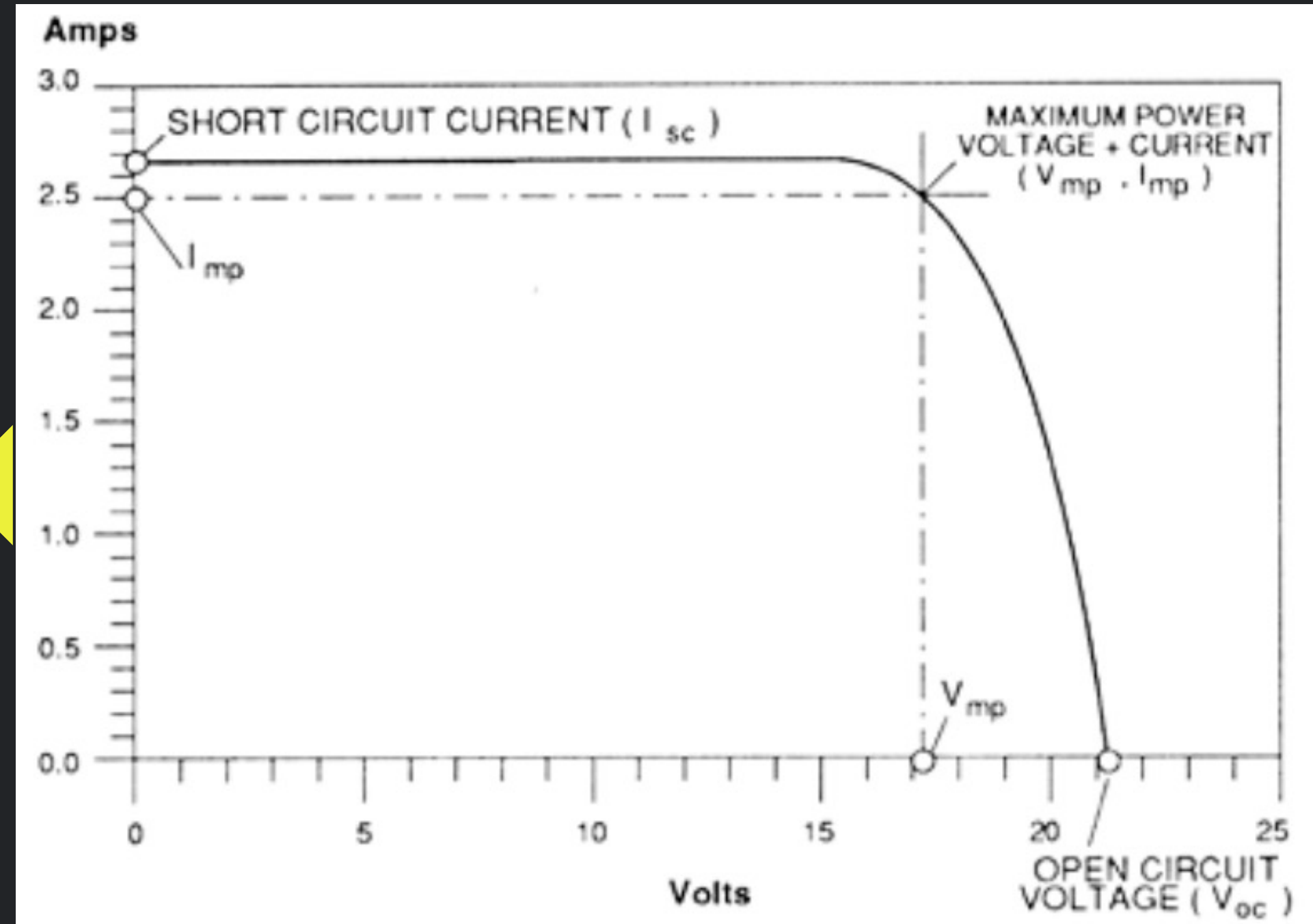
The point where current = 0 (open circuit)

- P_{max} (Maximum Power)

$$P_{max} = V_{mp} \times I_{mp}$$

- MPPT (Maximum Power Point Tracking)

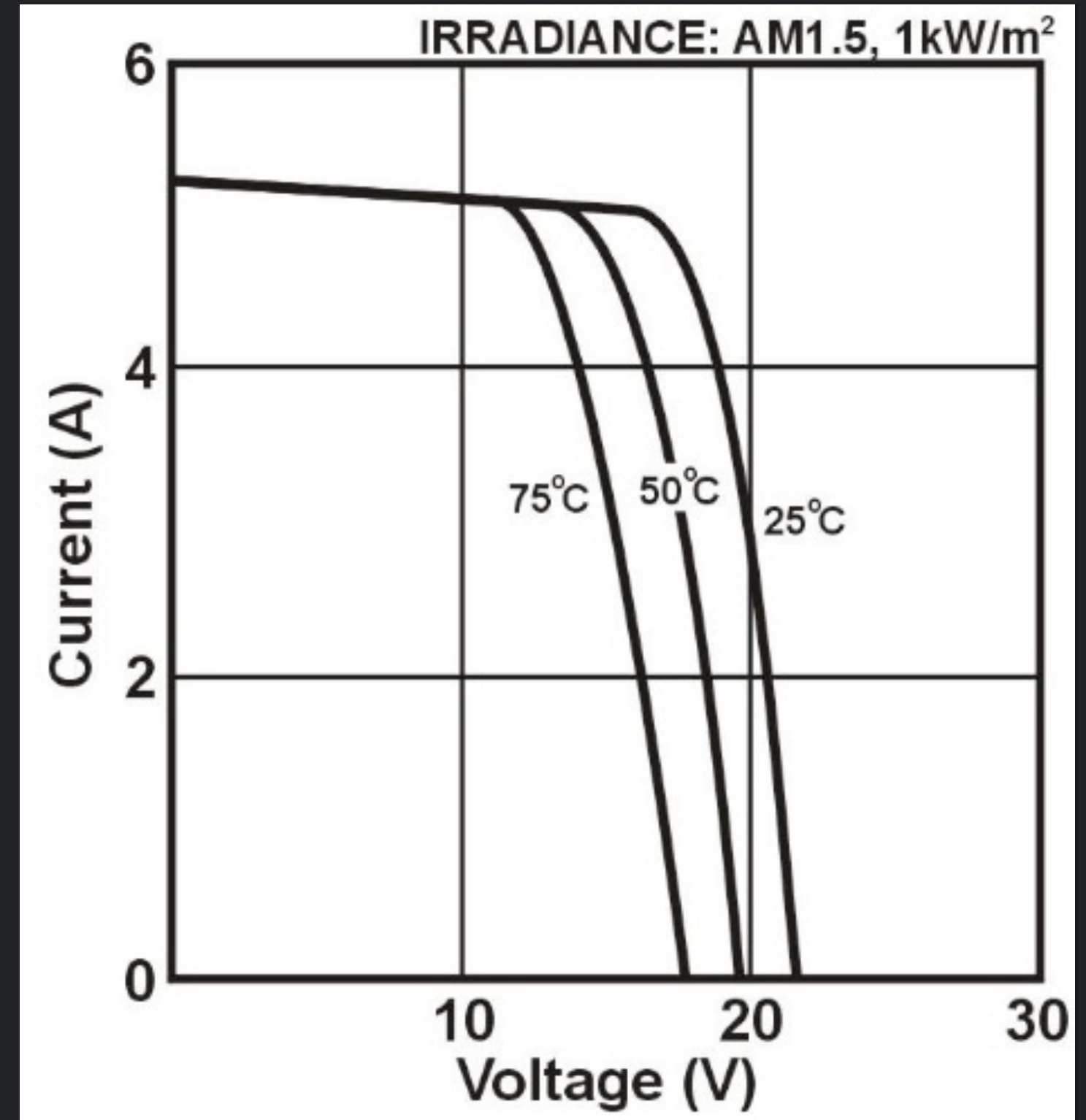
Optimizes and stabilizes the system to always operate at V_{mp} and I_{mp}





Effect of Temperature

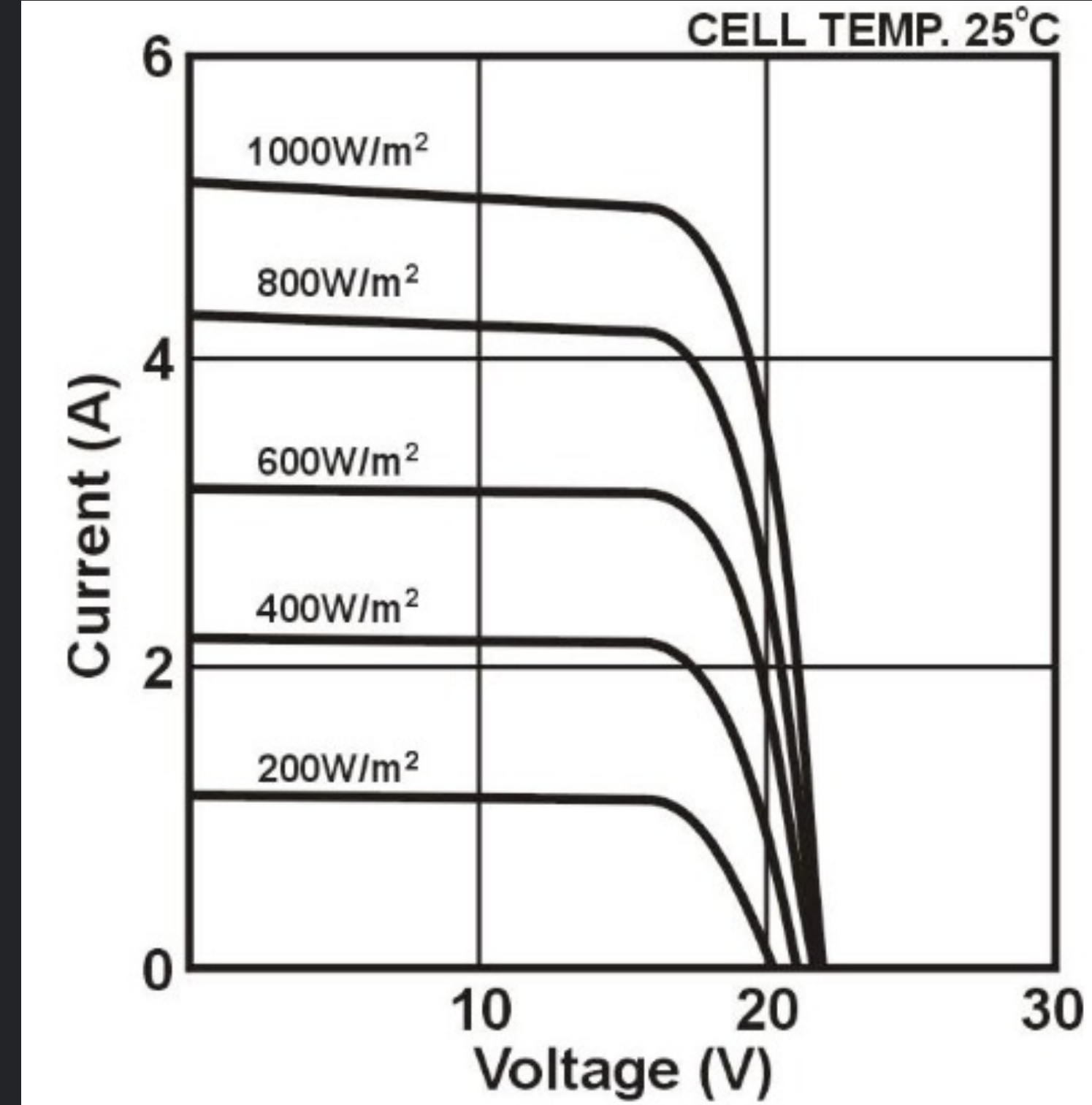
- As the PV cell temperature increases above 25°C, the module V_{mp} decreases by approximately 0.5% per °C
- PV cell produces power supplied by irradiance, not by temperature





Effect of Shading/Low Insolation

- As insolation increases, amperage increases while voltage remains roughly constant

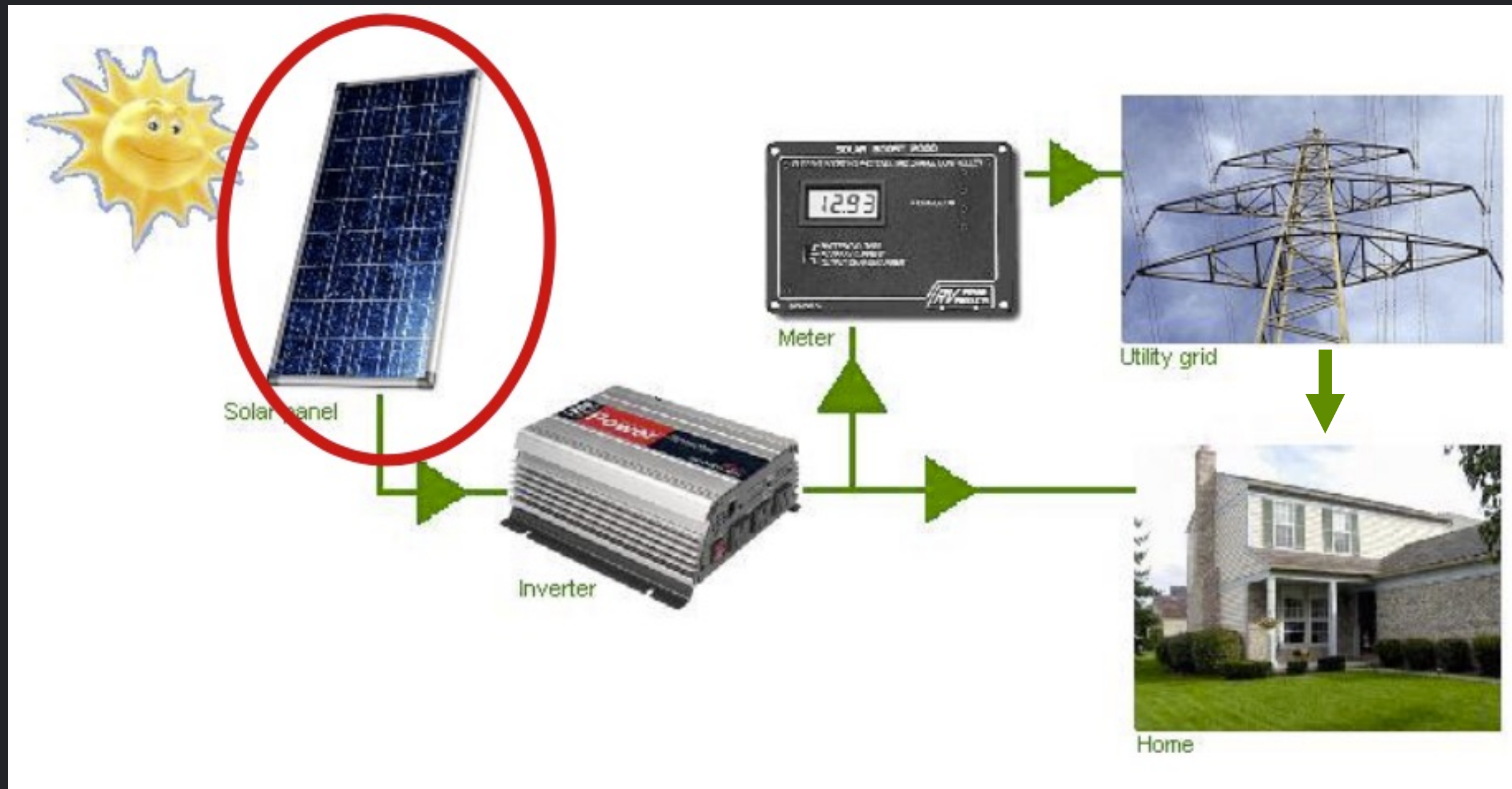




PV WIRING



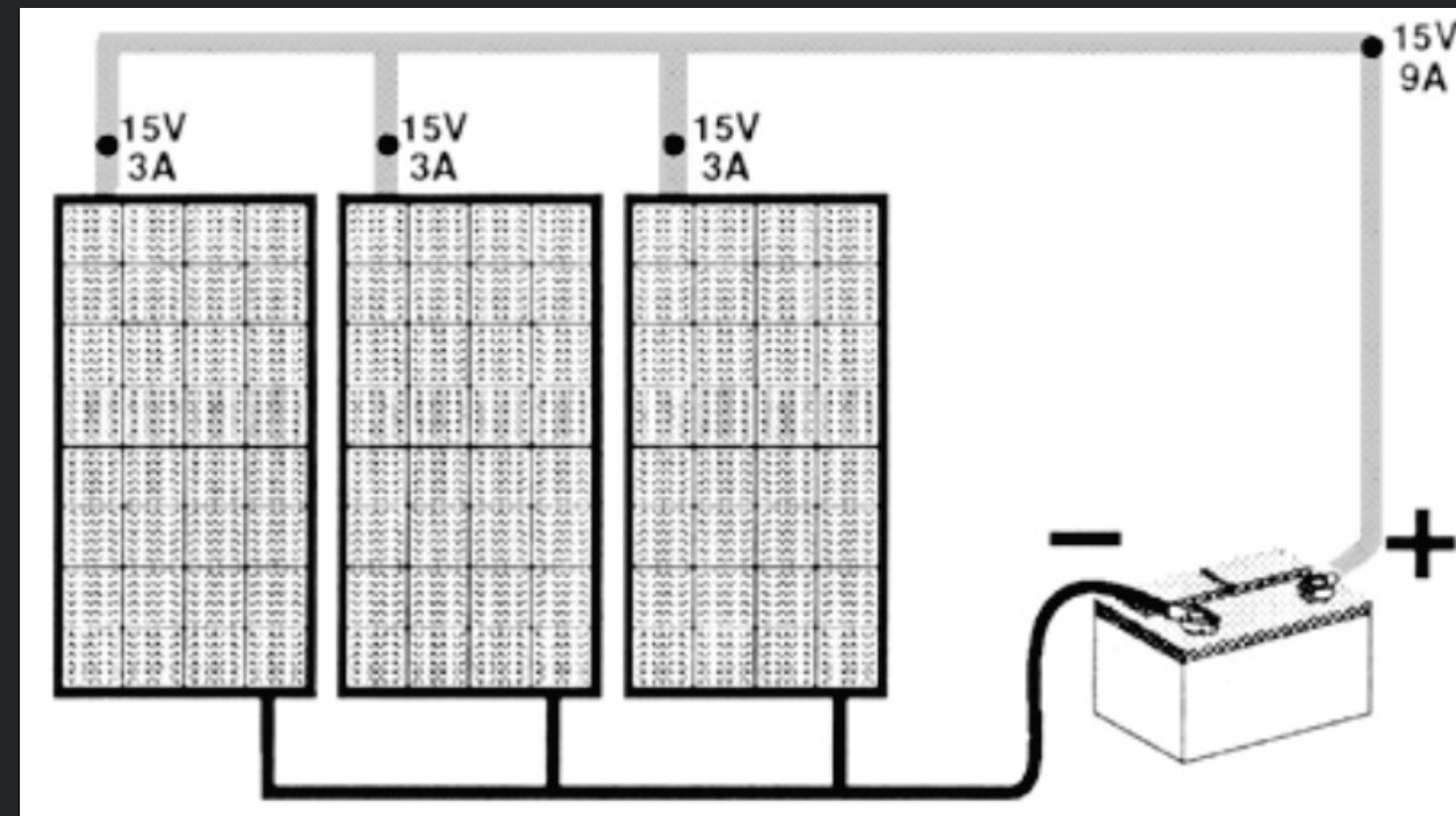
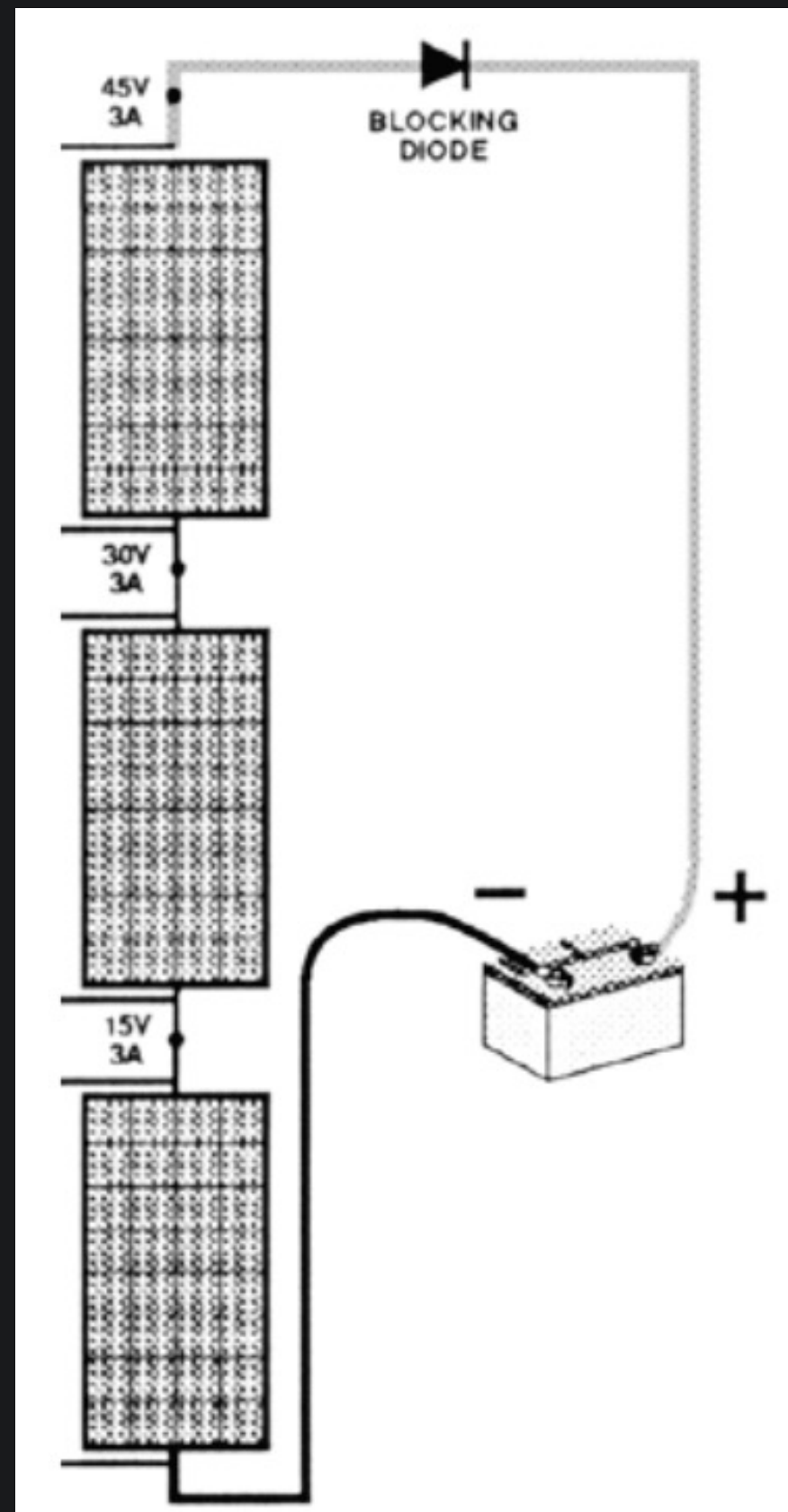
Solar PV System On Grid



PV WIRING

Loads/sources wired in series

- VOLTAGES ARE ADDITIVE
- CURRENT IS EQUAL



Loads/sources wired in parallel

- VOLTAGE REMAINS CONSTANT
- CURRENTS ARE ADDITIVE



PV ANGLE & MOUNTING



Solar Energy Source



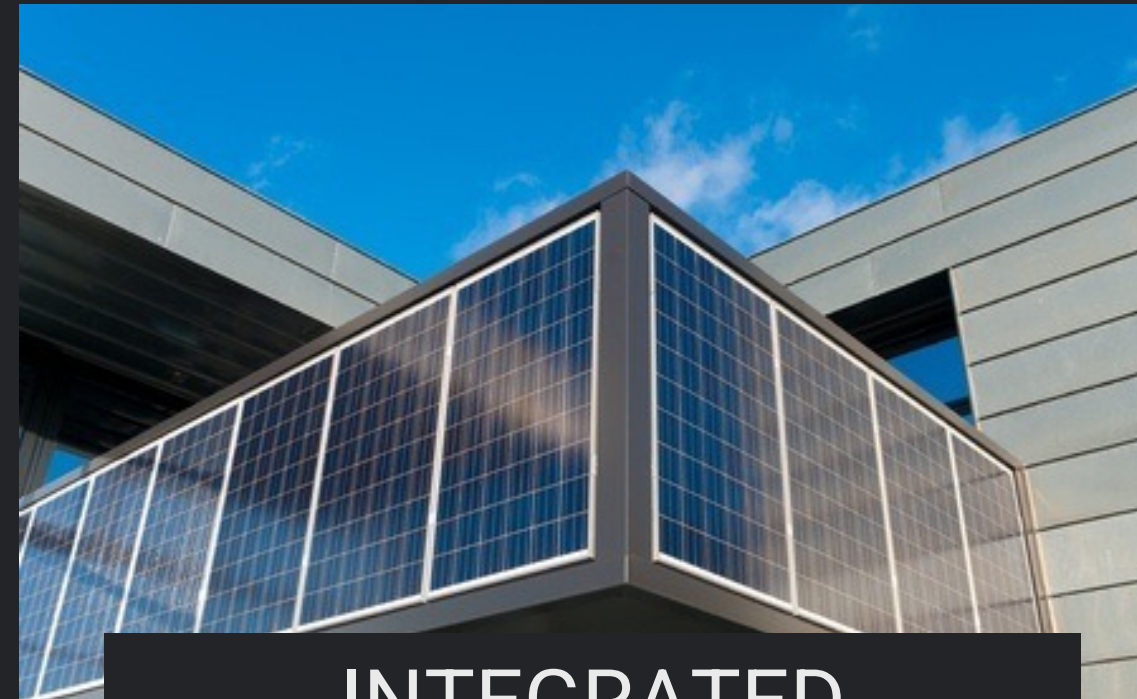
1. Understand azimuth and altitude
2. Describe the proper orientation and tilt angle for solar collection
3. Describe the concept of “solar window”
4. Evaluate structural considerations
5. Pros and cons of different mounting techniques

Basic Mounting



FIXED

- Roof
- Ground
- Pole



INTEGRATED



TRACKING

- Pole Active
- Pole Pasive



END