ECE 530: Contemporary Energy Applications

Solar

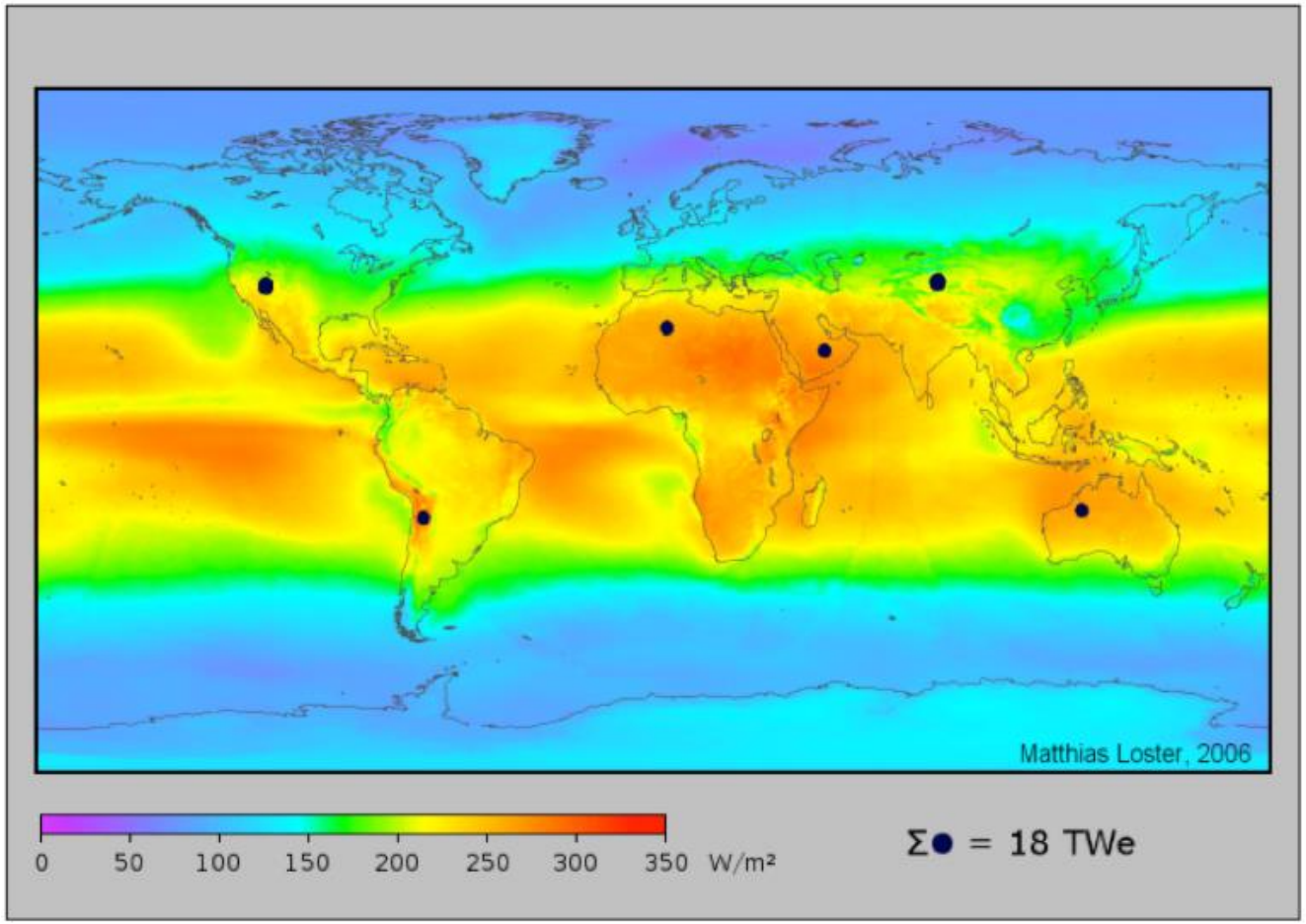
Monocrystalline

Polycrystalline

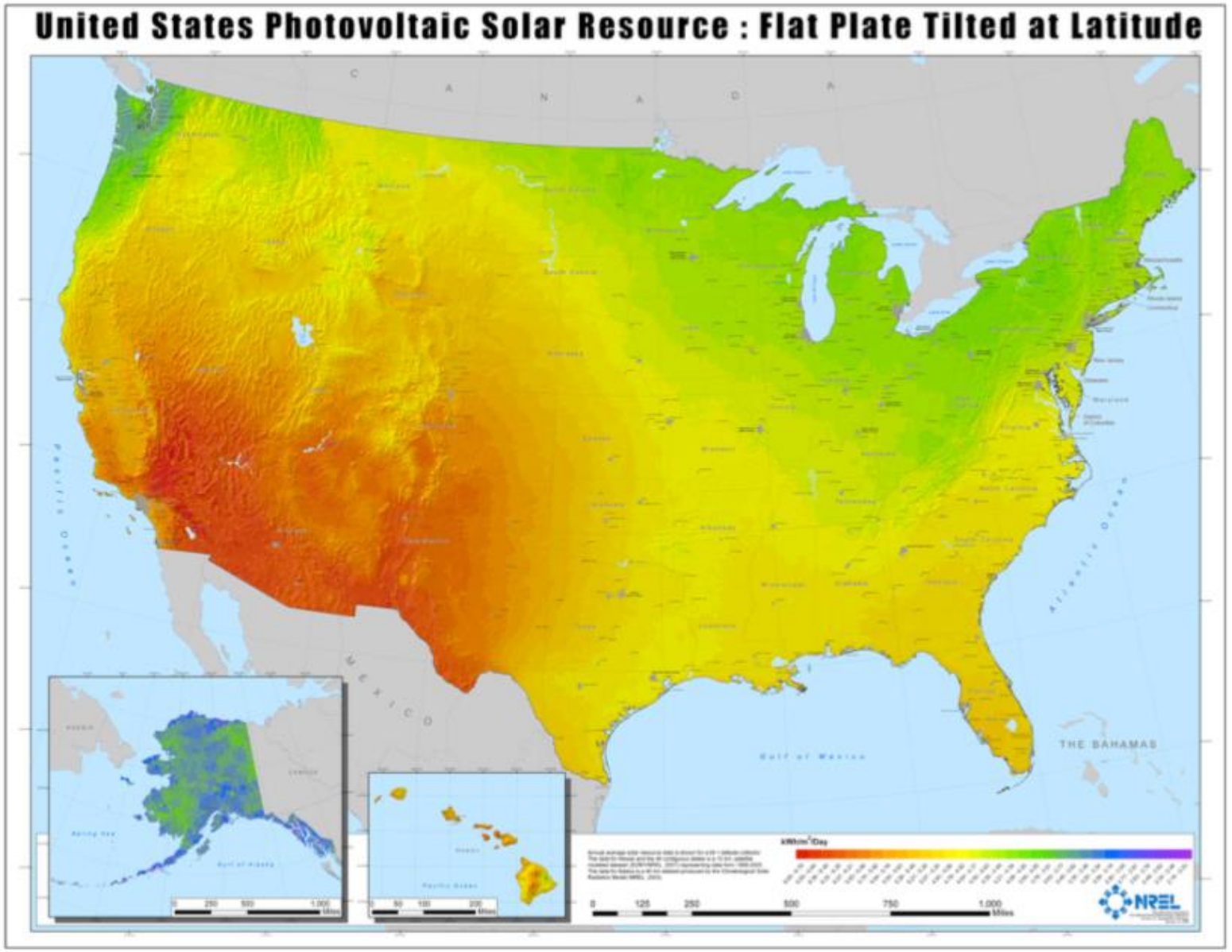
Thin Film

Resource

- Approximately 25% of incoming solar radiation is reflected and absorbed by atmosphere. An additional 25\% is absorbed and reflected by clouds, dust, and pollution.
- North American annual average of 125 to 375 W/m^2.
- Peak instantaneous radiation is around 1 kW/m^2.



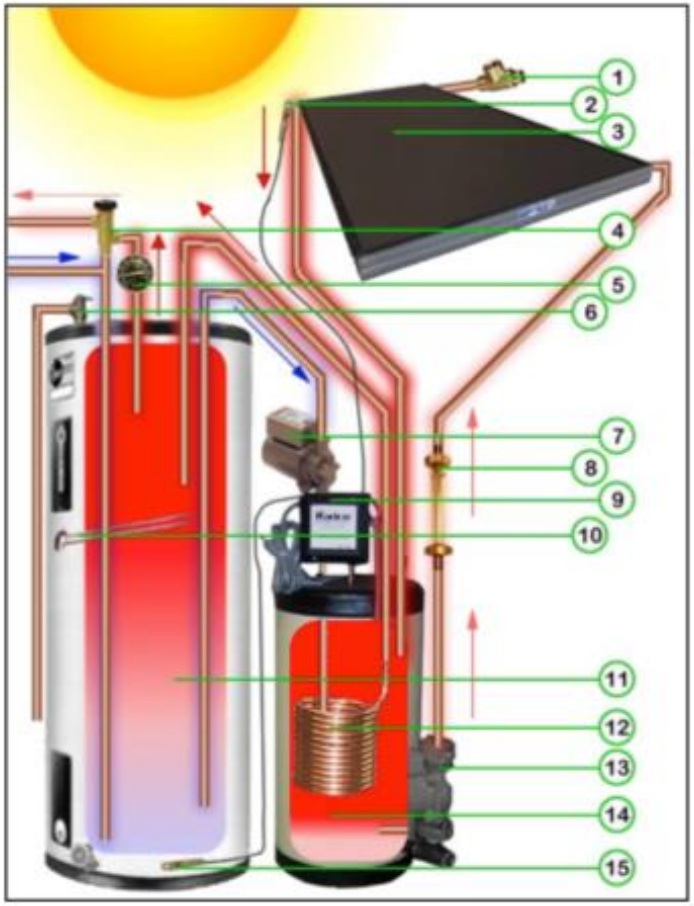
US Resource


United States Photovoltaic Solar Resource : Flat Plate Tilted at Latitude
THE BAHAMAS
NREL

Technology

15% to 20%

- Can be active or passive. Passive includes water heating, south-facing windows, lighting, cooking.
- Solar panels are about 15% efficient in their conversion. Assuming 125 to 375 W/m² in the US, an average solar panel will have a power output of 19 to 56 W/m² (annual average).
- Biomass is also stored solar energy but converts at only 0.2 to 2 %.



SPR-220 HIGH EFFICIENCY PV MODULE
Unprecedented power density and exceptional energy production per peak kW

Solar Thermal

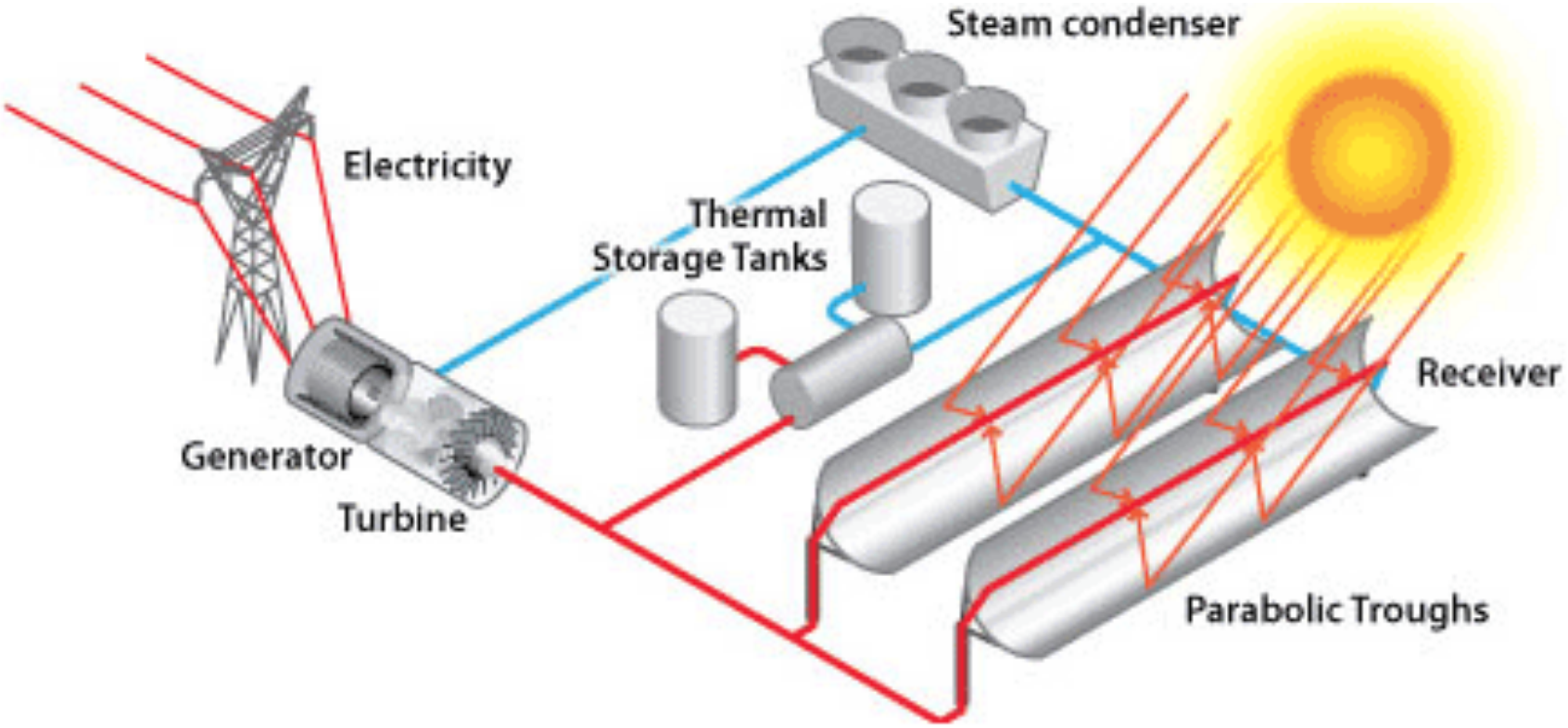
Non Photovolt Tech

[http://www.renewables-made-in-germany.com/es/renewables-made-in-germany/corporate-news/detail/article/ultimate-troughR-the-next-generation-collector-for-parabolic-trough-power-plants-first-demonstra.html]

Solar Thermal

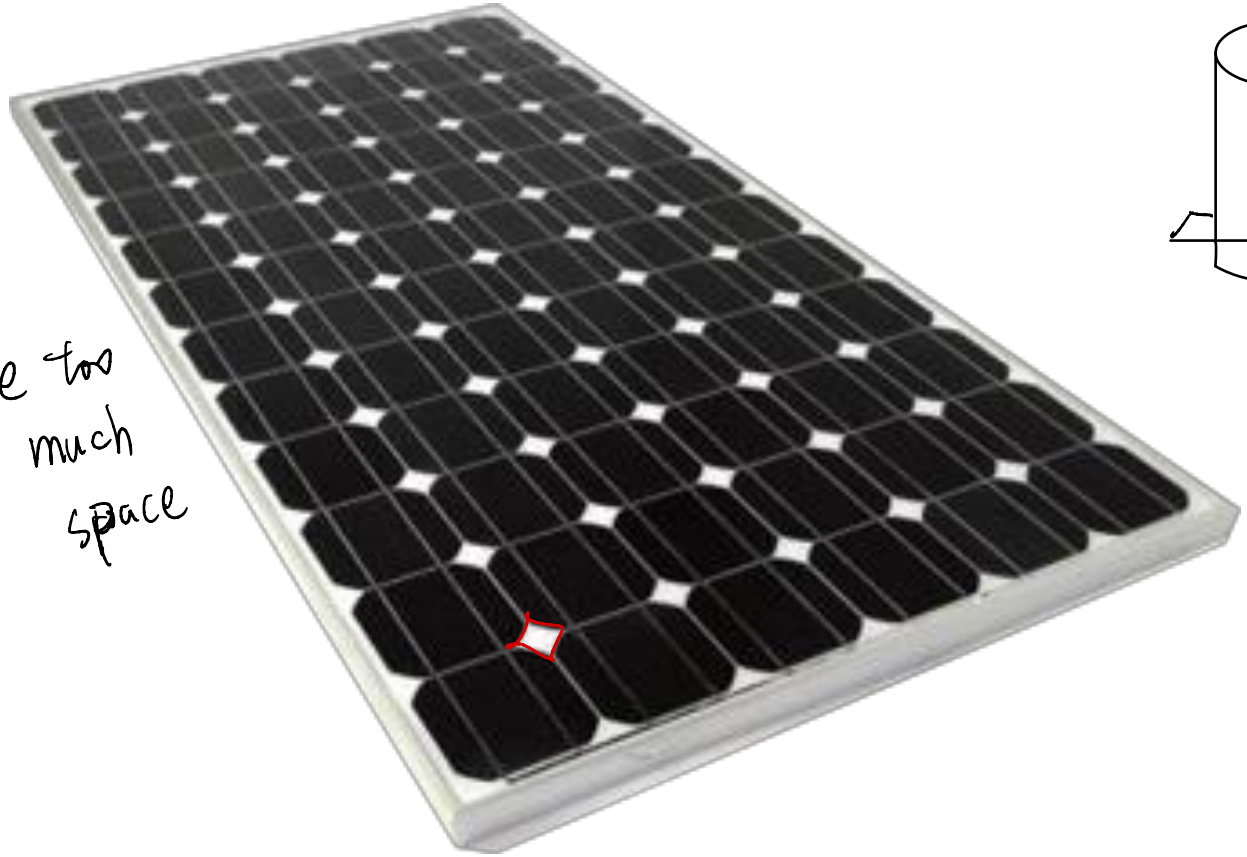
Solar Thermal

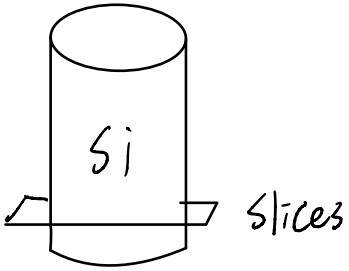
- Essentially a thermal plant (i.e., steam turbine)
- Storage for several hours.

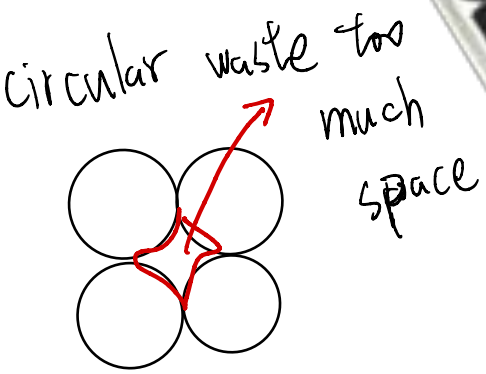


Photocell Technology: Monocrystalline

- Oldest PV technology
- Highest grade silicon, and highest efficiency
- Most expensive $$$

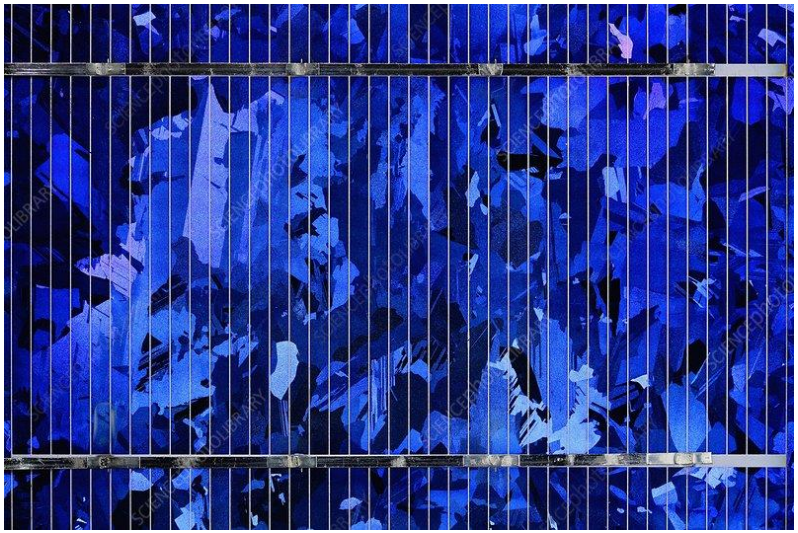






Photocell Technology: Polycrystalline

- Cheaper, less waste $$
- Efficiencies around 15%

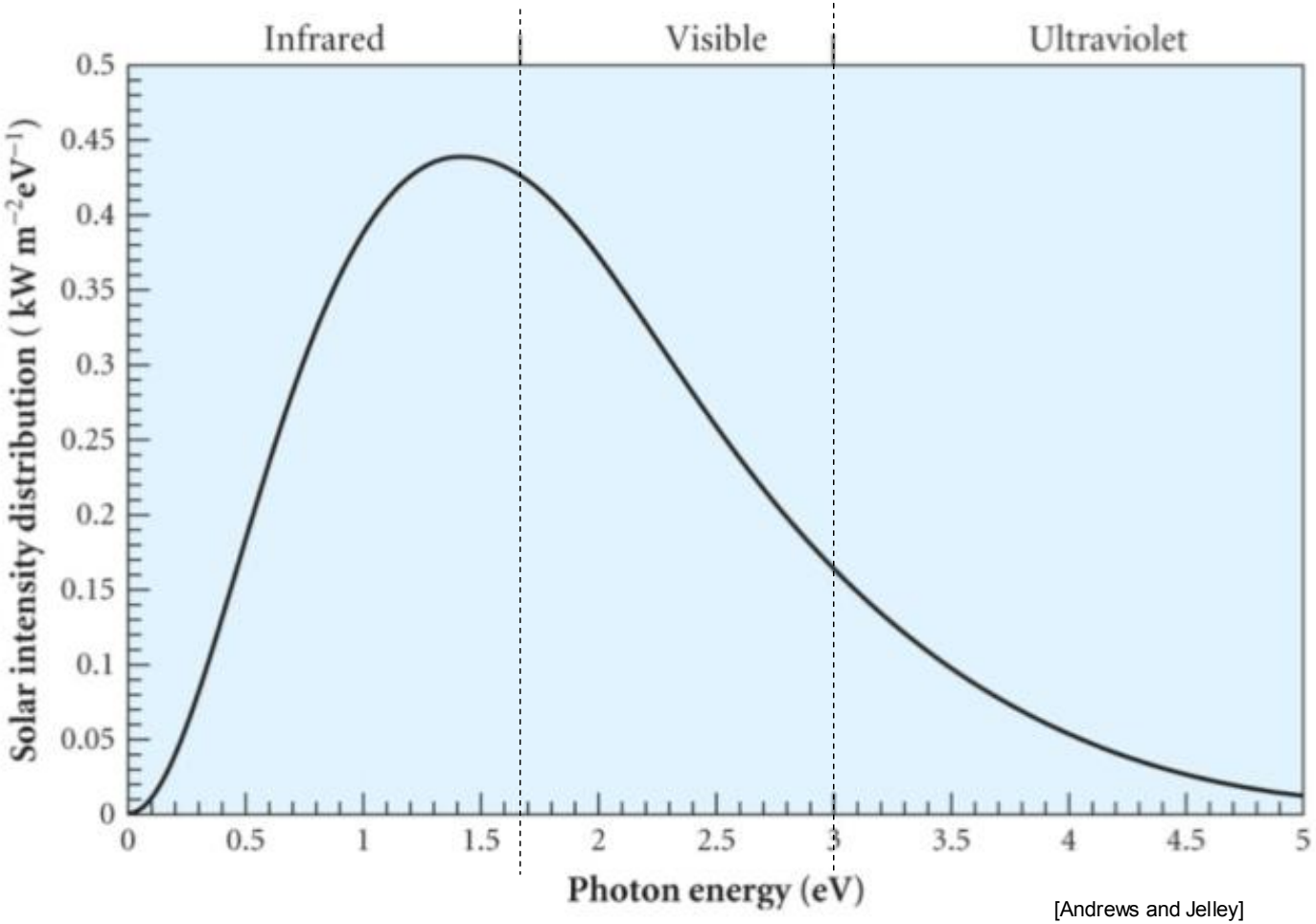


Photocell Technology: Thin Film

- Potentially cheapest $
- Lowest efficiency
- Can be made flexible
- Shorter lifetime

Solar Spectrum

- Most of the solar radiation is focused at the high end of infrared and the low end of the visible spectrum.
- Radiation is either direct (focusable) or diffuse (unfocusable). Typically about 30% is diffuse.



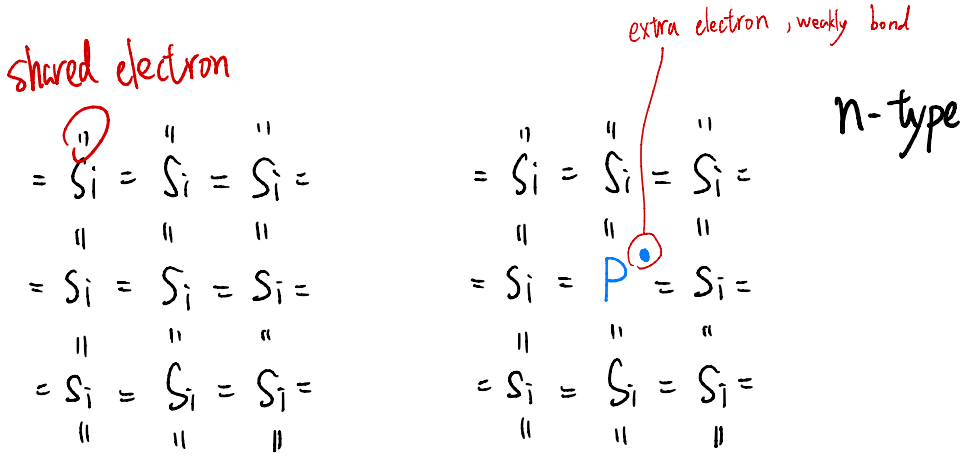
[Andrews and Jelley]

Doping

- Doping adds either a weakly bound electron that is easily promoted to the conduction band (n type), or a spot for an electric to easily fall into the valence band (p type).

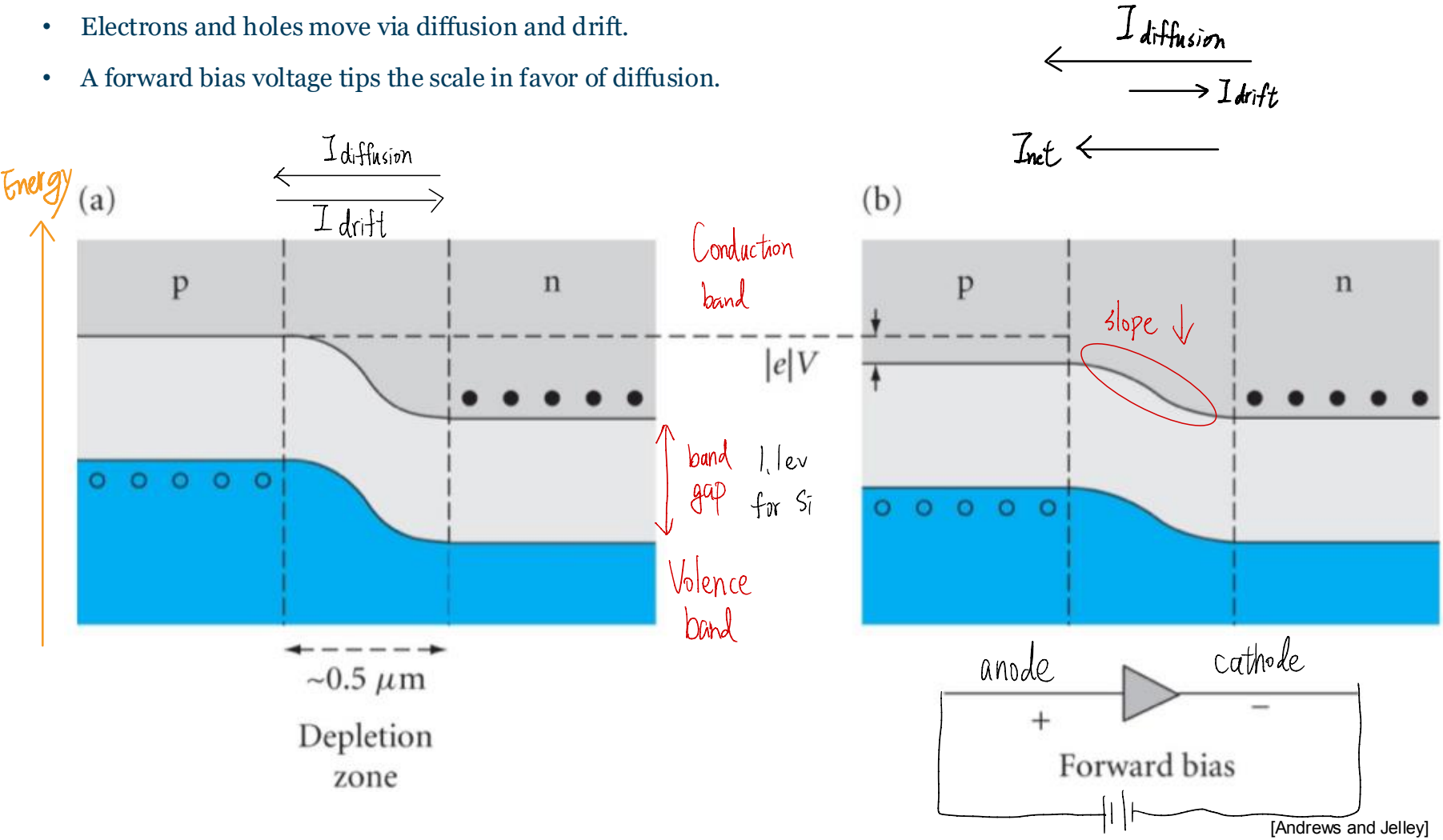
extra hole

extra electron



PN Junction

- A PN junction is the back to back connection of a p-type semiconductor and an n-type semiconductor.
- A PN junction forms a diode. Significant electric current can only flow in one direction.
- Electrons and holes move via diffusion and drift.
- A forward bias voltage tips the scale in favor of diffusion.

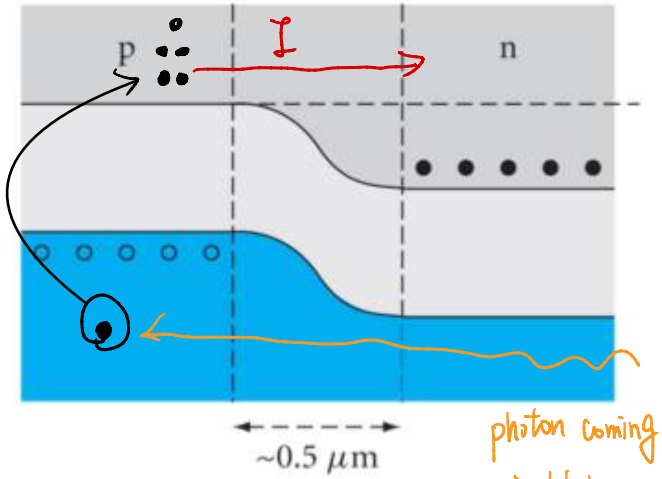


[Andrews and Jelley]

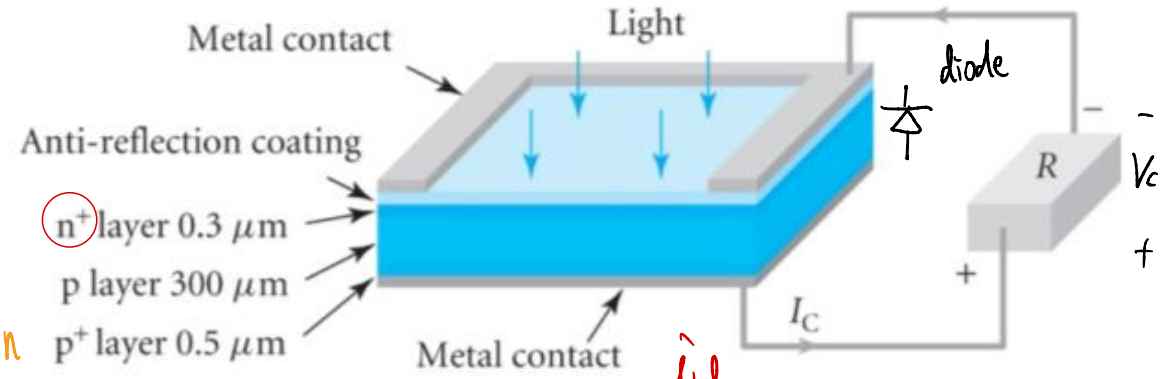
Photocells

Just a regular diode with an additional current.

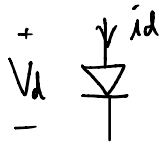
- If a photon strikes the material with an energy greater than the bandgap, an electron gets kicked up from the valence band to the conduction band. This electron is swept to the n side (anode).
- PERC (Passivated Emitter and Rear Contact) technology redirects photons back up through the p layer.
- Bifacial photocells have a clear glass backing so that photons can enter from the back.



photon coming in > 1.1eV



Recap:



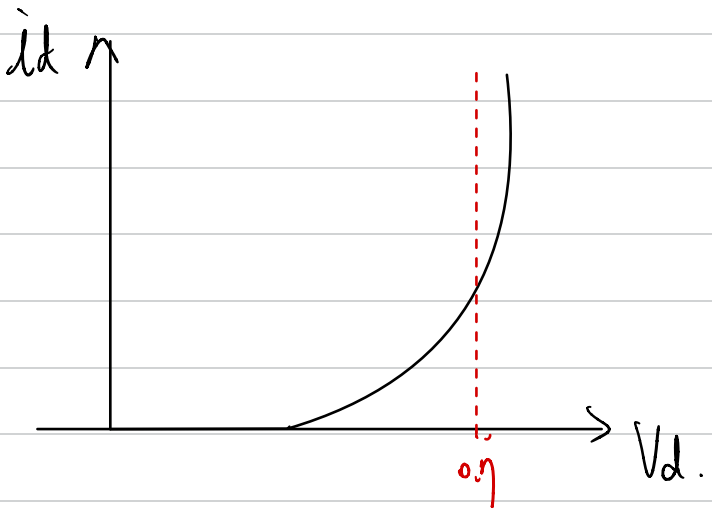
$$i_d = I_s \cdot \left(e^{\frac{V_d}{V_T}} - 1\right)$$

$$I_C = i_L - I_s\left(e^{\frac{V_d}{V_T}} - 1\right)$$

[Andrews and Jelley]

$$i_d = I_S \left(e^{V_d / V_T} \right)$$

constant

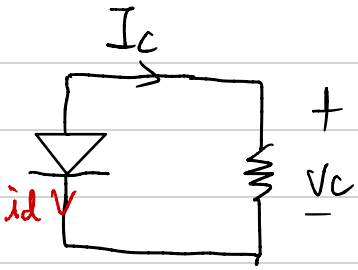


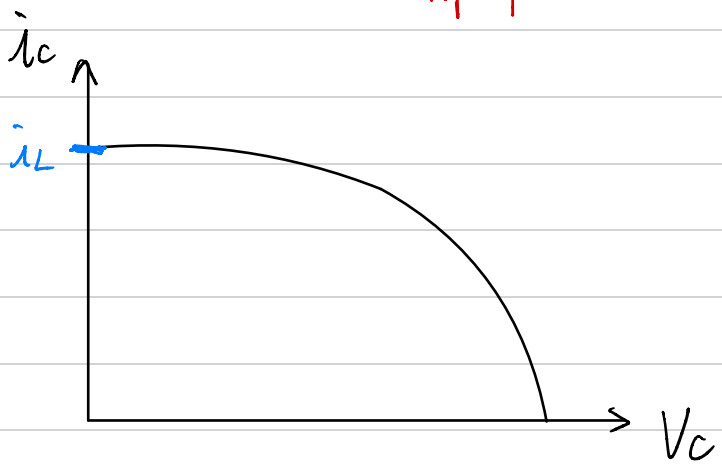
Photocell i V curve

$$i_C = i_L - I_S\left(e^{V_d/V_T} - 1\right)$$

offset

flip up side down

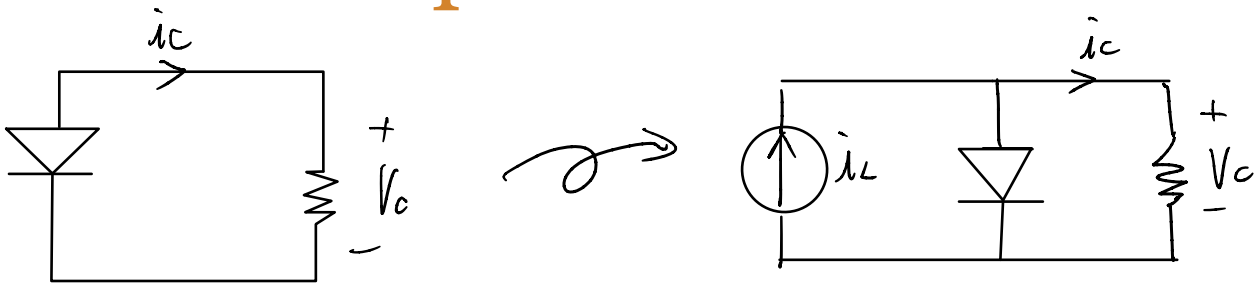


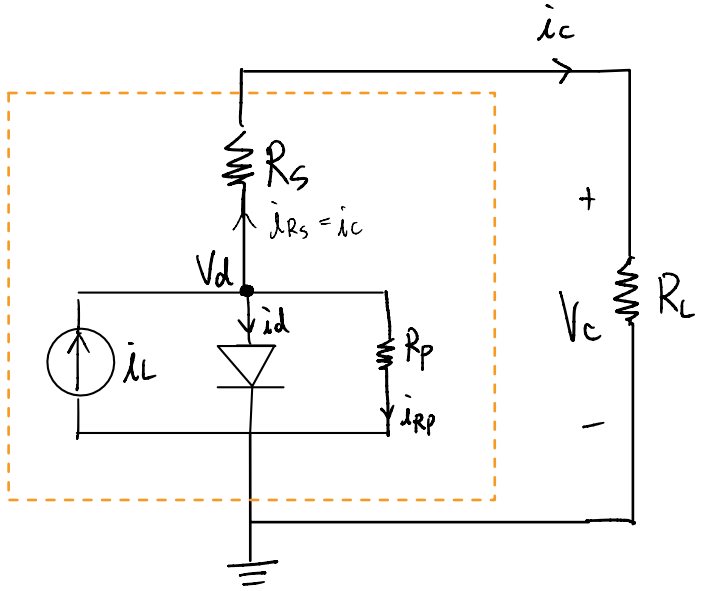


Photocell Equivalent Circuit

full sunlight

→ $i_L \sim 5A$



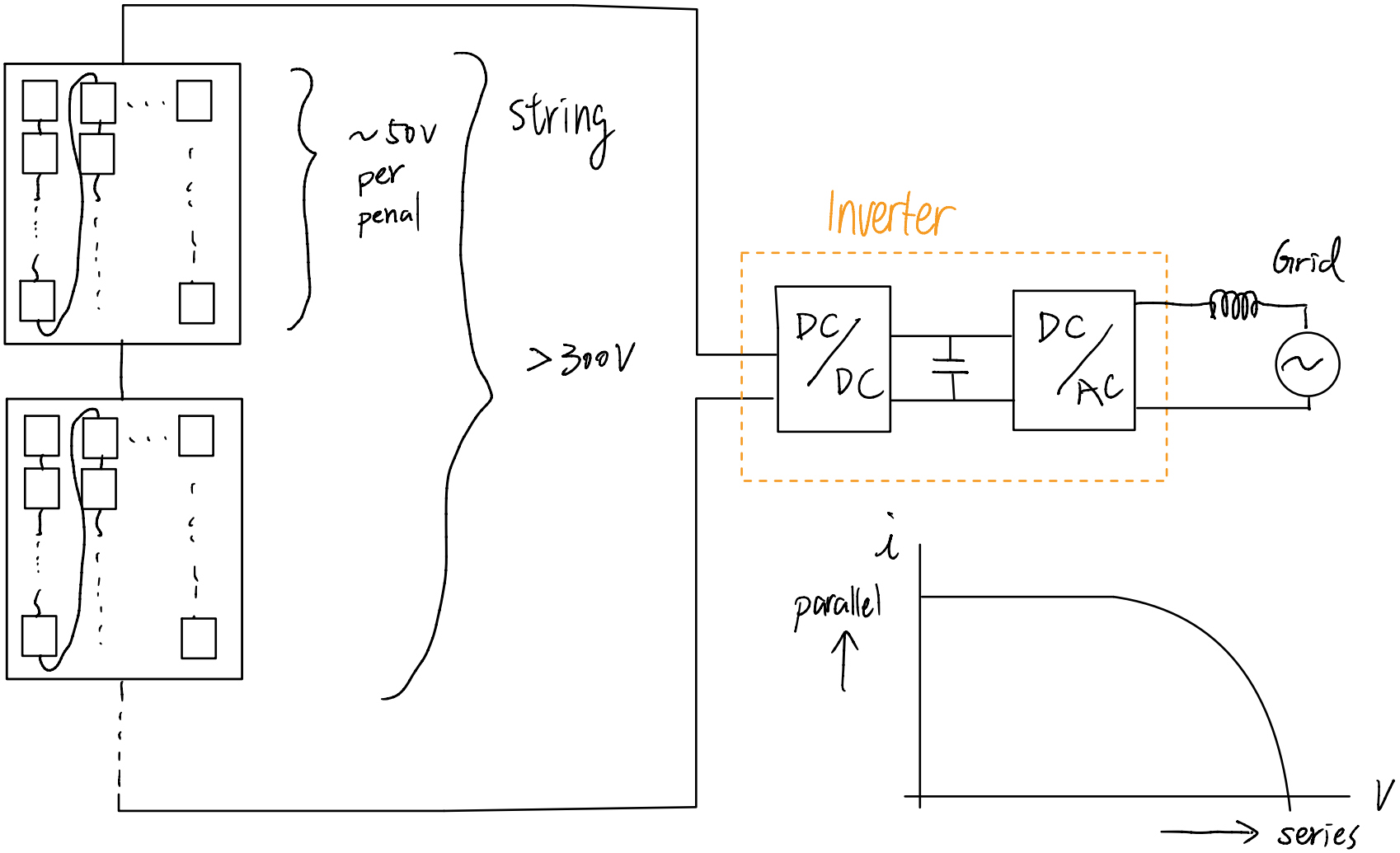


R_S: nothing is super conductor, smaller better

R_P: Recombination, large better

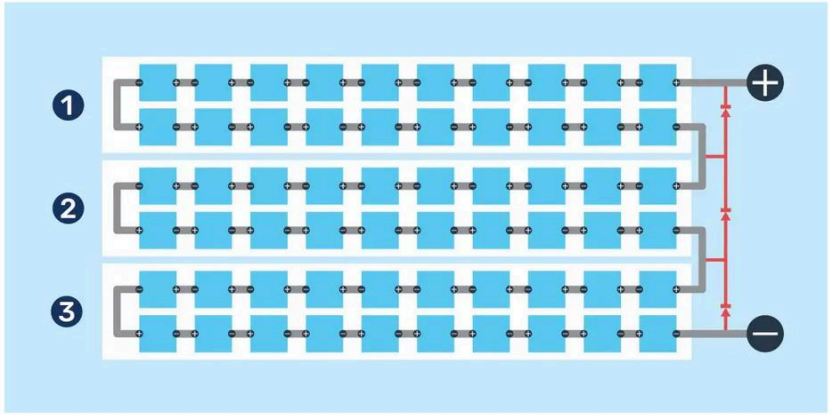
String (i.e., panel) Equivalent Circuit

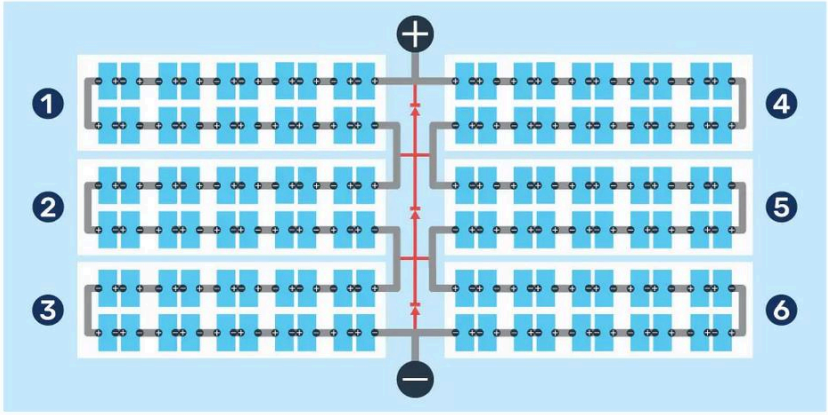
- Usually photocells are connected in series into a string.
- Series scales voltage, parallel scales current.



Half-Cut Panels

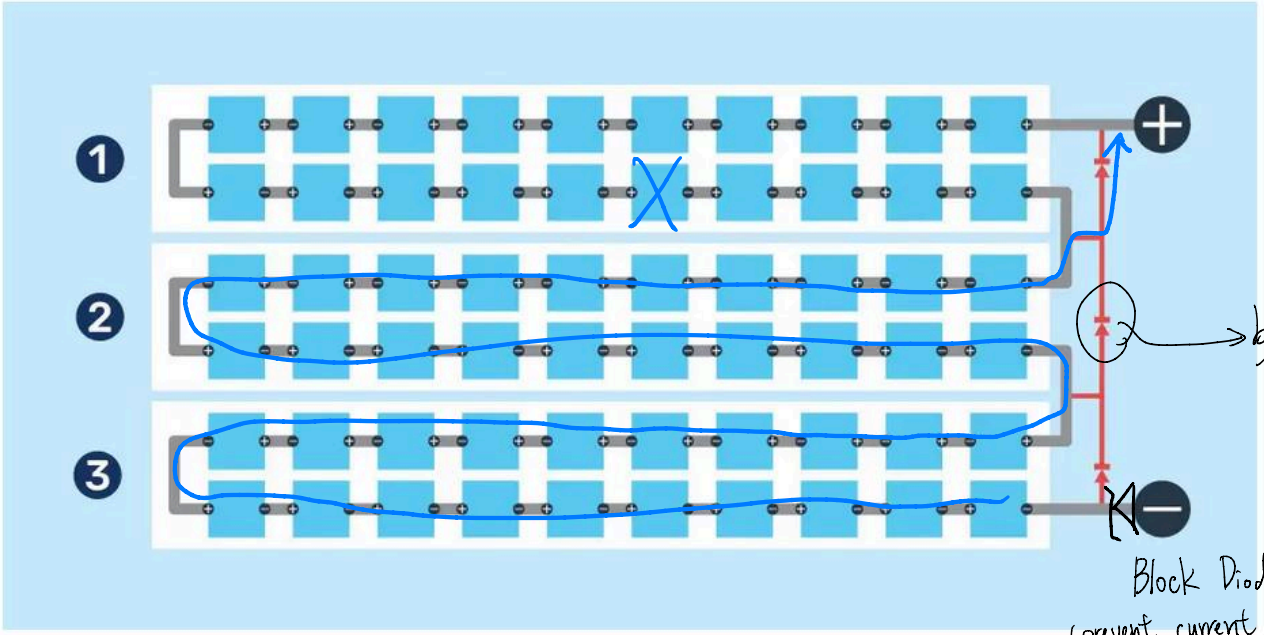
- Photocells are laser cut, doubling the number of photocells, then arranged as effectively two parallel panels in one. (From 60-72 photocells to 120-144 photocells.)
- Lower resistive losses.
- Better performance in partial shade.





Modules: Blocking and Bypass Diodes

- Blocking diodes prevent reverse power flow
- Bypass diodes prevent a poorly performing photo cell from limiting the entire module
- Can develop hotspots



Maximum Power Point Tracking

$i_c \uparrow \quad V_c \downarrow$

- As current increases, voltage decreases.
- Adaptively find the highest product of current and voltage. A simple form of adaptive, online optimization.