INTEGRATED POWER MODULATION

SOLAR ENERGY

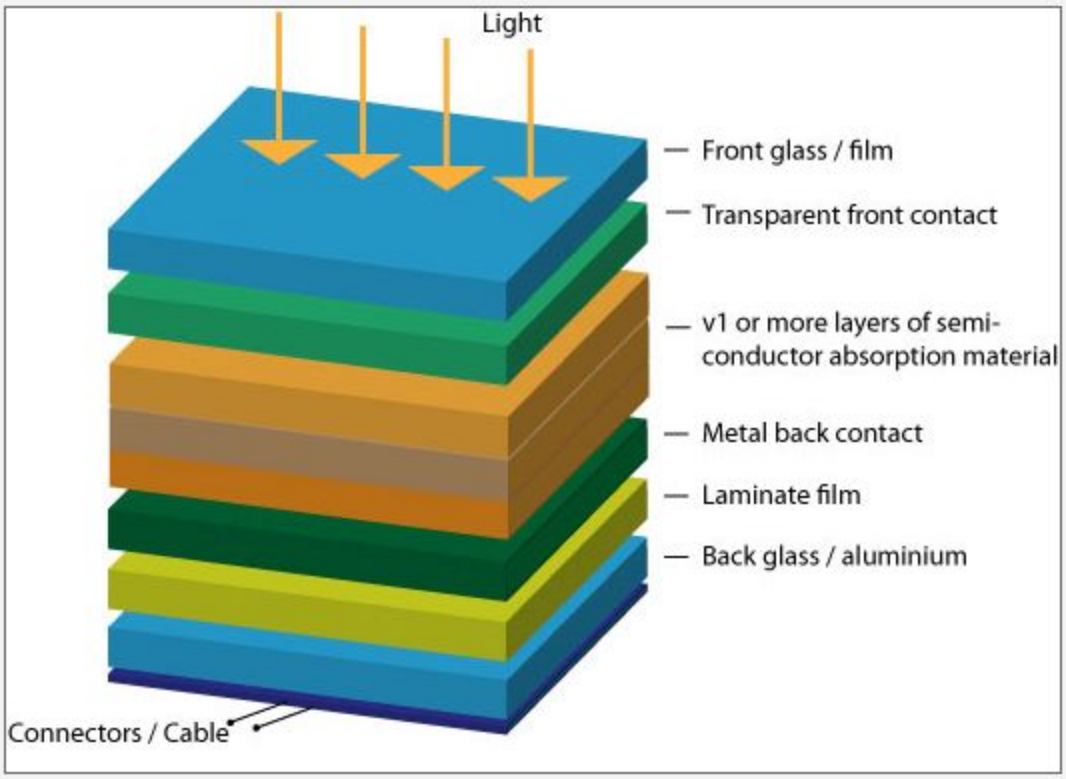
- Solar power is amazing.
- On average, every square meter of Earth's surface receives 164 watts of solar energy !
- The energy the Sun sends out arrives on Earth as a mixture of light and heat.
- We have to find some way of converting solar energy into other forms of energy we can use more easily, such as electricity.
- And that's exactly what solar panels do.

SOLAR PANEL

- A solar panel is a large flat rectangle made up of many individual solar energy collectors called **solar cells** covered with a protective sheet of glass.
- Just like the cells in a battery, the cells in a solar panel are designed to generate electricity.
- But where a battery's cells make electricity from chemicals, a solar panel's cells generate power by capturing sunlight instead.
- They are sometimes called **photovoltaic (PV)** cells because they use sunlight to make electricity.

PHOTOVOLTAIC CELL

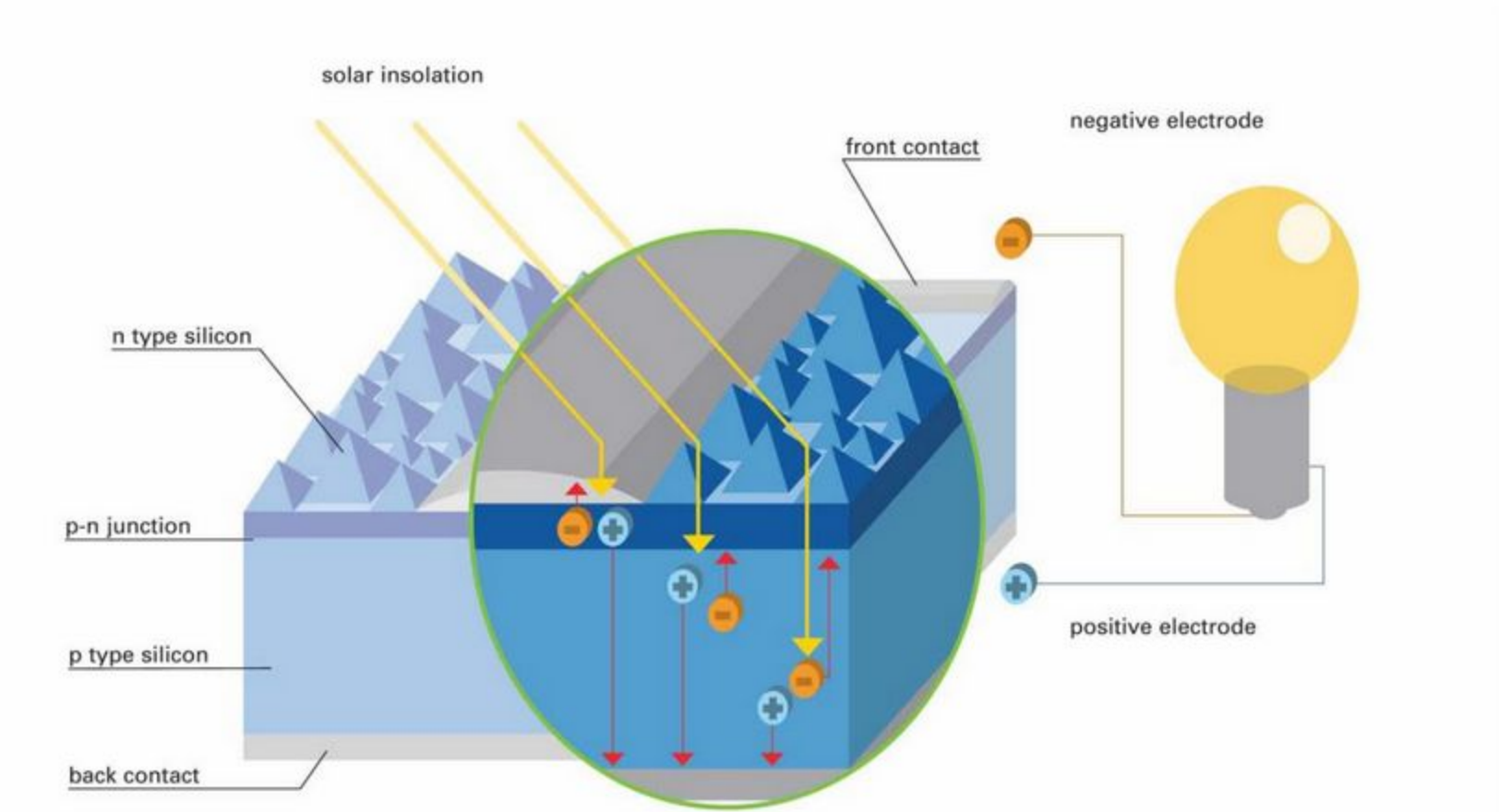
- Photovoltaic cells are solid state devices that convert light directly into electricity.
- Photovoltaic cell consists of high quality Silicon.
- Silicon is a type of semiconductor.
- A solar cell is a sandwich of two different layers of silicon that have been specially treated or **doped** so they will let electricity flow through them in a particular way.
- Photovoltaic cells generally consist of five layers.
- Two of these layers are semiconductors and the remaining three are merely for protection and to aid absorption of light.


Light
Front glass / film
Transparent front contact
v1 or more layers of semi-conductor absorption material
Metal back contact
Laminate film
Back glass / aluminium
Connectors / Cable

How does a PV cell works?

- When we place a layer of n-type silicon on a layer of p-type silicon, a barrier is created at the junction of the two materials.
- The light as a stream of energetic "light particles" called **photons**.
- As photons enter our sandwich, they give up their energy to the atoms in the silicon.
- The incoming energy knocks electrons out of the lower, p-type layer so they jump across the barrier to the n-type layer above and flow out around the circuit.
- The more light that shines, the more electrons jump up and the more current flows.

How a Solar Cell Works



How much electricity does a solar panel produce?

- The amount of electricity a solar panel produces depends on three main things: the amount of sunlight hitting the panel, the size of the panel, and the efficiency of the solar cells inside.
- Calculating solar panel output for your location
- Since you probably don’t live at the equator, your roof will get a different amount of sunlight, and of course the amount of sunlight also varies based on time of day, the season, and the weather. You can’t use the maximum power rating to directly predict how much power you’ll get from a solar panel. It is possible to do a bit of math to get a better sense of how a solar panel will work in your location, however.

How to calculate the annual solar energy output of a photovoltaic system?

The global formula to estimate the electricity generated in output of a photovoltaic system is :

$$E = A * r * H * PR$$

E = Energy (kWh)
A = Total solar panel Area (m²)
r = solar panel yield (%)
H = Annual average solar radiation on tilted panels (shadings not included)
PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75)

r is the yield of the solar panel given by the ratio : electrical power (in kWp) of one solar panel divided by the area of one panel

Example : the solar panel yield of a PV module of 250 Wp with an area of 1.6 m² is 15.6%
Be aware that this nominal ratio is given for standard test conditions (STC) : radiation=1000 W/m², cell temperature=25 °C, Wind speed=1 m/s, AM=1.5 The unit of the nominal power of the photovoltaic panel in these conditions is called "Watt-peak" (Wp or kWp=1000 Wp or MWp=1000000 Wp).

H Between 200 kWh/m².y (Norway) and 2600 kWh/m².y (Saudi Arabia). You can find this global radiation value here : solar radiation data
You have to find the global annual irradiation incident on your PV panels with your specific inclination (slope, tilt) and orientation (azimut).

PR : PR (Performance Ratio) is a very important value to evaluate the quality of a photovoltaic installation because it gives the performance of the installation independently of the orientation, inclination of the panel. It includes all losses.

Example of losses details that gives the PR value (depend on the site, the technology, and sizing of the system) :

- Inverter losses (4% to 15 %)
- Temperature losses (5% to 18%)
- DC cables losses (1 to 3 %)
- AC cables losses (1 to 3 %)
- Shadings 0 % to 80% !!! (specific to each site)
- Losses weak radiation 3% to 7%
- Losses due to dust, snow... (2%)
- Other Losses (?)