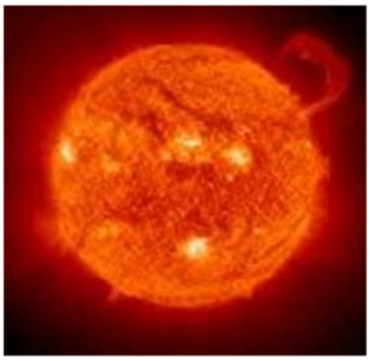
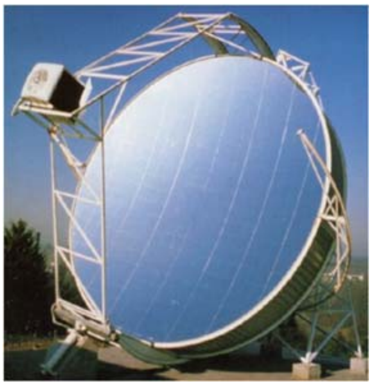


# Fuel and Energy

## Photovoltaic Cells



Dr.-Eng. Zayed Al-Hamamre

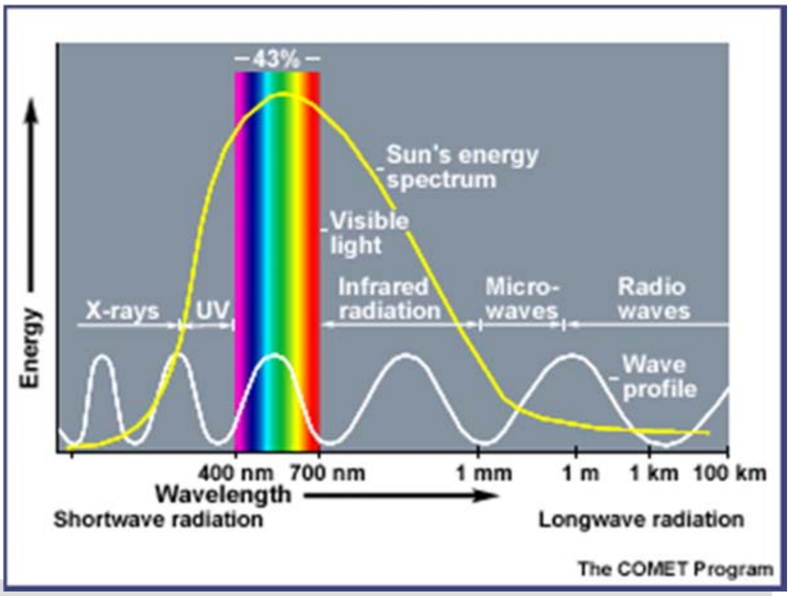


# Content

- Introduction
- PV Effects
- Absorption of Light by Atoms and Molecules
- Type of PV Cells
- PV systems

# What is Solar Energy?

- Originates with the thermonuclear fusion reactions occurring in the sun.
- Represents the entire electromagnetic radiation (visible light, infrared, ultraviolet, x-rays, and radio waves).





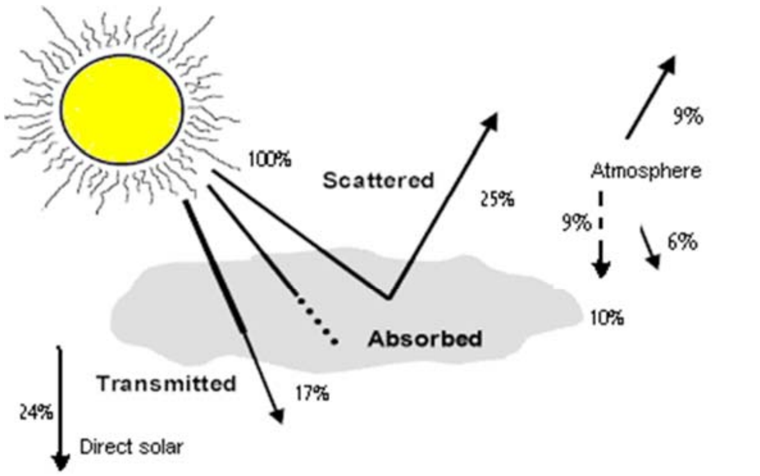


# Advantages and Disadvantages

- **Advantages**
  - All chemical and radioactive polluting byproducts of the thermonuclear reactions remain behind on the sun, while only pure radiant energy reaches the Earth.
  - Energy reaching the earth is incredible. By one calculation, 30 days of sunshine striking the Earth have the energy equivalent of the total of all the planet's fossil fuels, both used and unused!
- **Disadvantages**
  - Sun does not shine consistently.
  - Solar energy is a diffuse source. To harness it, we must concentrate it into an amount and form that we can use, such as heat and electricity.
  - Addressed by approaching the problem through:
    1) collection, 2) conversion, 3) storage.



# How much solar energy?

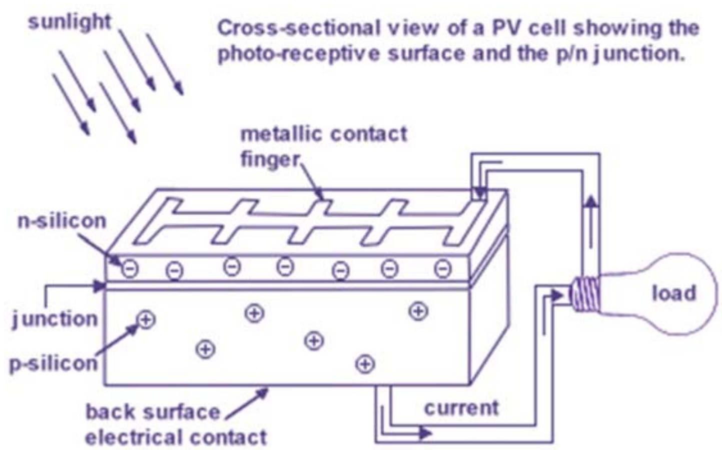



- The surface receives about 47% of the total solar energy that reaches the Earth. Only this amount is usable.



# The Photoelectric Effect

- Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon
- Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity.



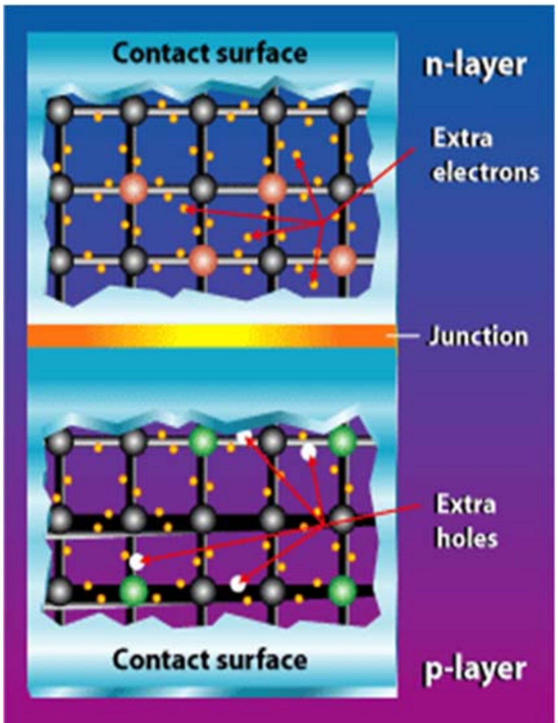
## Single-Crystal Silicon Cell Construction

- The majority of PV cells in use are the single-crystal silicon type.
- Silica ($SiO_2$) is the compound used to make the cells.
- It is first refined and purified, then melted down and re-solidified so that it can be arranged in perfect wafers for electric conduction. These wafers are very thin.
- The wafers then have either Phosphorous or Boron added to make each wafer either a negative type layer or a positive type layer respectively.
- Used together these two types treated of crystalline silicon form the p-n junction which is the heart of the solar–electrical reaction.
- Many of these types of cells are joined together to make arrays, the size of each array is dependent upon the amount of sunlight in a given area.

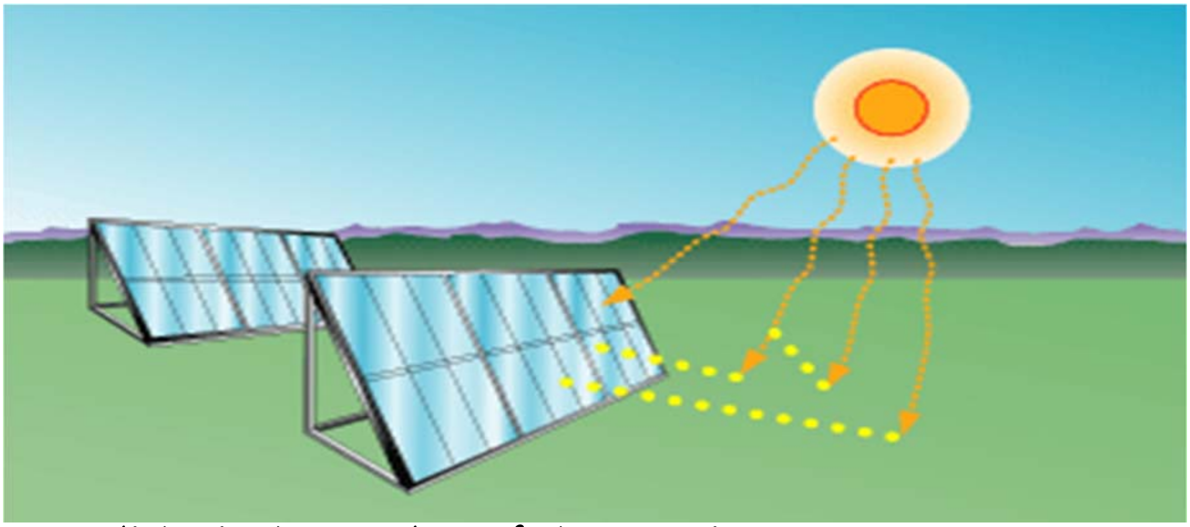


## The Photoelectric Effect

- The photoelectric effect relies on the principle that whenever light strikes the surface of certain metals electrons are released.
- In the p-n junction the n-type wafer treated with phosphorus has extra electrons which flow into the holes in the p-type layer that has been treated with boron.
- Connected by an external circuit electrons flow from the n-side to create electricity and end up in the p-side.



# Photoelectric Effect



- Sunlight is the catalyst of the reaction.
- The output current of this reaction is DC (direct) and the amount of energy produced is directly proportional to the amount of sunlight put in.
- Cells only have an average efficiency of 30%

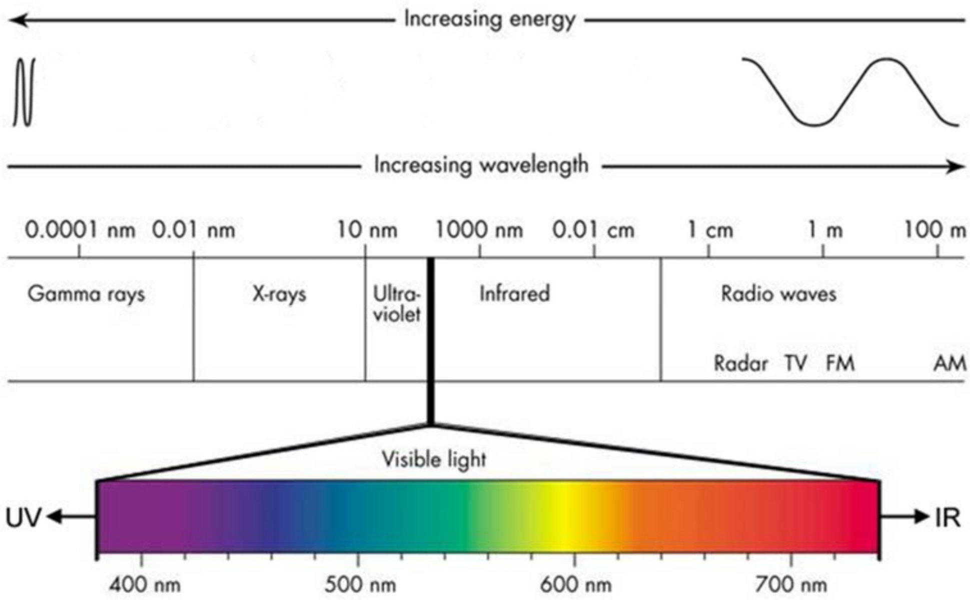


# But Not All Energy is Converted

- Like chloroplasts in plants, solar cells can only absorb specific wavelengths of light.
- In both, light that isn't absorbed is either transmitted through or reflected back.
- Whether a certain wavelength of lights gets absorbed depends on its energy.

Chlorophyll molecules absorb blue and red light, but reflect green light

# A Little Background on Light

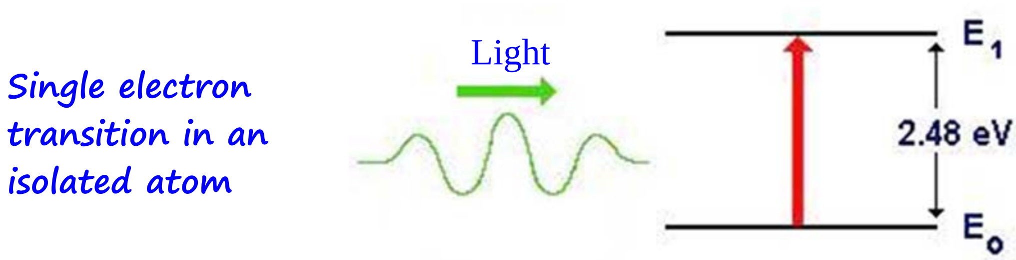



- Different colors of light have different wavelengths and different energies



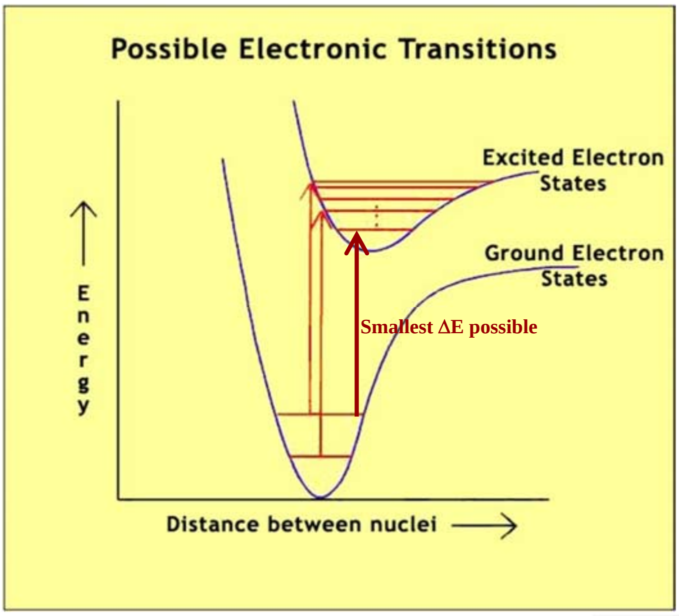
# Absorption of Light by Atoms

- Absorption occurs only when the energy of the light equals the energy of transition of an electron



# Absorption of Light by Molecules

- Molecules have multiple atoms bonded together
- More energy states in molecules than atoms
- More electron "jumps" possible – light with a range of frequencies are absorbed



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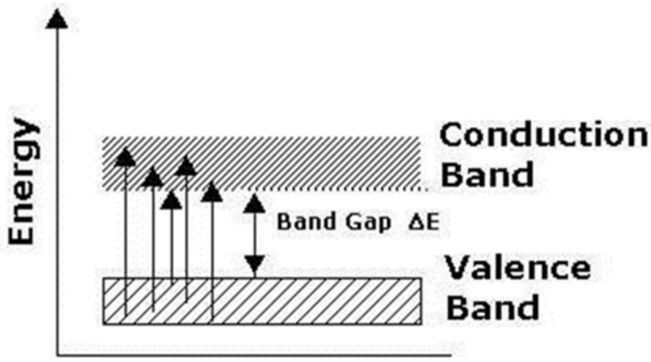
# Absorption of Light by Ionic Compounds

- Electrons can jump between "bands"
- Incident light with energy ≥ than the "band gap" energy can be used to excite the electrons




- ➢ Valence band is the highest range of electron energies in which electrons are normally present at absolute zero temperature.
- ➢ Conduction band is the range of electron energies, higher than that of the valence band, sufficient to free an electron from binding with its individual atom and allow it to move freely within the atomic lattice of the material
- ➢ Electrons within the conduction band are mobile charge carriers in solids, responsible for conduction of electric currents in metals and other good electrical conductors



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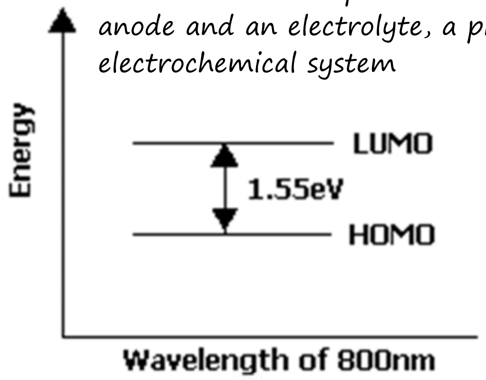
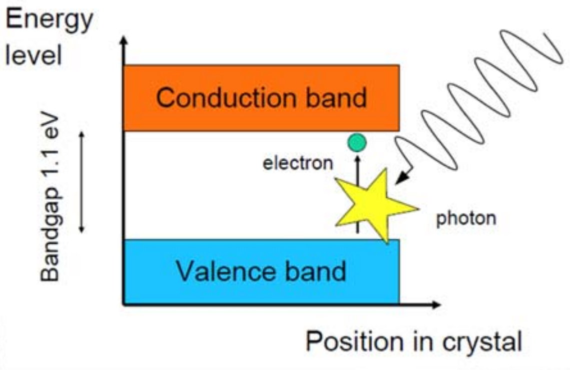
## So What Does this Mean for Solar Cells?

- **In dye-sensitized solar cells…**
  - Talk about highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO)
- **In single-crystal silicon solar cells…**
  - Talk about "conduction band" (excited states) and "valence band" (ground states)

It is based on a semiconductor formed between a photo-sensitized anode and an electrolyte, a photo electrochemical system






## A Closer Look at Solar Cells

- How do traditional, silicon-based solar cells and newer, dye-sensitized solar cells work?
- What are the advantages and disadvantages of each type of cell?

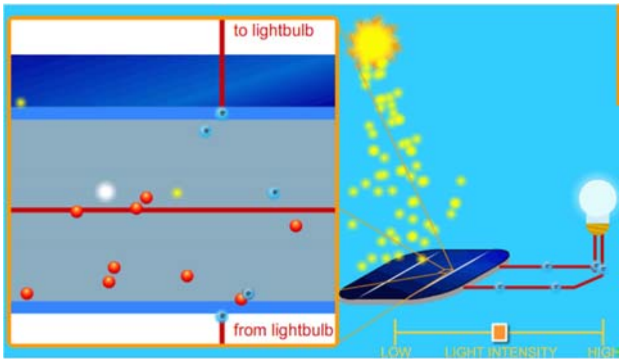
Silicon-based solar cell

Dye-sensitized solar cell

# How a Silicon-Based Solar Cell Works

- Light with energy greater than the band gap energy of Si is absorbed
- Energy is given to an electron in the crystal lattice
- The energy excites the electron; it is free to move

- A positive "hole" is left in the electron's place
- This separation of electrons and holes creates a voltage and a current

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# Silicon-Based Solar Cell Attributes

- **Expensive**
  - Made in high vacuum at high heat
  - High manufacturing costs
- **Need TLC**
  - Fragile, rigid, thick
- **Long return on investment**
  - Takes 4 years to produce energy savings equivalent to cost of production

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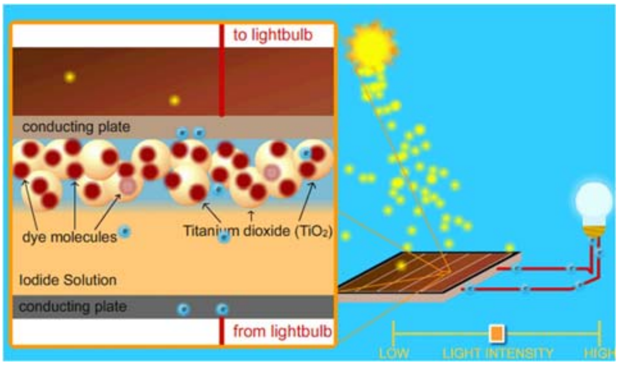
➢Source: http://www.powerhousekids.com/stellent2/groups/public/documents/pub/phk_ee_re_001505-2.gif

## How a Dye-Sensitized Cell Works

- Light with high enough energy excites electrons in dye molecules
- Excited electrons infused into semiconducting $TiO_2$, transported out of cell
- Positive "holes" left in dye molecules
- Separation of excited electrons and "holes" creates a voltage



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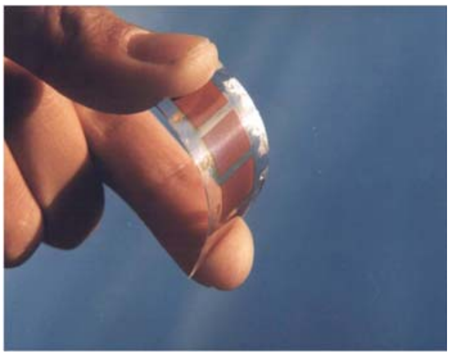
## Dye-Sensitized Solar Cells

- **Relatively inexpensive**
  - Made in non-vacuum setting mainly at room temperature
  - Relatively simple manufacturing process
- **Need little TLC**
  - Thin, lightweight, flexible
- **Short return on investment**
  - Takes approx 3 months to produce energy savings equivalent to cost of production





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➢Source: http://www.imo.uhasselt.be/polytech/images/zonnecel1.jpg

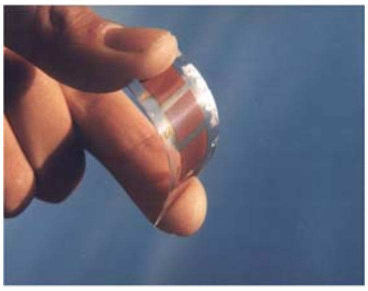
# Dye-Sensitized and Silicon-based Solar Cells Compared

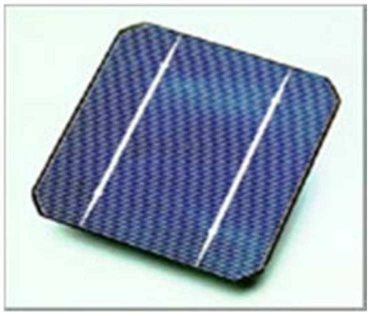
**Dye-Sensitized**

- Relatively inexpensive
- Need little TLC
- Short return on investment

**Traditional**

- Expensive
- Need TLC
- Long return on investment







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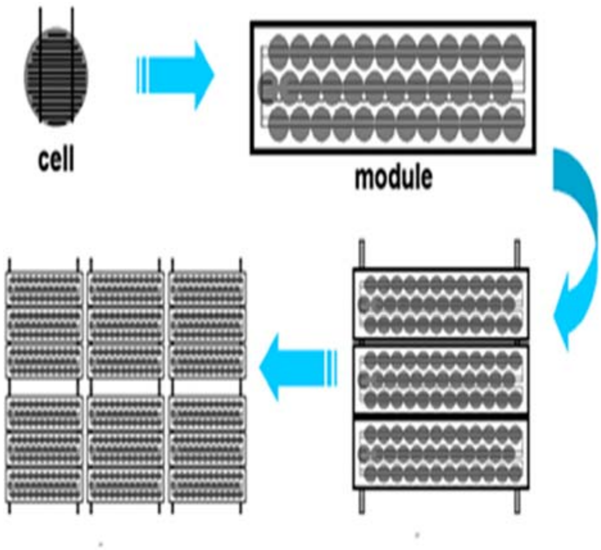
- Sources: http://www.imp.uhasselt.be/polytech/images/zonnecel1.jpg
- http://www.norfolksolar.co.uk/img/system.gif

# How Does A Cell Become A Module?

- A solar cell is the basic building block of a PV system.
- A typical cell produces .5 to 1V of electricity.
- Solar cells are combined together to become modules or if large enough, known as an array.
- A structure to point the modules towards the sun is necessary, as well as electricity converters, which convert DC power to AC.
- All of these components allow the system to power a water pump, appliances, commercial sites, or even a whole community.



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# PV Cells: Attractions and Drawbacks

### Attractions

- Converts sunlight directly to electricity
- Sunlight is the most abundant renewable resource (175 PW)
- Electricity is a very versatile form of energy
- No moving parts, long lifetime (>20 years)

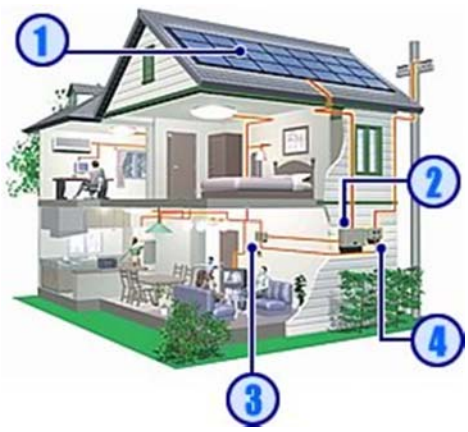
### Drawbacks

- Sunlight is very spread out (<1 kW/m$^2$)
- It is irregular and somewhat unpredictable
- Electricity is difficult to store
- So far PV cells are expensive compared to other means of power generation





# PV Cells Applications




1. PV array
2. Inverter/power-conditioner
3. Indoor distribution panel
4. Energy meter (kWh, connected to grid)

# PV Cells Applications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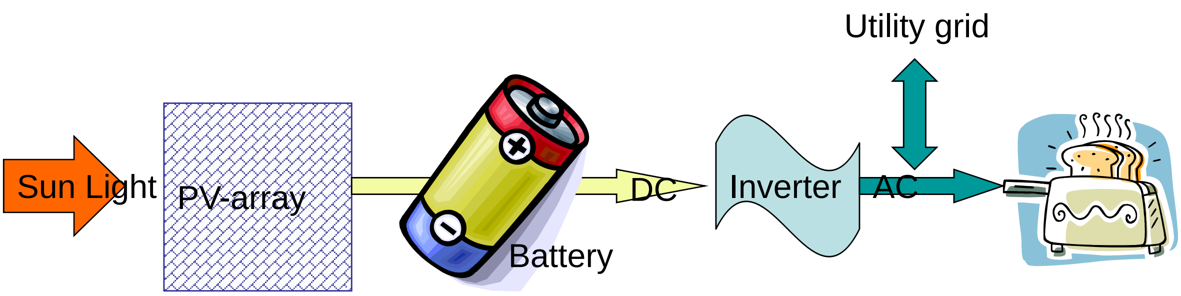
# Photovoltaic Power Scheme




- Sunlight is turned into DC voltage/current by PV
- Can charge battery (optional)
- Inverted into AC
- Optionally connect to existing utility grid
- AC powers household appliances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