Solar Electrical Systems, components and types

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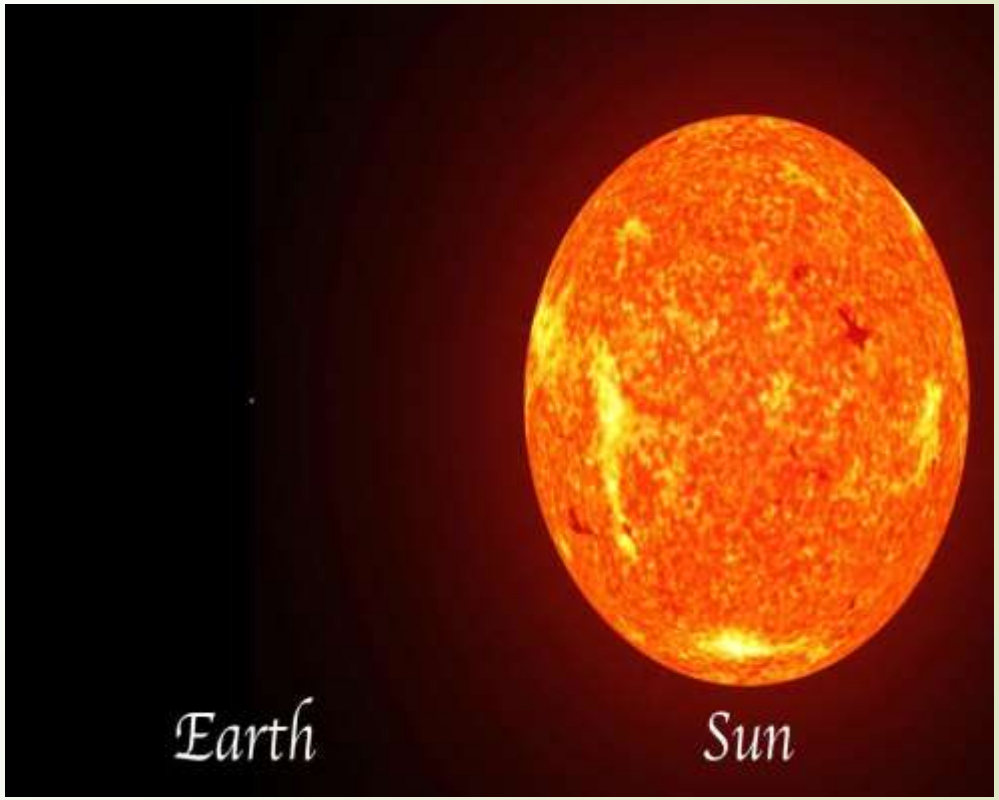
Outlines:

- Source of solar energy.
- Sunlight wavelengths.
- Solar Electrical System Components.
- Solar Panels most common types.
- How do solar cell generate electricity?
- The new generation of solar cells.
- Types of Solar Electrical Systems.
- Factors that effect PV Panel output.
- Advantages and disadvantages.

Source of solar energy:

- Nuclear activity → Radiation → Photons.
- Photons carry momentum & energy.
- Photons reach earth in 8.33 minutes.
- Photons could collide, deflected, or absorbed.
- Atmosphere absorbs many photons (350 Watt/m²).
- Solar constant = 1000 Watt/m².

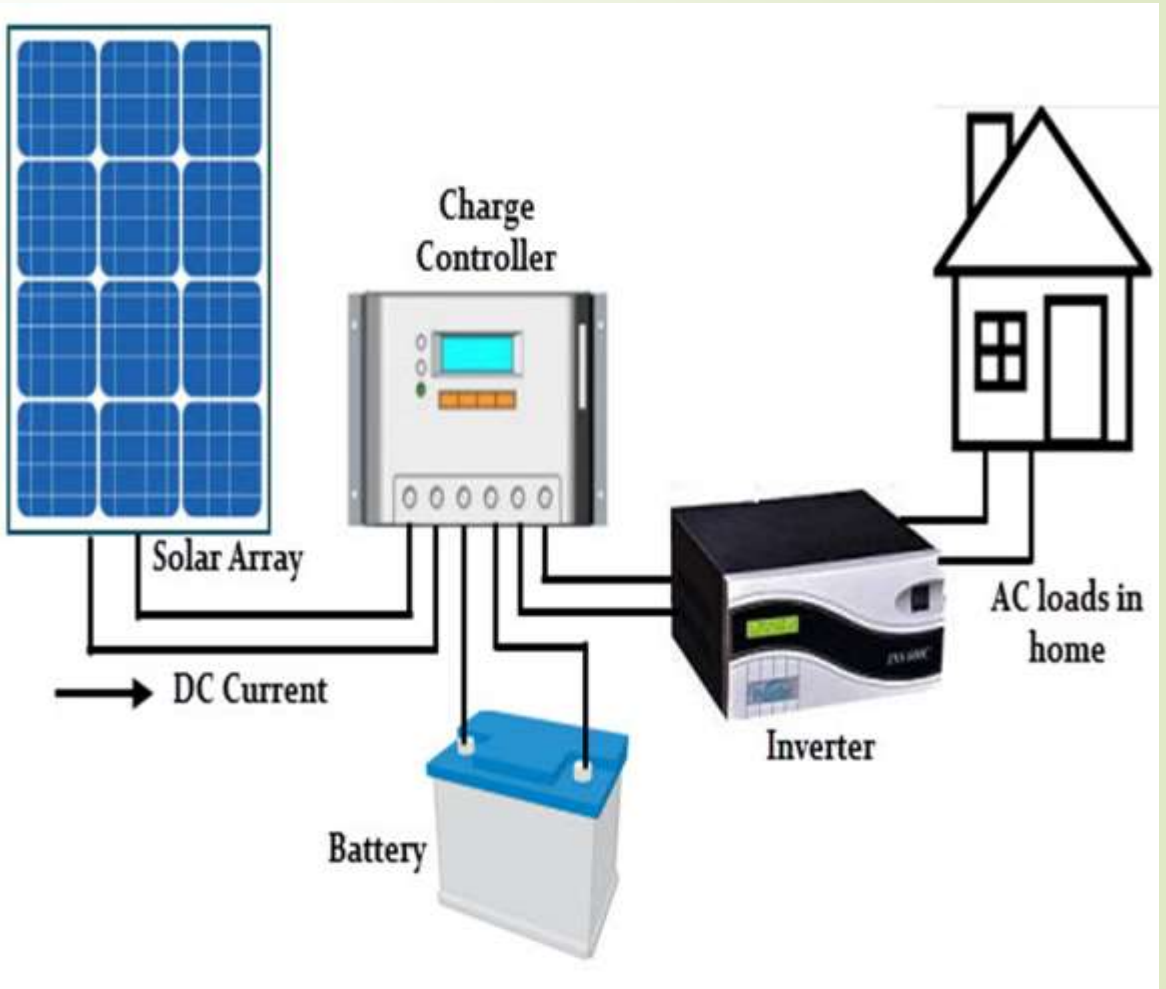


Sunlight wavelengths:

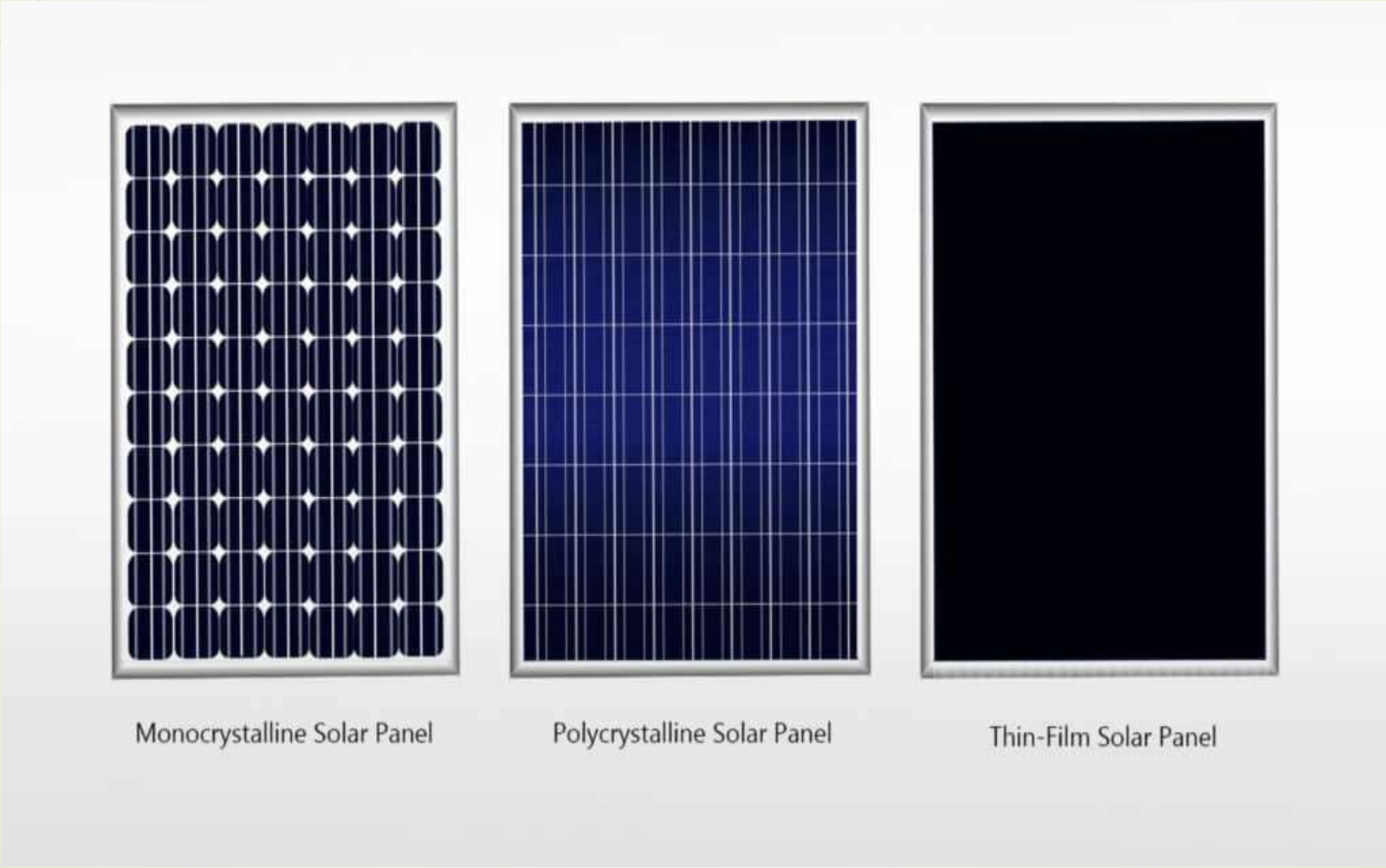
	Wavelength	Percentage of Sunlight
Ultraviolet	10 nm - 380 nm	7%
Violet	380 - 450 nm	46%
blue	450 - 495 nm	
green	495 - 570 nm	
yellow	570 - 590 nm	
orange	590 - 620 nm	
red	620 - 750 nm	
Infrared	750 - 1,000,000 nm	47%

Solar Electrical System components.

1. Solar Panel (PV panels).
2. Charge Controller.
3. Inverter.
4. Batteries.
5. Electrical Devices(Loads)

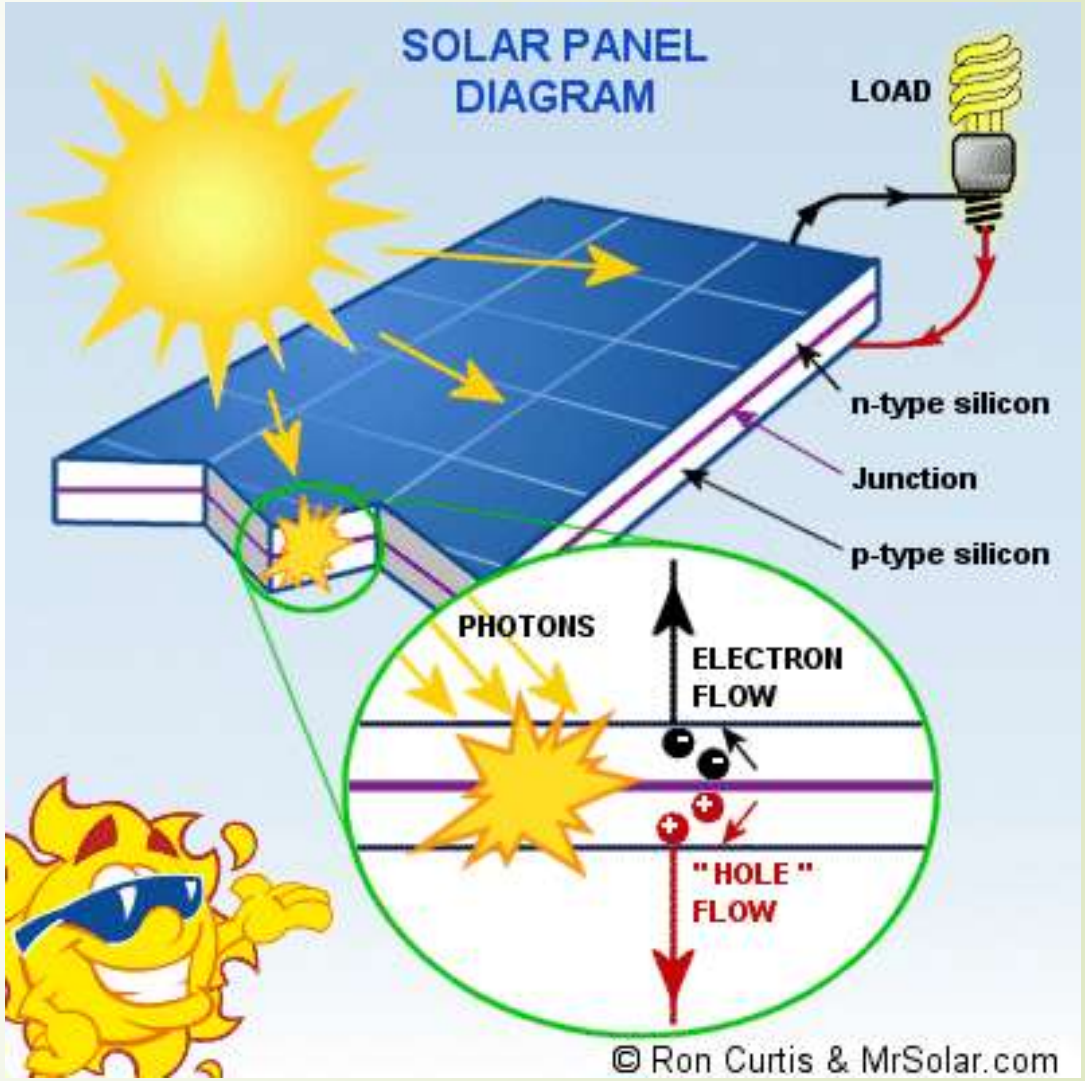


Solar Panels most common types:

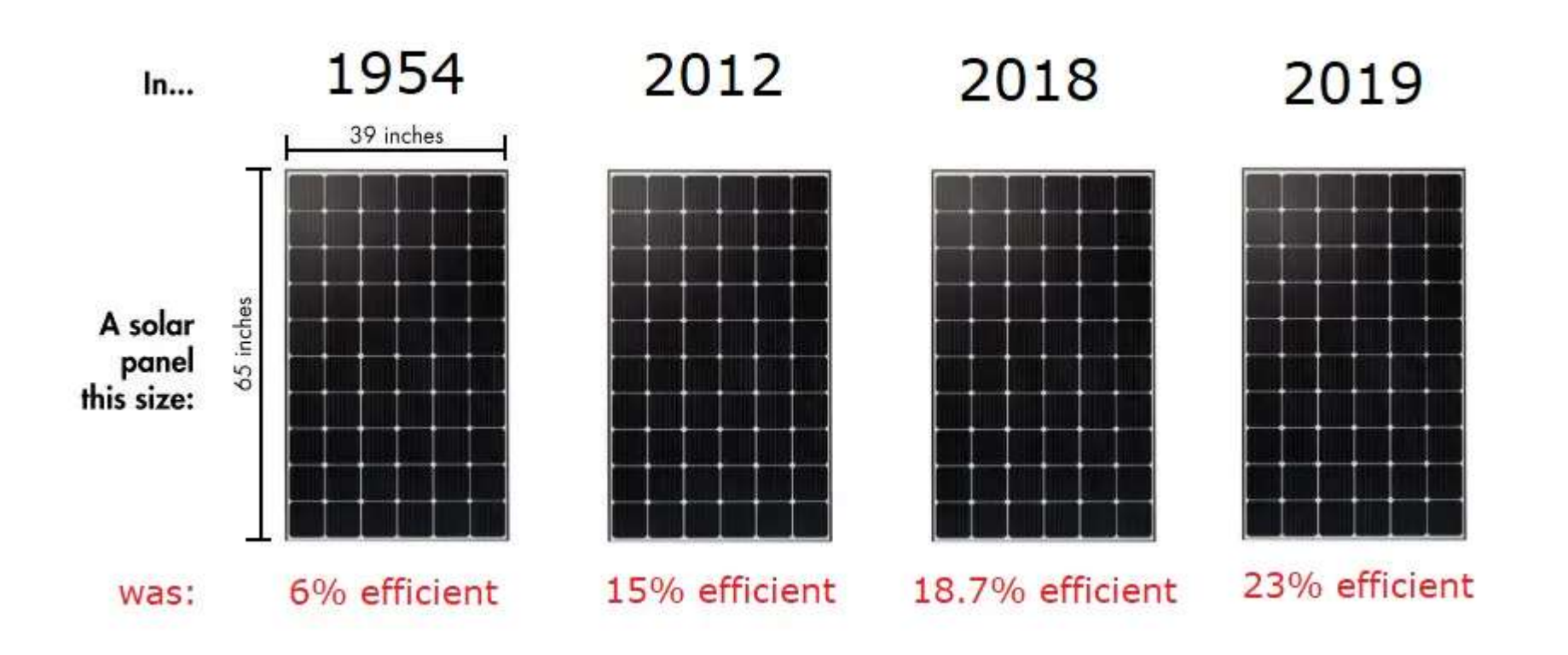


How do solar cell generate electricity?

- Photovoltaic effect.
- Two semi – conducting layers combined.
- One of them has a depleted no. of electrons.
- Photon hit solar cell :
    1. Absorbed → electrical charge.
    2. Reflected off cell.
    3. Pass straight cell.
- Solar cells generate electricity from direct sun.

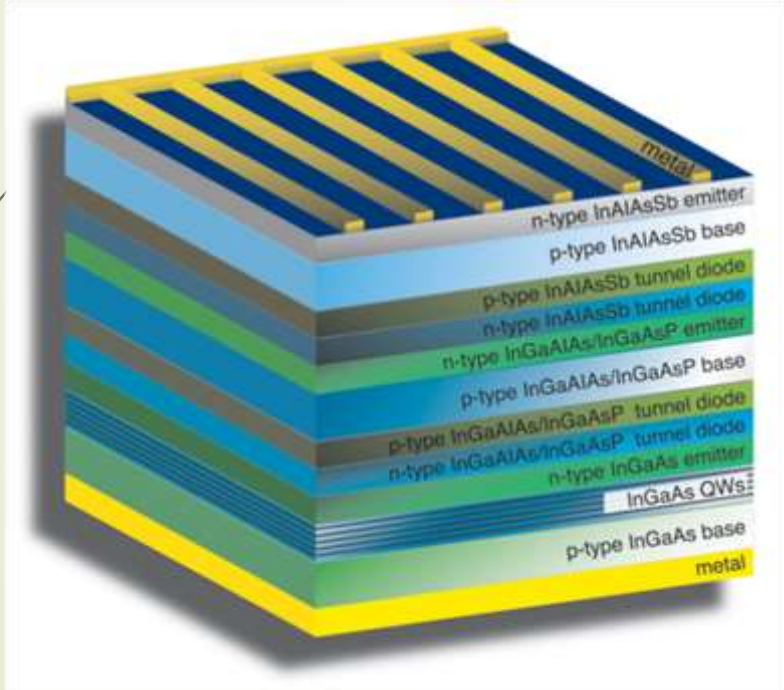


PV panel Development through years:

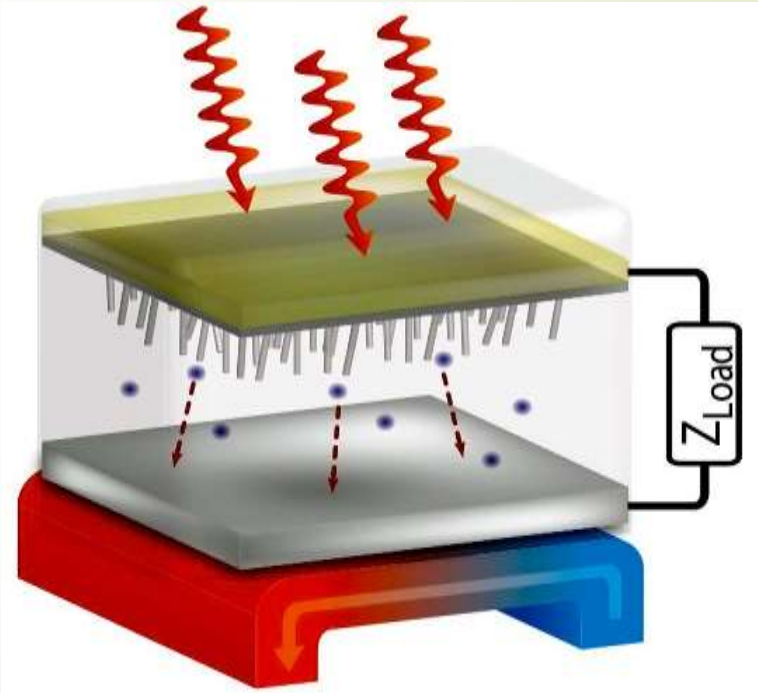


The new generation of solar cells:

DOE & Spectrolab: multi-junction



Stanford Institute: PETE chip



Charge Controller:

Inverter:


Inverter
DC
AC
Grid
Solar Panels
DC
Home appliances
Battery


DC
AC
Home appliances
Solar Panels
Solar Inverter

Batteries:

- A battery is a tool that can convert chemical energy to electrical energy by an electrochemical redox reaction between the electrodes of the battery , it can be made of one electrochemical cell or more .

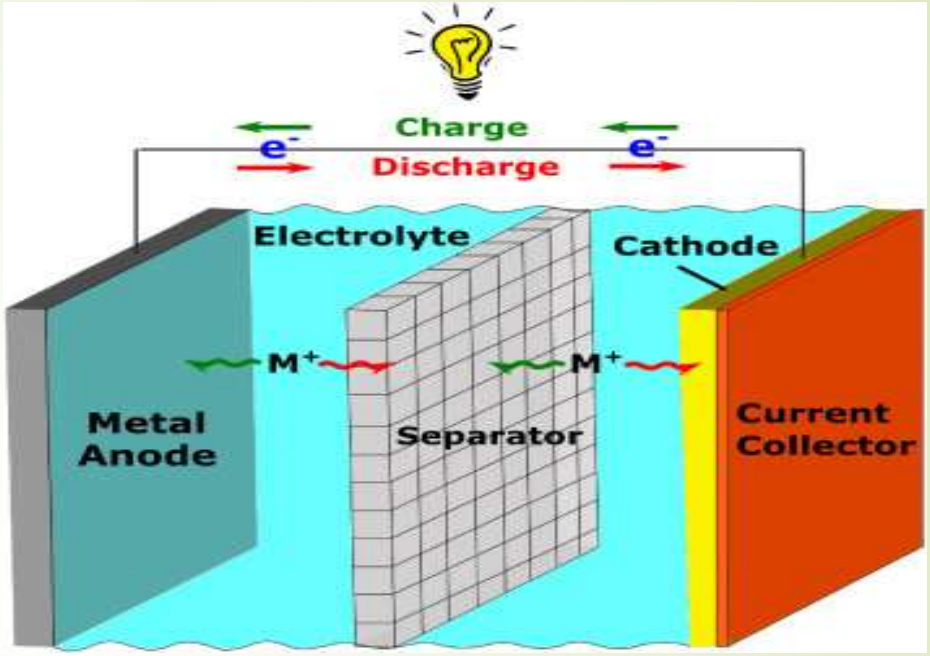
- **Batteries used in solar cell systems:**

It is a storage unit that contains unused excess electrical energy generated by solar panels. Often more than one unit is required to function effectively as a solar energy store.

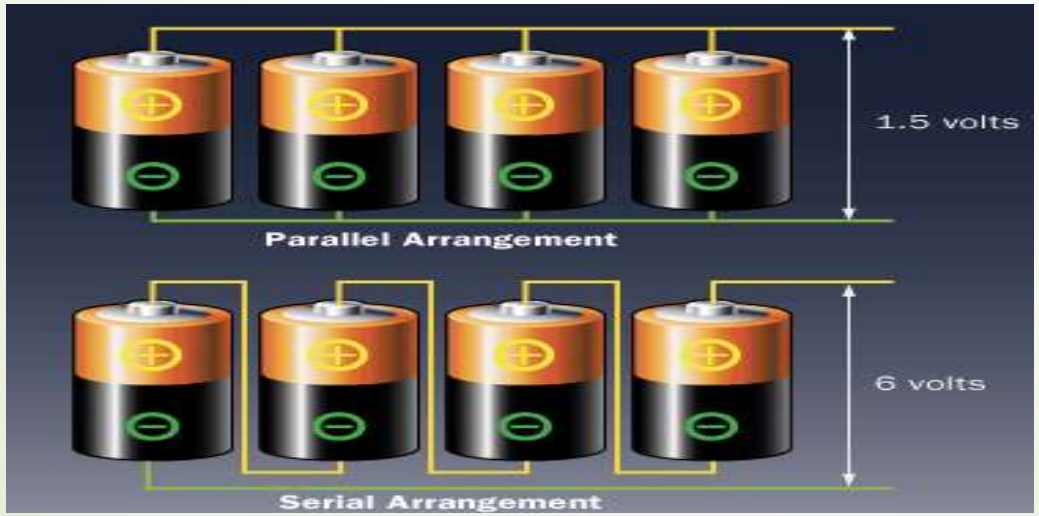
Battery main components:

1. The positive electrode (Cathode)
2. The negative electrode (Anode)
3. The electrolyte
4. separator

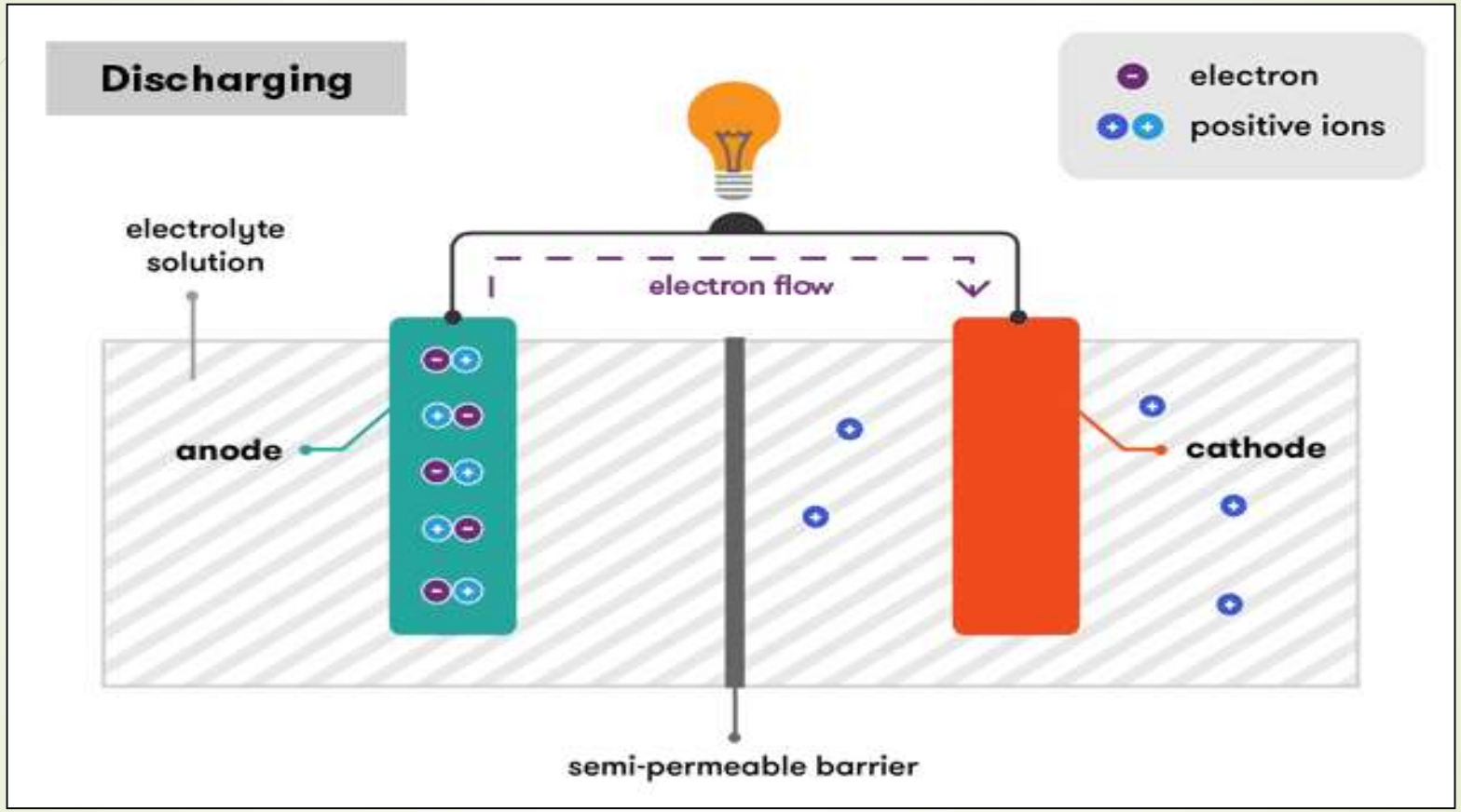
$$\Delta E^{o} = E^{o(+)} - E^{o(-)}$$



Batteries can be connected either in series or in a parallel pattern:



The negative electrode, oxidation reaction occurs, releasing electrons,



The positive electrode , reduction reaction occurs, gaining electrons

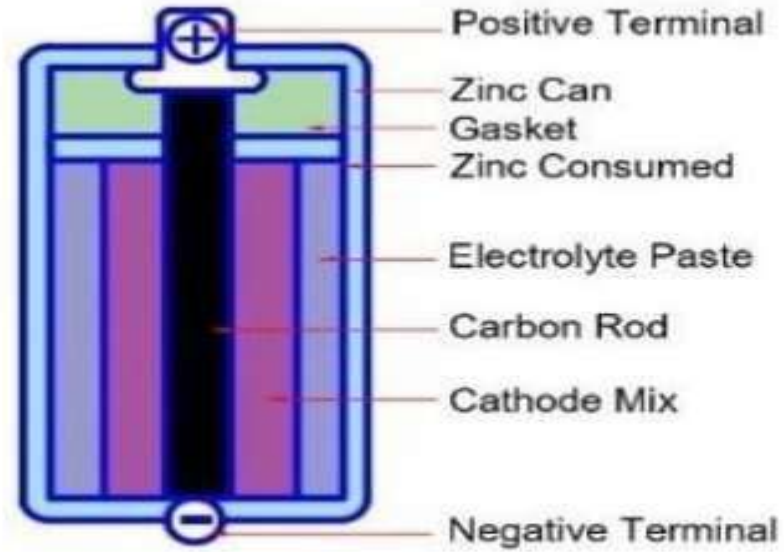
Classification of batteries :

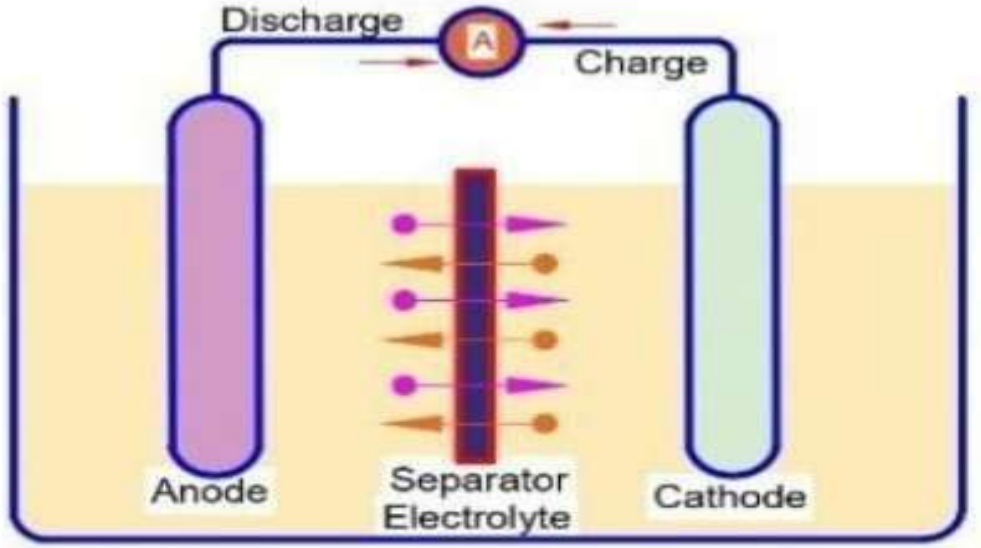
There are two types of batteries:

1- Primary batteries: In this type of batteries, the chemical reaction is irreversible and can be discharged once due to the formation of inactive materials or spent materials. Examples of primary batteries (zinc chloride) and (zinc - mercury).

2- Secondary batteries: In this type of battery, the chemical reaction is reversible and can be recharged whenever external electrical energy is applied and the active materials will return to their original forms. Examples of this type of battery are lead, nickel-cadmium, nickel-metal hydride, zinc - manganese dioxide and lithium-ion batteries.

Difference between Primary & Secondary Cell





PRIMARY CELL

SECONDARY CELL

Primary battery developments

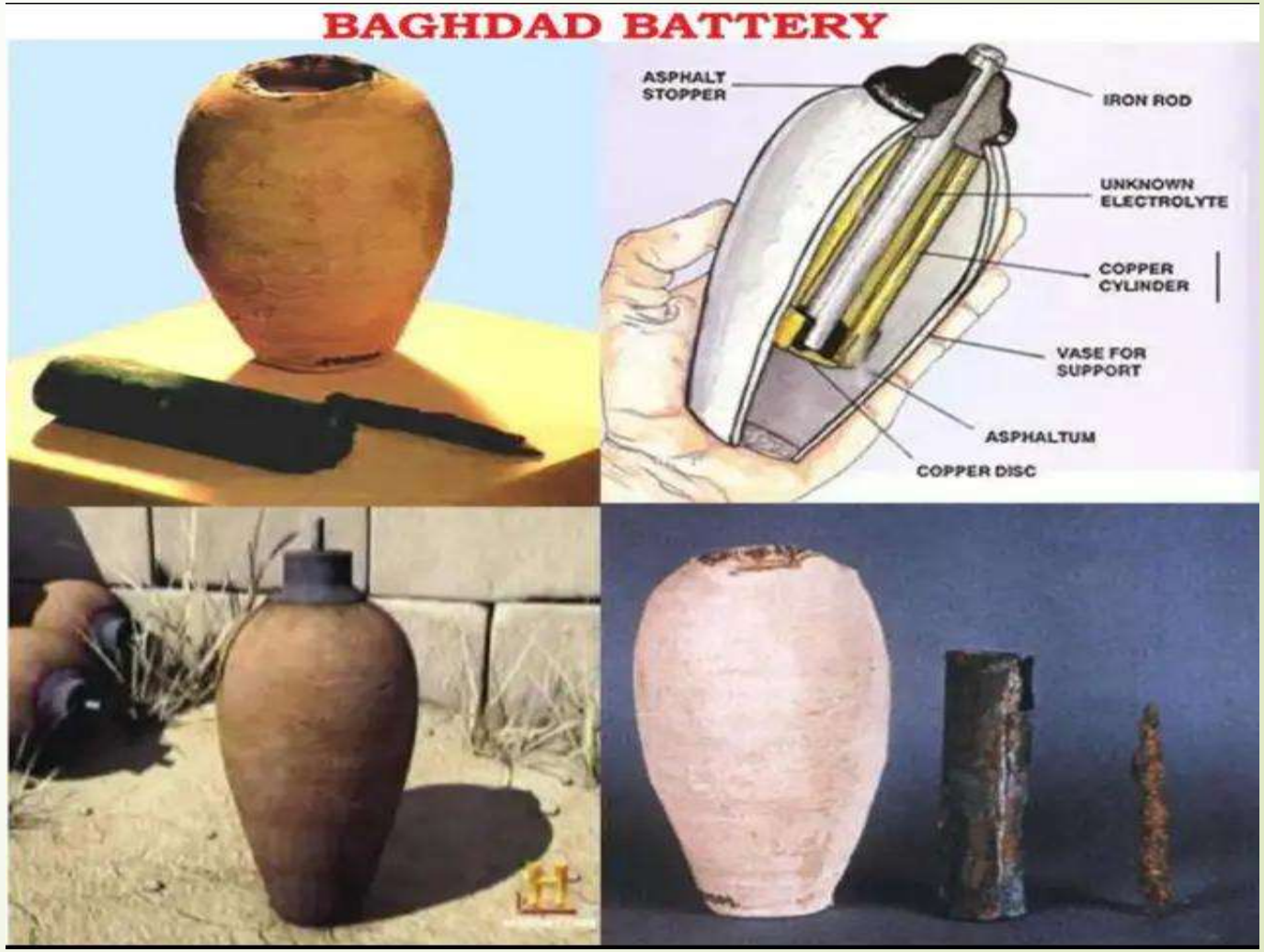
Date	Inventor	Cell design
1000 BC	Baghdad cell	Jar containing an iron rod surrounded by a copper cylinder
1782	Volta	Stack of zinc and silver disks
1813	Davy	First public demonstration of electric lighting
1836	Daniell	$Zn/ZnSO_4/CuSO_4/Cu$
1839	Grove	Nitric acid battery
1866	G. Leclanché	Zinc/manganese dioxide cell
1878	Zinc air cell	$Zn/NaOH/O_2$
1945	Ruben and Mallory	Mercury button-type cell
1949	Lew Urry	Alkaline dry cell commercialized by Eveready Batteries Co.
1961	Silver-zinc cell	$Zn/KOH/Ag_2O$
1970–1980	Lithium-iodine	$Li/Li/I_2$ developed for pace-maker
	Coin cell	Li/aprotic electrolyte/MnO_2
	Li soluble cathode	$Li/SOCl_2$

Secondary battery developments

Date	Inventor	Cell design
1859	Planté	PbO_2/dilute H_2SO_4/Pb
1899	Waldemar Jungner	Nickel-cadmium cell Ni/2NiOOH/Cd
1905	Edison	Nickel-iron cell Ni/2NiOOH/Fe
1949	Lew Urry	Alkaline dry cell commercialized by Eveready Batteries Co.
1959	Francis Bacon	First practical fuel cell using Ni electrodes
1960s	Volkswagen	Nickel-metal hydride cell with $LaNi_5$ or ZrNi hydrogen sponges
1965	Ford	Beta cell Na/β-Al_2O_3/S
1980s	Li polymer	Li/PEO-$LiClO_4$/Ic (Ic=V_6O_{13}, TiS_2, V_2O_5)[a]
	Microbattery	Li/Li^+ fast ion conductor/TiS_2
1990s	Sony Corp.	Lithium-ion cell based on graphite/$LiCoO_2$ electrodes

First battery in history:

The Baghdad Battery is the name given to a set of a ceramic pot, a tube of copper, and a rod of iron , it was discovered in 1936 near the town of Salman Pak



The main types of batteries used in Solar Electrical Systems:

1- Lead acid battery:

1- The nominal voltage of about 2v

2- The current capacity is approximately 1Ah to almost 150Ah on manufacturer and size (12v with 150Ah battery can be used for an inverter) .

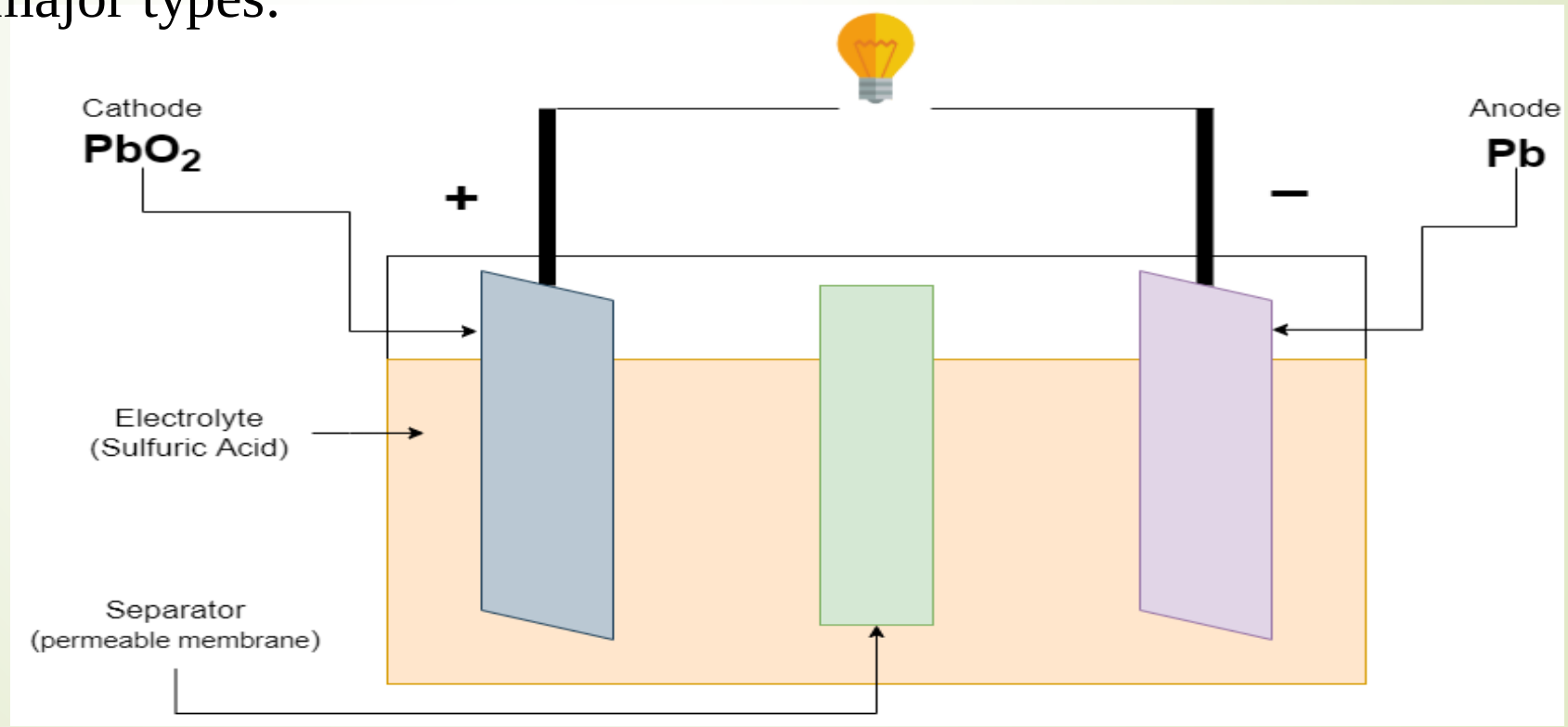
3- The lead-acid battery life cycle is about 200 to 300 cycles .

4- there are three major types:

Flooded

AGM

Gel



Advantages

1. It can easily be recycled
2. Highly reliable
3. Very low risk
4. Long-lasting and safe
5. Compatible with most inverters
6. The battery does not disconnect even at very low voltages

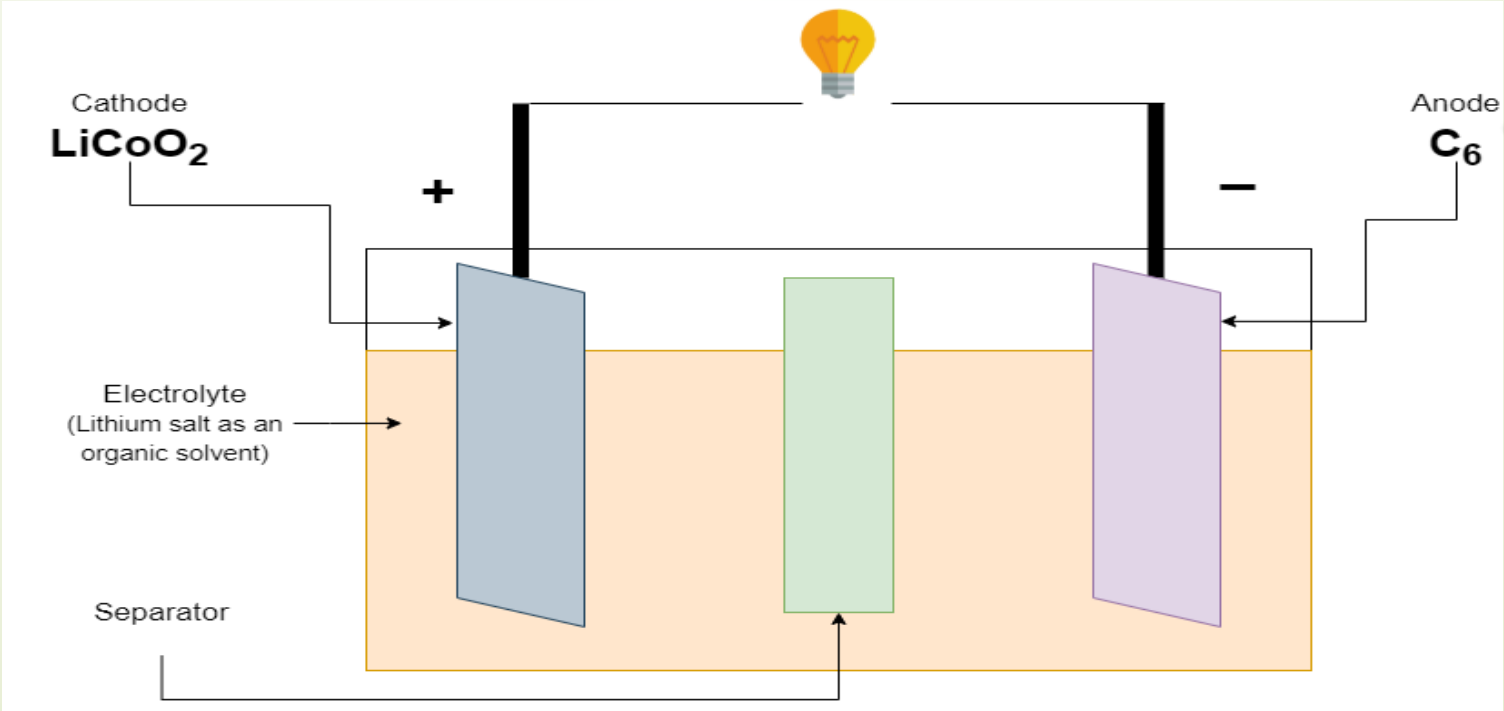
Disadvantages

1. Battery life will get reduced if operated at a high temperature
2. Low energy density
3. Hard to retain partial charge for long hours
4. Efficiency is slightly low compared to other models 75% to 80%

2- Lithium ion battery:

1. Its nominal voltage is 3.60V per cell
2. The capacity of the battery is near 150-200 mAh , but it can vary with the type of the lithium ion battery .
3. This battery has a discharge/charge cycle is about 400 – 1200 cycles.

- $LiNiO_2$
- $LiMnO_2$
- $LiNiCoO_2$
- $LiNiMnO_2$
- $LiNiMnCoO_2$
- $LiFePO_4$



- Carbone based
- Silicone
- Tin
- Metal oxides

The most popular Li-ion technologies developed so far

Acronym	Cathode	Anode	Cell voltage (V)	Energy density (Wh kg^{-1})
LCO	$LiCoO_2$	Graphite	3.7–3.9	140
LNO	$LiNiO_2$	Graphite	3.6	150
NCA	$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	Graphite	3.65	130
NMC	$LiNi_xMn_yCo_{1-x-y}O_2$	Graphite	3.8–4.0	170
LMO	$LiMn_2O_4$	Graphite	4.0	120
LNM	$LiNi_{1/2}Mn_{3/2}O_4$	Graphite	4.8	140
LFP	$LiFePO_4$	$Li_4Ti_5O_{12}$	2.3–2.5	100

Advantages

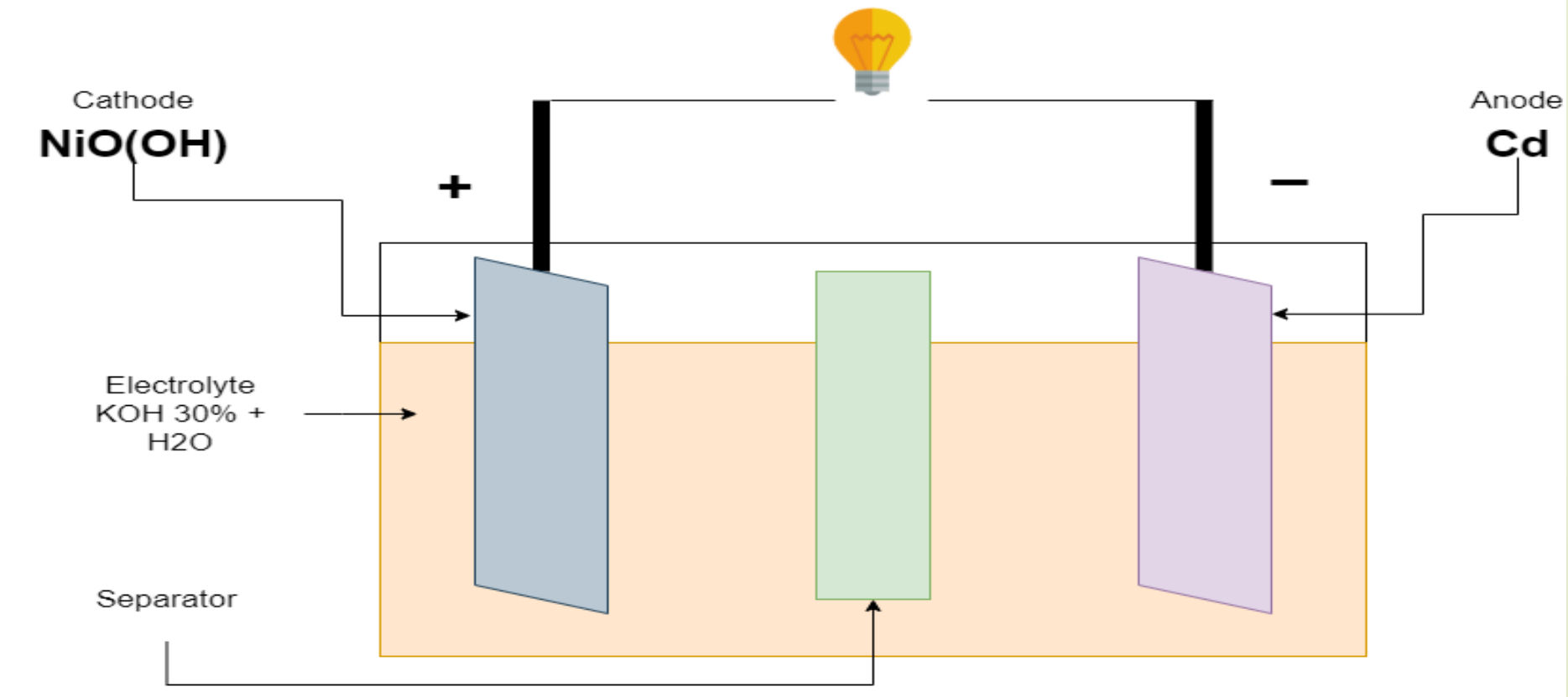
1. Has a long warranty of over ten years
2. Low risk and safe
3. High discharge and charging allowed
4. No degradation problem with less charge
5. Scalable and modular
6. Has a very high energy density
7. Have a peak efficiency of 92%-98%
8. Lithium-ion batteries can charge 70% faster than lead-acid batteries.

Disadvantages

1. Difficulty in recycling the components
2. Won’t function if the inverter is not compatible
3. Will shut down if the temperature is high(above 40+ degrees)
4. Will trip off if the load is high
5. It will stop working if the temperature is too low(below 5 degrees)

3- Nickel – cadmium battery:

1. Its nominal voltage is 1.2v per cell, its fully charged voltage is 1.55v
2. The capacity of the battery is near 1000mAh
3. This battery has a discharge/charge cycle is about 2000 cycles.



Advantages

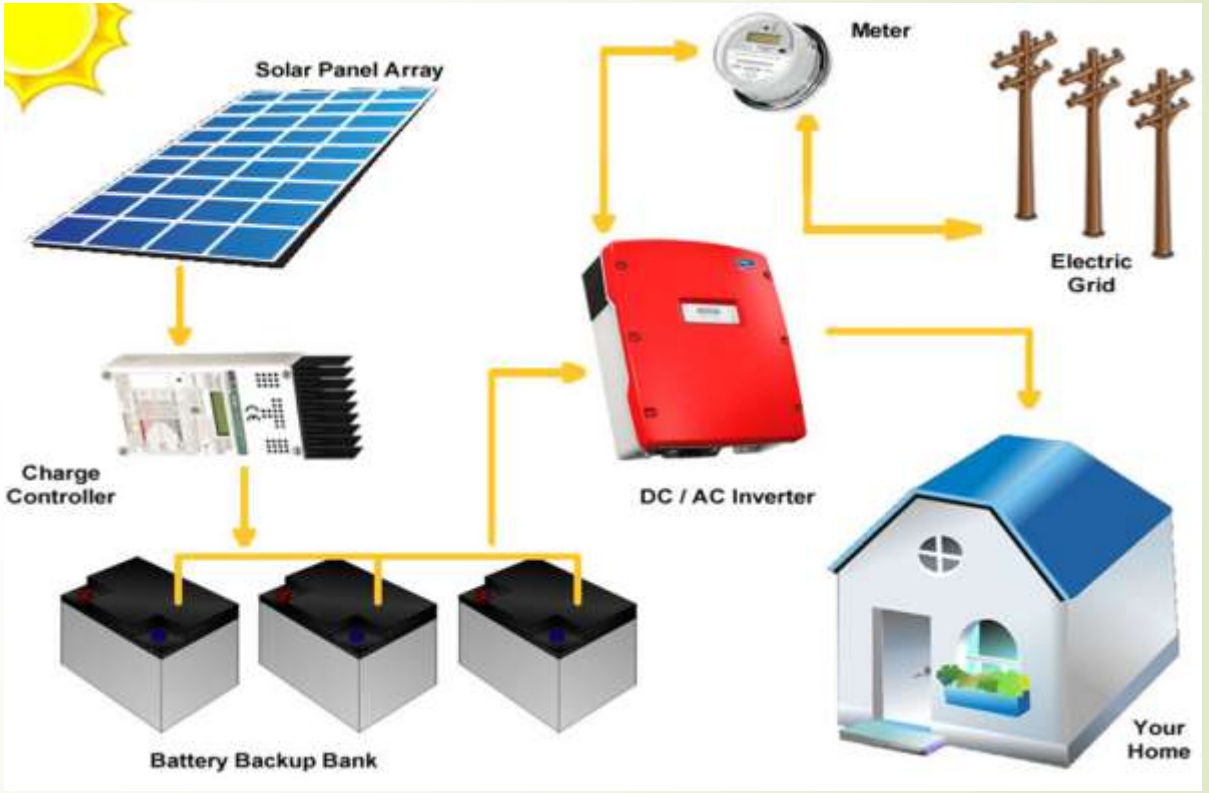
1- a long lifespan if properly maintained
2- it is maintenance-free
3- can operate at extreme temperatures.

Disadvantages :

1- Very expensive
2- Cadmium is considered VERY hazardous.
3- Low efficiency (65-80%)
4- Non-standard voltage and charging curves may make it difficult to use some equipment, such as standard inverters and chargers.

Types of Solar Electrical Systems:

1. Stand alone / Off-grid.
2. Grid – Tie.
3. Grid tie with power backup.
4. Grid fallback.
5. Grid failover.



Factors that can effect PV Panel efficiency:

1. Temperature
   Ideal …….. (25 C^{o} = 77 F^{o}).
   Temperature Coefficient of power …. (1 c^{o} ↑ , 0.5%↓).
2. Shade.
3. Angle (Tilt angle during Winter, Summer).
4. Weather (Cloudy, Sunny).
5. Pollutants (Dust, sand, ...etc).

Advantages and disadvantages:

1. The Advantage:

- There is no production of noise.
- There is absolutely no pollution .
- Cheaper to produce energy in the long term.

2. The disadvantage:

- Weather affect the system output.
- High start up cost.

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