Energy

* Solar Energy:

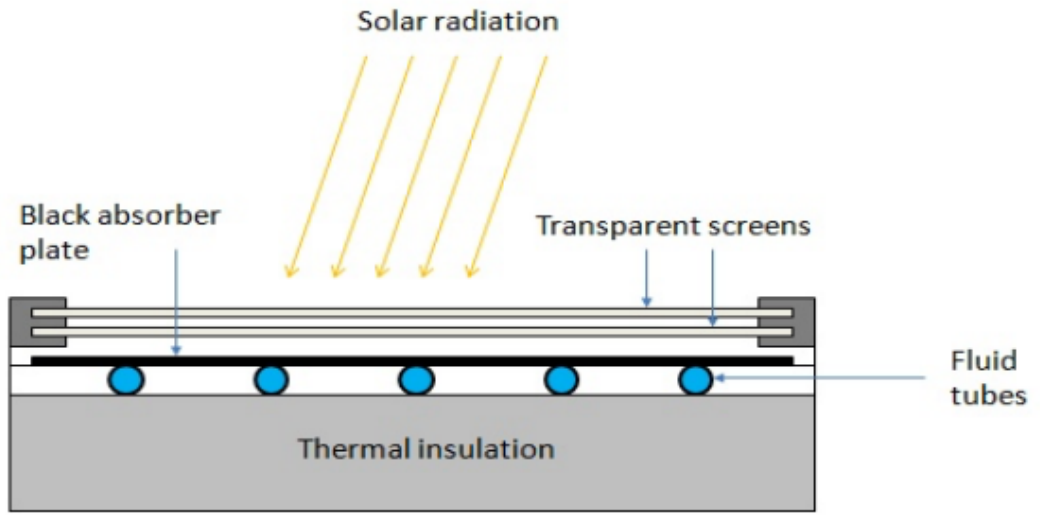
The electromagnetic radiation from sun is commonly known as solar energy.

Resulted due to thermo nuclear fission rxns of surface of sun.

Flat Plate Collector:

The device works on the principle of black body in which heat absorbing capacity and tendency of a black surface is utilized to achieve benefits for human.

Diagram:



Construction:

These are the main components of a typical flat-plate solar collector:

- Black surface - absorbent of the incident solar energy
- Glazing cover - a transparent layer that transmits radiation to the absorber, but prevents radiative and convective heat loss from the surface
- Tubes containing heating fluid to transfer the heat from the collector
- Support structure to protect the components and hold them in place
- Insulation covering sides and bottom of the collector to reduce heat losses

Application

Some advantages of the flat-plate collectors are that they are:Easy to manufacture

- Low cost, Collect both beam and diffuse radiation
- Permanently fixed (no sophisticated positioning or tracking equipment is required)
- Little maintenance

Active heating system

a] Active systems use one or more pumps to circulate water or heating fluid. This permits a much wider range of system configurations.

b] Easily controlled & higher efficiency.

c] Features like safety functions, remote access, informative displays, backups, etc make it expensive.

Passive heating System

a] Relies or natural convection for circulation.

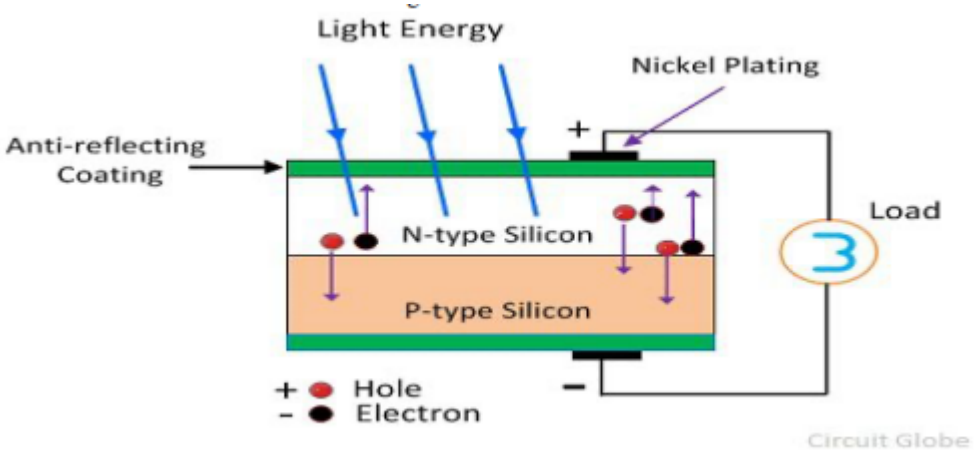
b] Less expensive than active systems

c] More reliable & may last longer.

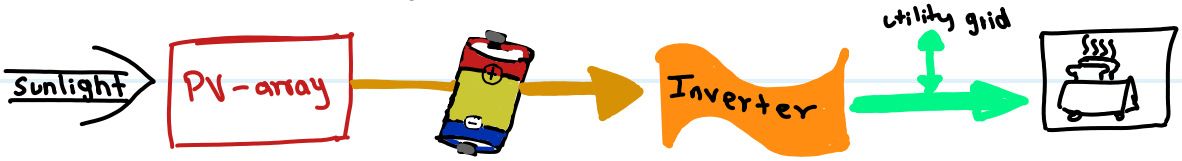
* Production of Electricity

- Photovoltaic cell
- Solar trough collector

- Photovoltaic cell



- Sunlight impinges on silicon crystal
- Photon liberates electron
- Electrons drifts aimlessly in p-region
- If it encounters junction, electron is swept across, constituting current.
- Electron collected at grid, flows through circuit (opposite current lines)



- 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.

→ A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by photo voltaic effect which is a physical and chemical phenomenon.

→ Solar cells are described as being photo voltaic, irrespectivic of whether the source is sunlight or an artificial light. They are used as a photo detector for detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

The operation of a photovoltaic (PV) cell requires three basic attributes:

I. The absorption of light, generating either electron-hole pairs or excitons.
II. The separation of charge carriers of opposite types.
III. The separate extraction of those carriers to an external circuit.

Advantages & Disadvantages

Photovoltaic solar energy

Advantages:

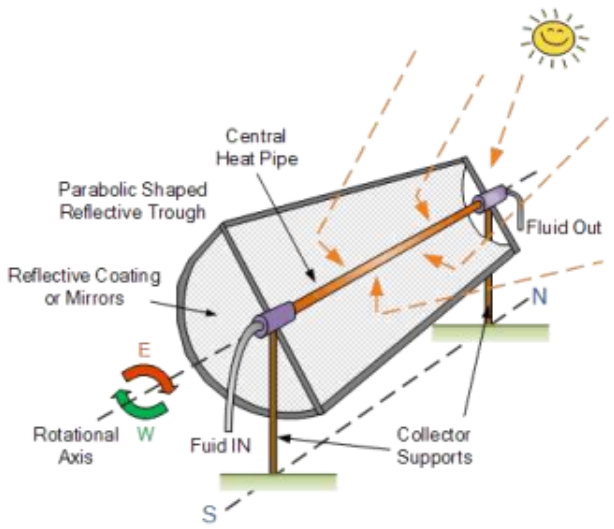
- environmentally friendly
- no noise, no moving parts
- no emissions
- no use of fuels and water
- minimal maintenance requirements
- long lifetime, up to 30 years
- electricity is generated wherever there is light, solar or artificial
- PV operates even in cloudy weather conditions
- modular "custom-made" energy can be sized for any application from watch to a multi-megawatt power plant

Limitations:

- PV cannot operate without light
- high initial costs that overshadow the low maintenance costs and lack of fuel costs
- large area needed for large scale applications
- PV generates direct current special DC appliances or an inverter are needed
- in off-grid applications energy storage is needed

Solar Trough Collector

that is



A parabolic trough is a type of solar thermal collector straight in one dimension and curved as a parabola in the other two, lined with a polished metal mirror. The energy of sunlight which enters the mirror parallel to its plane of symmetry is focused along the focal line, where objects are positioned that are intended to be heated.

Fuels

! Fuels can be defined as substances which undergo combination in the presence of air to produce a large amount of heat that can be used economically for domestic & industrial purpose.

Eg:- Wood, Coal, Kerosene, Petrol.

Classification of Chemical fuels

Based on origin

i] Primary or natural fuels

ii] Secondary or artifical or derived fuels

Based on Physical State

i] Solid Fuels

ii] Liquid Fuels

iii] Gaseous Fuels

Based on Chemical Nature

i] organic eg:- Vegetable fuel, coal

ii] Inorganic eg:- Iron Pyrites

iii] Nuclear Fuels eg:- Uranium oxide

* Characteristic Properties of Fuels :-

i] Calorific value should be as high as possible.

ii] Ignition temp - moderate

iii] Flame temp should be as high as possible.

iv] Flash & fire point should be as high as possible.

v] Aniline point should be low.

vi] Cloud & Pour point should be as low as possible.

vii] Viscosity should be adequate.

viii] Coke no. should be as high as possible.

ix] Moisture content - as low as possible.

x] Volatile matter as low as possible.

xi] Ash content should be absent.

xii] Easy risk free transport should be possible.

xiii] Storage space - ideally fuel should occupy small space.

xiv] Air requirement - adequate

xv] Harmless products should be produced on combustion.

* Calorific Value

- Calorific value is defined as the number of parts of water which gets heated through 1°C by the heat evolved by the complete combustion of one unit weight of fuel under the conditions such as

i] Whole of heat evolved is absorbed by water

ii] The product formed leave the system at atmospheric temp & pressure.

- Units of calorific value

1] B.T.U. (British Thermal Unit)

→ Heat req. to raise the temp of one pound of water from 60°F to 61°F

2] K.C.U. (Kilogram Centrigrade Unit)

→ Heat req. to raise the temp of one KG of water from 15°C to 16°C.

Correlation b/w BTU & KCU:

1 BTU = 0.252 KCal = 252 Cal

1 KCal = 3.968 BTU

3] C.H.U. (Centrigrade Heat Unit)

→ Heat req. to raise the temp of one pound of water through one degree centrigrade.

- High Calorific value (HCV) or Gross Calorific value (GCV):

GCV may be defined as the total amount of heat produced when one unit of the fuel has been burnt completely and the products of combustion have been cooled to 16°C or 60°F.

- Low calorific value (LCV) or Net Calorific value (NCV):

NCV may be defined as net heat produced when unit mass or volume of fuel is completely burnt and produced are allowed to escape.

NCV = GCV - Latent Heat of water formed

NCV = GCV - Mass of Hydrogen x 9 x Latent Heat of steam

NCV = GCV - 0.09 x % H x 587

Because 1 part by weight of hydrogen produces 9 parts (1+8) by mass of water.

* Dulong Formula

The calorific value of fuels is determined theoretically by Dulong formula or I.A. Davies formula.

$$Q = \frac{1}{100}\left[8080 \times C + 34500 \times \left(H - \frac{O}{8}\right) + 2240 \times S\right]$$

Q = KCU

C = % C , H = % H , O = % O , S = % S

Dulong formula for HCV & LCV

$$HCV/GCV = \frac{1}{100}\left[8080 \times C + 34500 \times \left(H - \frac{O}{8}\right) + 2240 \times S\right]$$

$$LCV/NCV = HCV - \left[\frac{9}{100} \times \% H \times 587\right]$$

Experimentally Calorific value of solid & liquid fuel is determined using Bomb Calorimeter.

Q] Numerical 1: A sample of coal contains C = 55%, O = 28%, H =7%, S = 0.7%, N =0.2%, Ash = 0.2%. Calculate the GCV and NCV.

→

$$GCV = \frac{1}{100}\left[8080 \times 55 + 34500 \times \left(7 - \frac{28}{8}\right) + 2240 \times 0.7\right.$$

$$GCV = 5667 \text{ Kcal/Kg}$$

$$NCV = HCV - 0.09 \times 7 \times 587$$

$$= 5667 - 0.09 \times 7 \times 587$$

$$= 5287.19 \text{ Kcal/Kg}$$

* Hydrocarbon as fuel

- Characteristics

· Hydrocarbon are highly energy-dense compounds.

· Exists in different forms solid (coal), liquid (crude oil) & gaseous (natural gas)

· Liquid hydrocarbons such as gasoline and diesel are relatively easy to transport & store compared to other forms of energy.

- Enviromental & Societal Impact:

· Decline & Exhaustion of the fossil energy resources is an issue our society is facing.

· Combustion of Hydrocarbons releases CO_2, a greenhouse gas contributing to climate change.

· Incomplete combustion can result in emissions of harmful pollutants like CO, NO_x etc.

- Future trends & Alternatives:

· Shift towards renewable energy: As ↑ing concerns about change and enviromental impact Renewable energy resources like power alcohol & biodiesel, fuel cell are gaining importance.

· Technological Innovations: Ongoing research & development aim to improve efficiency of hydrocarbon-based fuel production and reduce their environmental footprint.

* Power Alcohol

Power alcohol also known as ethanol or ethyl alcohol, is a type of renewable biofuel derived from plant materials such as sugarcane, corn, barley, wheat or cellulose-rich materials like wood chips & agricultural residues.

Production:

- Fermentation: Sugars present in plant materials are converted into ethanol by the action of yeast or bacteria in absence of oxygen.

$$\text{starch} \xrightarrow{\text{diastase}} \underset{\text{(maltose)}}{C_{12}H_{22}O_{11}}$$

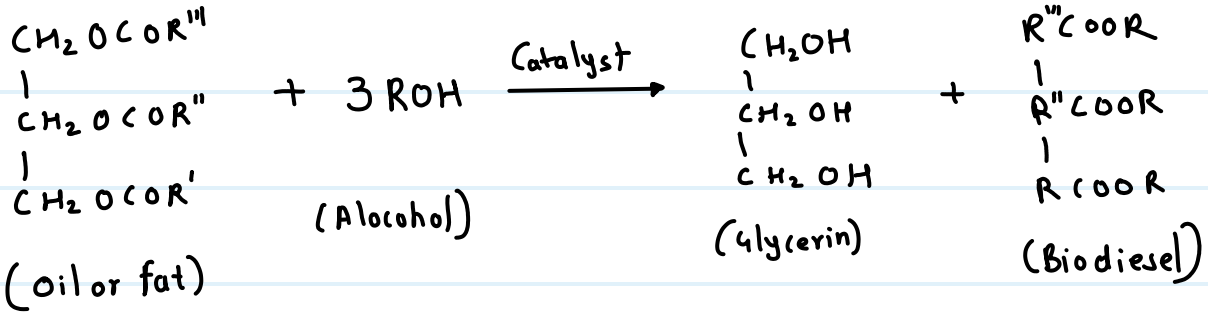
$$\underset{\text{(maltose)}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{maltase}} 2\,\underset{\text{(glucose)}}{C_6H_{12}O_6}$$

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} \xrightarrow{\text{Zymase}} 2\,\underset{\text{(ethanol)}}{C_2H_5OH} + 2\,CO_2$$

Advantages	Limitations
• Lower CO_2 emissions, ∴ reduce greenhouse gas emission	• Calorific value of ethanol < gasoline, ∴ reduced mileage in vehicals.
• Domestic production of ethanol is generally high, ∴ reducing dependence on imported oil	• Ethanol has high water content making it prone to cold weather.
• Ethanol has high octane ratings hence can used as a blending component in gasoline.	• There are a lot infrastructure & compatibity issues resulting it to be cost-ineffective.
• Renewable & Enviromentally Friendly.	

* Biodiesel

- Biodiesel is a liquid biofuel obtained by chemical processes from vegetable oils or animal fats
- Can be used as substitute for petroleum-based diesel fuel.
- The product of biodiesel chemical reaction is known as transesterification.
- Transesterification is the chemical process, which converts natural fats and oils into Biodiesel.



Advantages	Disadvantages
• Low toxicity, in comparison with diesel fuels.	• Slightly higher fuel consumption due to lower calorific value of biodiesel.
• Degrades more rapidly than diesel fuel, minimizing environmental consequence of biofuel spill	• Slightly higher nitrous oxide (NO_x) emissions than diesel fuel.
• Lower emissions of contaminants: CO, SO_2 particulate matter, poly cyclic aromatic hydrocarbon	• Higher freezing point than diesel fuel results in inconvinence in cold climates.
• Lower health risk due to reduced emissions of carcinogenic substances	• Less stable than diesel ∴ long term storage of biodiesel is not recommended

Rechargeable Batteries

Battery is a device consisting of two or more galvonic cells connected in series or parallel or both

Classification of Batteries

Primary Battery

- cell reaction is not reversible,
- after discharging cannot be rechargeable

Eg:- $Zn - MnO_2$ dry cell.

Secondary Battery

- cell reaction is reversible,
- after discharging can be rechargeable

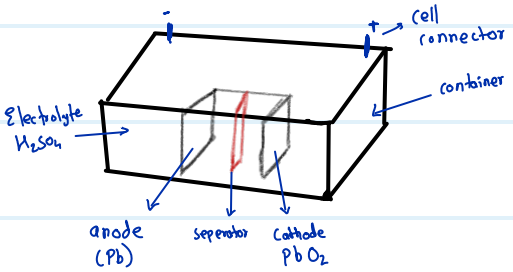
Eg:- Lead-acid, Ni-Cd battery

Types of Secondary Batteries

- Lead-acid battery
- Nickel-Cadimium battery
- Lithium-ion battery

The chemical process of extrachng current from a secondary battery (forward rxn) is called discharging. The method of regenerating active material is called charging.

1] Lead Acid Batteries



- Construction

Cathode: Group of lead plate bearing spongy lead

Anode: A grid of lead bearing lead oxide

Electrolyte: In lead acid battery dil. H_2SO_4 (38%) is used

Separator: Seperates +ve & -ve plates from each other to prevent short circuit. Wood, rubber, glass wood mate, pvc etc are used as separators

- Working

Electrolyte: $2H_2SO_4 \longrightarrow 4H^+ + SO_4^{2-}$

$H \rightarrow H^+$
$O \rightarrow H_2O$

Anode: $Pb + SO_4^{2-} \underset{\text{charging}}{\overset{\text{discharging}}{\rightleftharpoons}} PbSO_4 + 2e^-$ (Oxidation)

Cathode: $PbO_2 + SO_4^{2-} + 4H^+ + 2e^- \underset{\text{charging}}{\overset{\text{discharging}}{\rightleftharpoons}} PbSO_4 + 2H_2O$ (Reduction)

Overall rxn: $Pb + PbO_2 + 2H_2SO_4 \longrightarrow 2PbSO_4 + 2H_2O$

- The optimum func^{n}al temp for lead acid battery is 25°C which means 77°F The increase in the range of temp shortens longevity. As per the rule, for every 80°C ↑ in temp, it reduces the half-life of battery.

While a valve regulated battery that func^n at 25°C has a lead acid battery life of 10 years. And when this is operated at 33°C, it has a life period of 5 years only.

Lead Acid Battery Applications :-

- Employed in emergency lightening to provide power for sump pumps.
- Used in Electric motors.
- Used in Submarines.
- Used in Nuclear Submarines.

2] Nickel - Cadmium battery

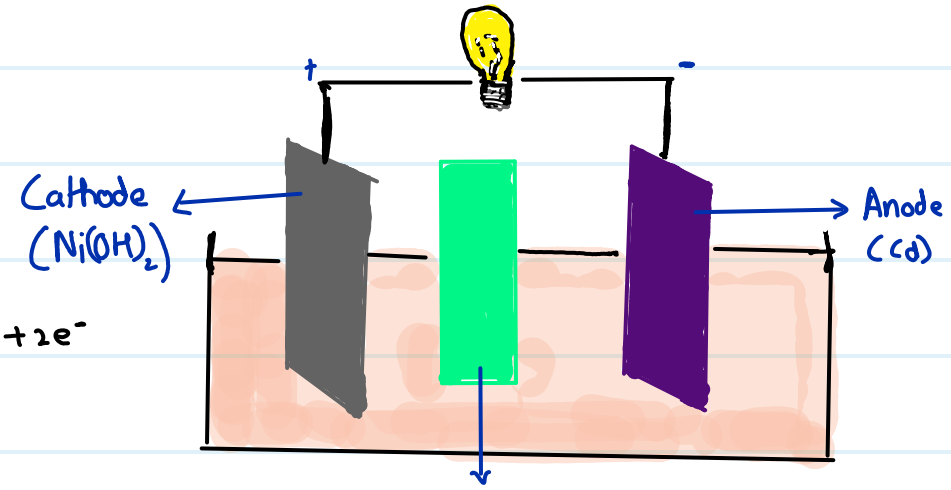
Rechargeable battery that uses metallic Cd along with $Ni(OH)_2$ as cell's electrode

- These batteries are capable of delivering excephonally high currents, can be rapidly recharged hundreds of time.
- It produces a voltage of about 1.4V.

- Construction

It is made up of three layers. The nickel layer is first, followed by separator layer, and then cadmium layer. Nickel layer acts as +ve electrode collector, while the cadmium layer acts as -ve electrode collector.

- KOH or NaOH is used as a separator layer b/w the two layers. Its role is to supply OH^- ions.
- A safety valve, sealing pad, insulation ring, insulation gasket, and an exterior case round out the package. The insulation ring's job is to keep the two layers apart by providing insulation.



- Working

Anode : $Cd + 2OH^- \longrightarrow Cd(OH)_2 + 2e^-$

Cathode: $2NiO(OH) + 2H_2O + 2e^- \longrightarrow 2Ni(OH)_2 + 2OH^-$

Overall rxn: $Cd + 2NiO(OH) + 2H_2O \longrightarrow Cd(OH)_2 + 2Ni(OH)_2$

Advantages	Limitations
• Fast & simple charing processes.	• More expensive than lead storage battery.
• Light & compact than traditional battery.	• It has lower energy density value.
• Longer life than lead acid battery.	• Cd is toxic metal, cannot be disposed easily.
• Good low-temp performance.	• High self-discharge; needs recharge after storage

- Applications:

Calculators, Electronic flash units, Transistors, cordless appliances.

3] Lithium-ion batteries

Lithium ion battery uses lithium based compound as active raw material. Since Li is very reactive compound it cannot be used in pure form.

- Construction

Anode: Pure graphite or Lithium hexa Carbide [LiC_6]

Cathode: Intercalated compound of Lithium metal oxide [$LiMO_2$] where metal can be Co, Mn, Ti

Electrolyte · Lithium hexa fluoro phosphate ($LiPF_6$)

Separator: A non-conductive polymer material is used as separator

- During charging & discharging process, the Li ions move back & forth b/w the two electrodes of battery, this principle is called rocking chair principle.

- Working :-

Cathode · $LiMO_2 \longrightarrow Li^+ + MO_2 + e^-$

Anode: $C_6 + Li^+ + e^- \longrightarrow LiC_6$

Overall rxn: $LiMO_2 + C_6 \longrightarrow LiC_6 + MO_2$

- Advantages:-

- Significantly low self-discharge rate as compared to other batteries.
- High energy density.
- Avg life span of Li-ion is 10x lead acid batteries.
- Charging rate is high.
- Work efficiently under extreme conditions like high pressure & temp fluctuations.
- Light weight & compact in size.
- Installation is easy.

- Applications:-

- Emergency Power Backup or UPS.
- Solar Power Storage
- Reliable & Lightweight marine performance.
- Surveillance or Alarm Systems in remote locations.