NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE
(NAAC Accredited)
(Approved by AICTE, Affiliated to APJ Abdul Kalam Technological University, Kerala)

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE MATERIALS

ME403 ADVANCED ENERGY ENGINEERING

VISION OF THE INSTITUTION

To mould true citizens who are millennium leaders and catalysts of change through excellence in education.

MISSION OF THE INSTITUTION

NCERC is committed to transform itself into a center of excellence in Learning and Research in Engineering and Frontier Technology and to impart quality education to mould technically competent citizens with moral integrity, social commitment and ethical values.

We intend to facilitate our students to assimilate the latest technological know-how and to imbibe discipline, culture and spiritually, and to mould them in to technological giants, dedicated research scientists and intellectual leaders of the country who can spread the beams of light and happiness among the poor and the underprivileged.

ABOUT DEPARTMENT

- Established in: 2002
- Course offered : B.Tech in Mechanical Engineering

- ♦ Approved by AICTE New Delhi and Accredited by NAAC
- ♦ Affiliated to the University of Dr. A P J Abdul Kalam Technological University.

DEPARTMENT VISION

Producing internationallycompetitive Mechanical Engineerswith social responsibility & sustainable employability through viable strategies as well as competent exposure oriented quality education.

DEPARTMENT MISSION

1. Imparting high impacteducation by providing conductive teaching learning environment.
2. Fostering effective modes of continuous learning process with moral & ethical values.
3. Enhancing leadership qualities with social commitment, professional attitude, unity, team spirit & communication skill.
4. Introducing the present scenario in research & development through collaborative efforts blended with industry & institution.

PROGRAMME EDUCATIONAL OBJECTIVES

PEO1: Graduates shall have strong practical & technical exposures in the field of Mechanical Engineering & will contribute to the society through innovation & enterprise.

PEO2: Graduates will have the demonstrated ability toanalyze, formulate & solve design engineering / thermal engineering / materials & manufacturing / design issues & real life problems.

PEO3: Graduates will be capable of pursuing Mechanical Engineering profession with good communication skills, leadership qualities, team spirit & communication skills.

PEO4: Graduates will sustain an appetite for continuous learning by pursuing higher education & research in the allied areas of technology.

PROGRAM OUTCOMES (POS)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and teamwork**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSO)

PSO1: graduates able to apply principles of engineering, basic sciences & analytics including multi variant calculus & higher order partial differential equations..

PSO2: Graduates able to perform modeling, analyzing, designing & simulating physical systems, components & processes.

PSO3: Graduates able to work professionally on mechanical systems, thermal systems & production systems.

COURSE OUTCOMES

CO1	Discuss the classification of energy resources and examine the layout and working principles of steam, hydro, nuclear, gas turbine and nuclear power plants Identify the value of facility planning on the strategy of a firm.
CO2	Classify the types of solar thermal and solar photovoltaic systems and examine the economics and sustainability attributes of solar power.
CO3	Discuss the types of wind power conversion systems and examine the design and economics of wind power plants
CO4	Explain the conversion methods of biomass into fuels and examine the economics of biomass power generation
CO5	Discuss and examine the scope and economics of geothermal energy, ocean thermal energy, MHD, fuel cells, wave and tidal energy plants
CO6	Discuss the environmental impacts of energy conversion and develop promising sustainable energy technologies

MAPPING OF COURSE OUTCOMES WITH PROGRAM OUTCOMES

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	1	1	-	-	1	2	-	-	-	1	-	-	2	2
CO2	1	1	2	-	-	2	2	-	-	-	1	-	-	2	2
CO3	2	1	3	-	-	2	2	-	-	-	1	-	-	2	3
CO4	1	1	1	-	-	1	2	-	-	-	1	-	-	1	1
CO5	2	1	2	-	-	1	2	-	-	-	2	-	-	1	1
CO6	1	1	3	-	-	2	3	-	-	-	2	-	-	1	2

Note: H-Highly correlated=3, M-Medium correlated=2, L-Less correlated=1

SYLLABUS

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME403	ADVANCED ENERGY ENGINEERING	3-0-0-3	2016

Prerequisite: Nil

Course Objectives:

1. To give an idea about global energy scenario and conventional energy sources
2. To understand solar, wind and Biomass energy
3. To know concepts of other renewable energy sources
4. To create awareness on the impacts of energy conversion and importance of sustainable energy

Syllabus

Global and Indian energy scenario, conventional energy sources, environmental effect of energy conversion, renewable energy sources- solar, wind, biomass, brief account of other renewable energy sources –geothermal, tidal, MHD, hydrogen, fuel cells, small scale hydro power plants. Environmental impact and Sustainability issues.

Expected outcome:

The students will be able to

i. Understand energy scenario and the environmental effects of energy conversion.
ii. Become aware of different renewable energy sources and choose sustainable energy for

Text Books:

1. Jefferson W Tester et.al., Sustainable Energy: Choosing Among Options, PHI, 2006
2. P K Nag, Power Plant Engineering, TMH, 2002
3. Tiwari G N, Ghosal M K, Fundamentals of renewable energy sources, Alpha Science International Ltd., 2007

References Books:

1. David Merick, Richard Marshall, Energy, Present and Future Options, Vol.I & II, John Wiley & Sons, 2001
2. Godfrey Boyle, Renewable Energy : Power for a Sustainable Future, Oxford University Press, 2012
3. Roland Wengenmayr, Thomas Buhrke, 'Renewable Energy: Sustainable energy concepts for the future, Wiley – VCH, 2012
4. Twidell J W and Weir A D, Renewable Energy Resources, UK, E&F.N. Spon Ltd., 2006

Course Plan

Module	Contents	Hours	End Sem. Exam Marks
I	Introduction to the course. Global and Indian energy resources. Energy Demand and supply. Components, layout and working principles of steam, hydro, nuclear, gas turbine and diesel power plants	7	15%
II	Solar Energy- passive and active solar thermal energy, solar collectors, solar thermal electric systems, solar photovoltaic systems. Economics of solar power. Sustainability attributes.	7	15%
FIRST INTERNAL EXAM			

III	Wind Energy-Principle of wind energy conversion system, wind data and energy estimation, wind turbines, aerodynamics of wind turbines, wind power economics. Introduction to solar-wind hybrid energy systems	7	15%
IV	Biomass Energy – Biomass as a fuel, thermo-chemical, bio-chemical and agro-chemical conversion of biomass- pyrolysis, gasification, combustion and fermentation, transesterification, economics of biomass power generation, future prospects.	6	15%
	SECOND INTERNAL EXAM		
V	Other Renewable Energy sources – Brief account of Geothermal, Tidal, Wave, MHD power generation, Small, mini and micro hydro power plants. Fuel cells – general description, types, applications. Hydrogen energy conversion systems, hybrid systems- Economics and technical feasibility	8	20%
VI	Environmental impact of energy conversion – ozone layer depletion, global warming, greenhouse effect, loss of biodiversity, eutrophication, acid rain, air and water pollution, land degradation, thermal pollution, Sustainable energy, promising technologies, development pathways	7	20%
	END SEMESTER EXAM		

Question Paper Pattern

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A
There should be 2 questions each from module I and II
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part B
There should be 2 questions each from module III and IV
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part C
There should be 3 questions each from module V and VI
Each question carries 10 marks
Students will have to answer any four questions out of 6 (4X10 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

QUESTION BANK

MODULE I			
Q:NO:	**QUESTIONS**	**CO**	**KL**
1	Explain different types of solar collectors	CO1	K2
2	Explain the difference between passive and active solar energy systems with neat sketches	CO1	K3
3	How solar thermal power plants classified. List the methods for converting solar energy into electric power	CO1	K2
4	What are the different solar thermal electric systems? Explain	CO1	K4
5	List advantages and disadvantages of solar energy	CO1	K2
6	Explain Active and Passive solar systems	CO1	K2
7	Briefly explain the types of concentrating solar thermal power plants	CO1	K2
8	Discuss the various types of concentrating collectors	CO1	K4
9	Explain the working of a flat plate collector with a neat sketch	CO1	K2
10	List out the advantages and disadvantages of photovoltaic cells	CO1	K2
11	.Explain with a neat sketch solar pond electric power plant.	CO1	K2
MODULE II			
1	Explain different types of solar collectors	CO2	K2
2	Explain the difference between passive and active solar energy systems with neat sketches	CO2	K4
3	How solar thermal power plants classified. List the methods for converting solar energy into electric power	CO2	K2
4	What are the different solar thermal electric systems? Explain	CO2	K5
5	List advantages and disadvantages of solar energy	CO2	K5
6	Explain Active and Passive solar systems	CO2	K3
7	Briefly explain the types of concentrating solar thermal power plants	CO2	K5
8	Discuss the various types of concentrating collectors	CO2	K4
9	Explain the working of a flat plate collector with a neat sketch	CO2	K2

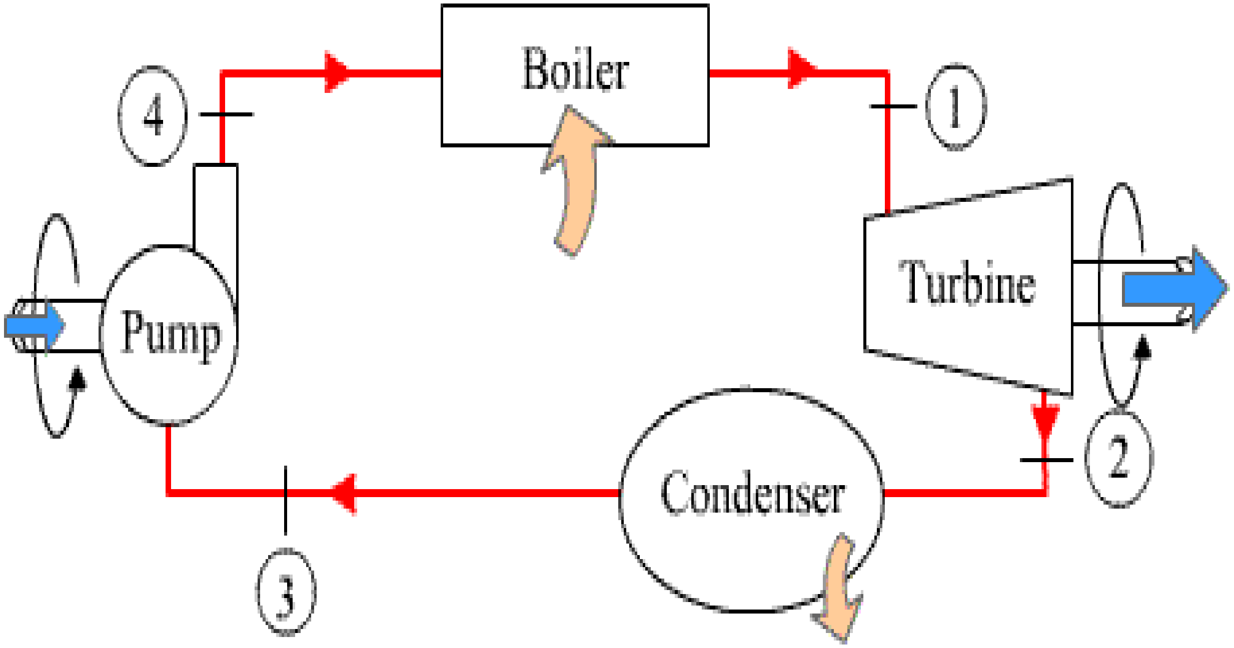
MODULE III			
1	Explain the basic principle of wind energy conversion.	CO3	K3
2	Discuss the advantages and disadvantages of wind energy conversion systems.	CO3	K3
3	What are vertical axis wind turbines? Explain the construction and working of any one type of vertical axis wind turbine with the help of neat sketches	CO3	K2
4	Discuss the advantages of vertical axis wind turbines over horizontal axis wind turbines	CO3	K3
5	Explain the main considerations in selecting a site for wind energy converters	CO3	K5
6	How wind turbines are classified? Explain the construction and working of a horizontal axis wind turbine with the help of neat sketches	CO3	K3
7	Write notes on solar-wind hybrid systems with a sketch	CO3	K2
8	Discuss the environmental impact of wind turbines	CO3	K5
9	What do you mean by (a) Yaw control (b) Rated wind speed (c) Pitch Control (d) Teethering control - with respect to wind turbines?	CO3	K5
10	Discuss site selection for wind power plants?	CO3	K2
MODULE IV			
1	Biomass can be considered as a form of solar energy'. Discuss	CO4	K2
2	Explain the category of biomass resources	CO4	K1
3	What are the advantages and disadvantages of a floating drum biogas plant?	CO4	K2
4	Explain the biochemical and thermo chemical methods of biomass conversion	CO4	K3
5	What is the difference between biomass and biogas?	CO4	K1
6	Explain the constructional details and working of a fixed dome	CO4	K2

	digester with the help of a neat sketch.		
7	What are the advantages and disadvantages of a fixed dome biogas plant	CO4	K3
8	What are the advantages of using biomass as an energy source?	CO4	K3
MODULE V			
1	Discuss single basin and double basin tidal power plant with neat Sketch.	CO5	K2
2	Explain the components of micro hydro power plant.	CO5	K4
3	Debate the different types of hydro thermal corrective system with sketch.	CO5	K44
4	What are the components of tidal power plant explain	CO5	K2
5	Give the advantages and limitations of tidal power plant.	CO5	K3
6	Explain the working principle of geo thermal power plant	CO5	K2
7	Discuss various types geo thermal power plants with block diagram.	CO5	K2
8	What are the advantages and limitations of geothermal energy?	CO5	K3
9	With a diagram explain closed, open and hybrid cycle OTEC.	CO5	K3
MODULE VI			
1	Discuss on ozone layer depletion .	CO6	K3
2	Debate the harmful effects of thermal pollution	CO6	K2
3	What are the various methods used to control atmospheric pollution caused by power plants? Explain.	CO6	K3
4	Describe the causes of land degradation?	CO6	K2
5	Illustrate various inspections carried out for a boiler.	CO6	K3
6	What are the types of radioactive waste?	CO6	K2
7	Give the various approaches adopted for the disposal of radioactive waste in detail.	CO6	K2
8	State the present method used to disposal of radioactive waste.	CO6	K3
9	Point out the actions needed for sustainable development.	CO6	K3

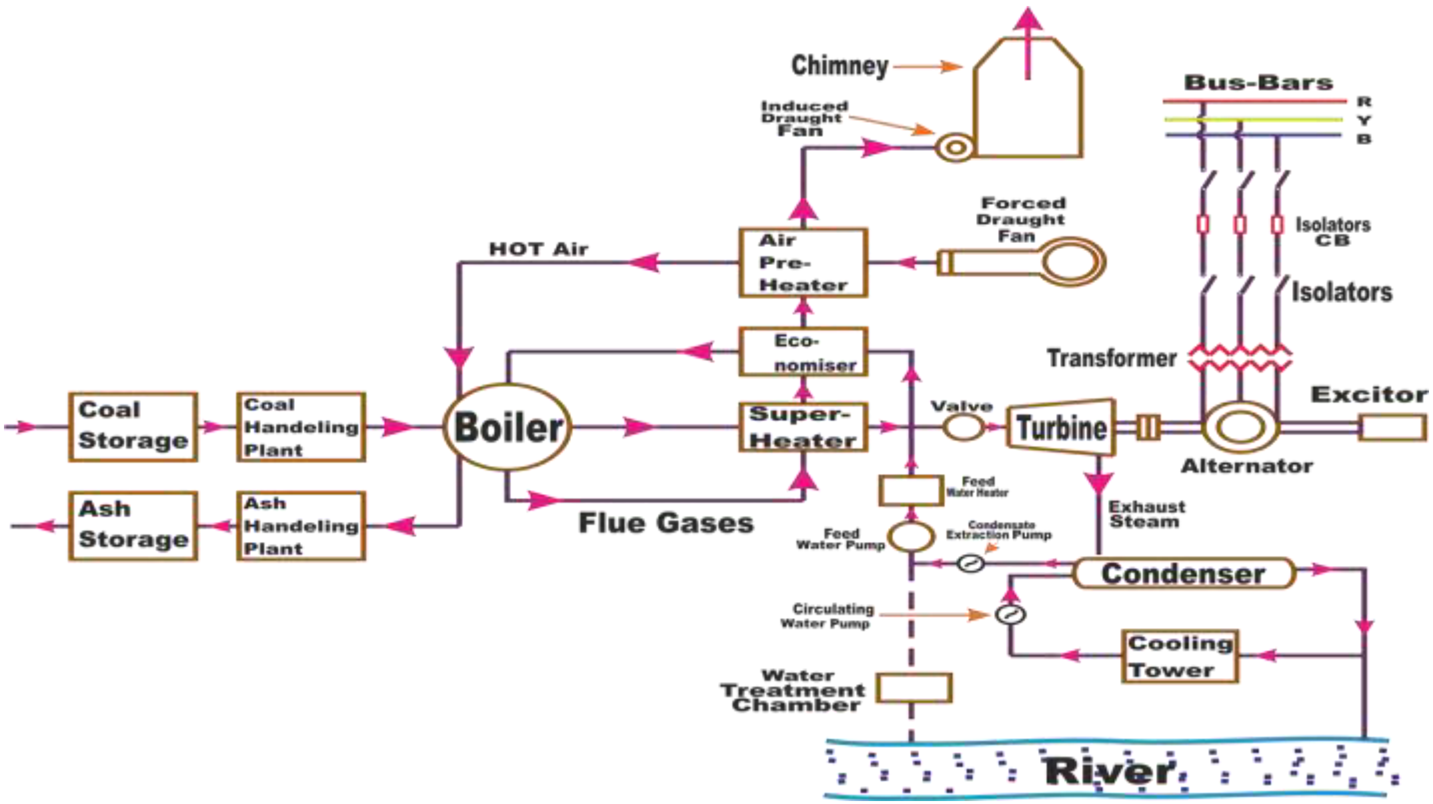
APPENDIX 1	
CONTENT BEYOND THE SYLLABUS	
S:NO.	**WEB SOURCE REFERENCES**
1	http://www.mdpi.com/journal/education
2	www.idc-online.com
3	https://www.ne.anl.gov/About/modern-day-alchemy/
4	http://www.awea.org/
5	http://www.nss.org/settlement/ssp/library/nsso.htm.

M1
Introduction to Advanced Energy Engineering

Basic Circuit of a Steam Power Plant



Layout of Steam Power plant



Components

1. Primary Air fan
2. Forced Draft Fan
3. Induced Draft Fan
4. Air Heater
5. Electrostatic Precipitator
6. Feed Pump
7. Boiler
8. Generator (Alternator)
9. Feed water heater
10. Economiser
11. Raw coal bunker
12. Super Heater

Coal and ash Circuit

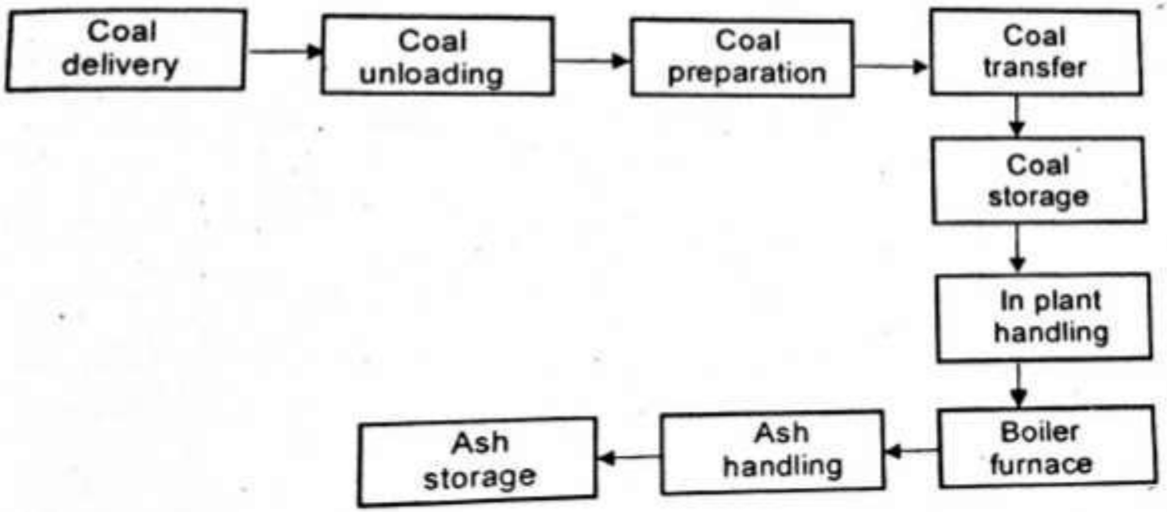
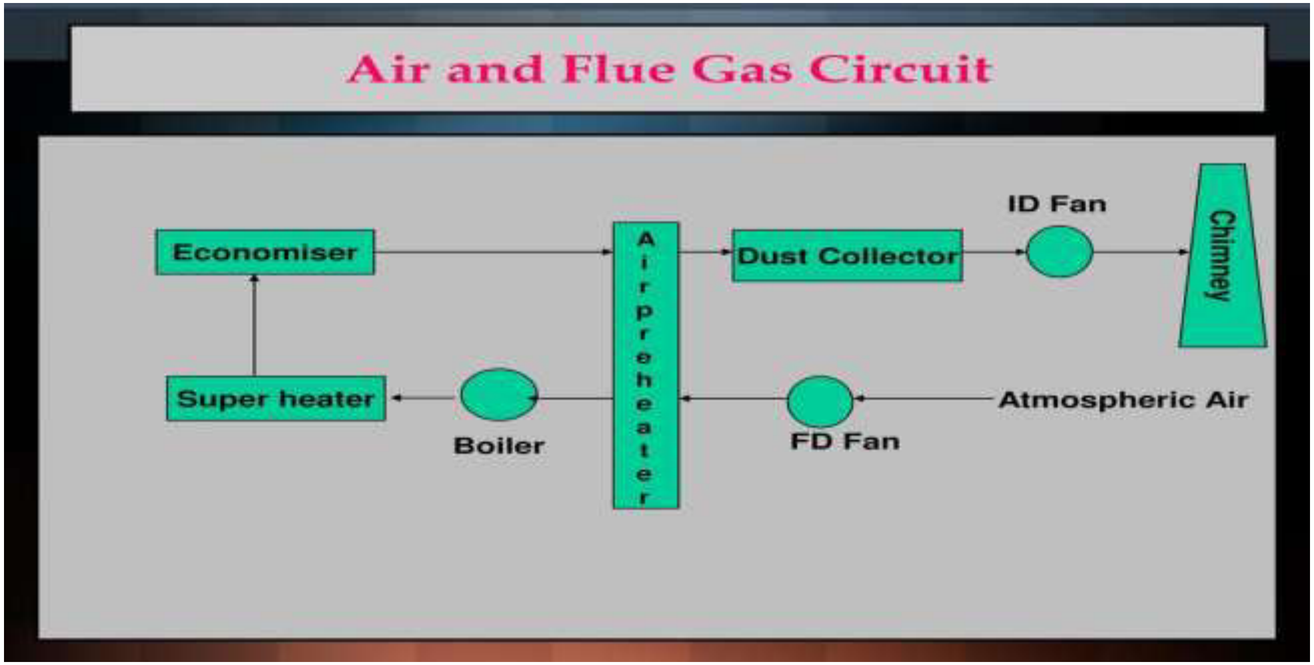
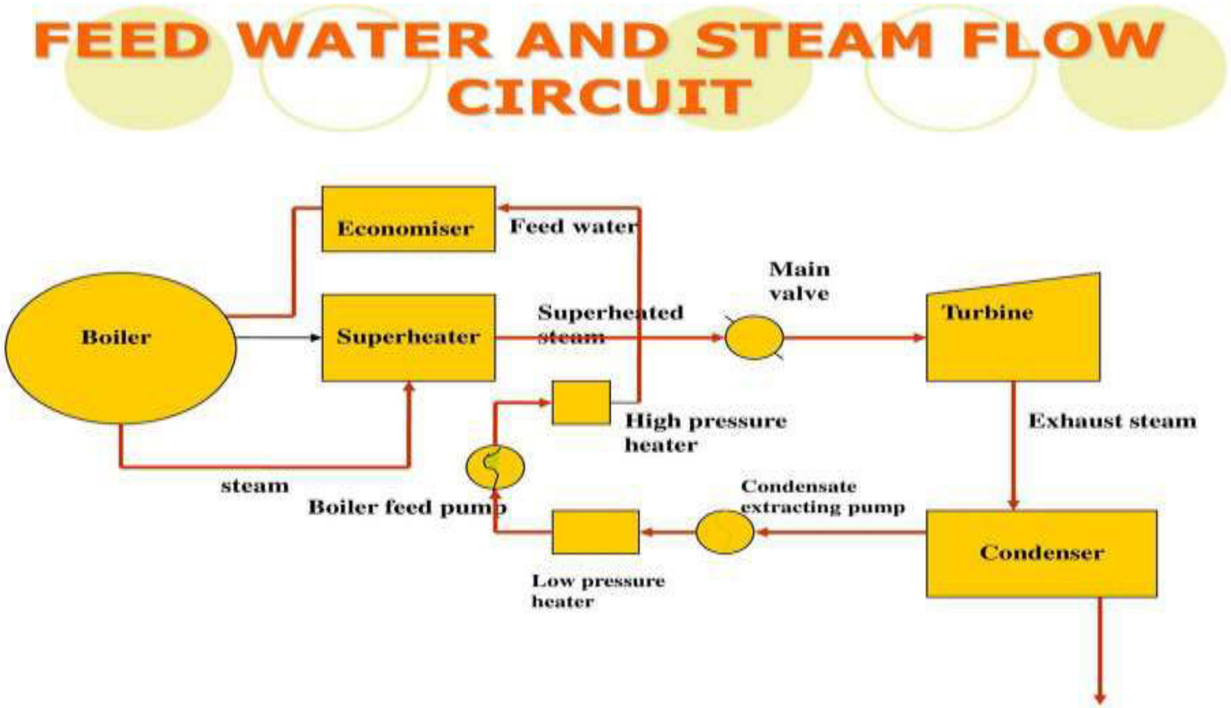


Figure : Fuel (coal) and ash circuit.

Air and Flue Gas Circuit



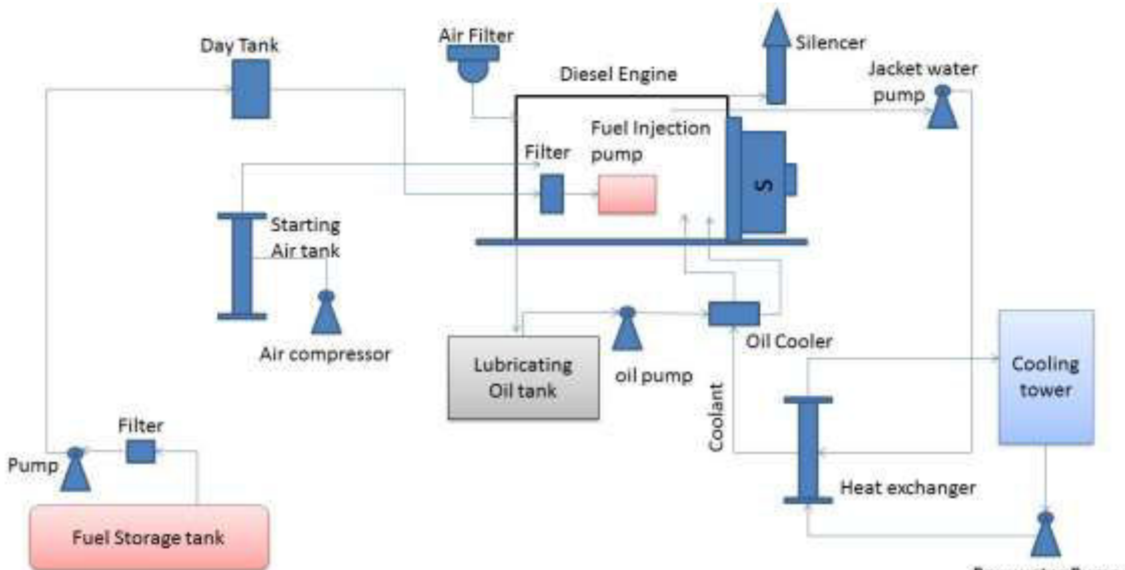
Feed water and Steam Flow Circuit



Selection of Site

1. Availability of raw material
2. Ash disposal facilities
3. Nature of Land
4. Cost of land
5. Availability of water
6. Size of plant
7. Availability of work force
8. Transportation
9. Load centre
10. Public problem
11. Future expansion

Diesel Power Plant



Layout of Diesel Engine Power Plant

Types

1. Peak load plant
2. Mobile plant
3. Stand-by plant
4. Emergency plant
5. Nursery plant
6. Starting stations
7. Central stations

Cooling system

1. Air cooling system
2. Water cooling system
3. Oil cooling system

Hydro Power Plant

1. Reservoir
2. Dam
3. Thrash rack- To prevent debris to turbine damage.
4. Surge tank
5. Fore bay

A fore bay is a basin area of hydropower plant where water is temporarily stored before going into intake chamber. The storage of water in fore bay is decided based on required water demand in that area. This is also used when the load requirement in intake is less.

Hydro Power Plant

6.Pen Stock

7. Spill way

8.Power house

9. Draft tube

If reaction turbines are used, then draft tube is a necessary component which connects turbine outlet to the tailrace. The draft tube contains gradually increasing diameter so that the water discharged into the tailrace with safe.

10. **Intake Structure**

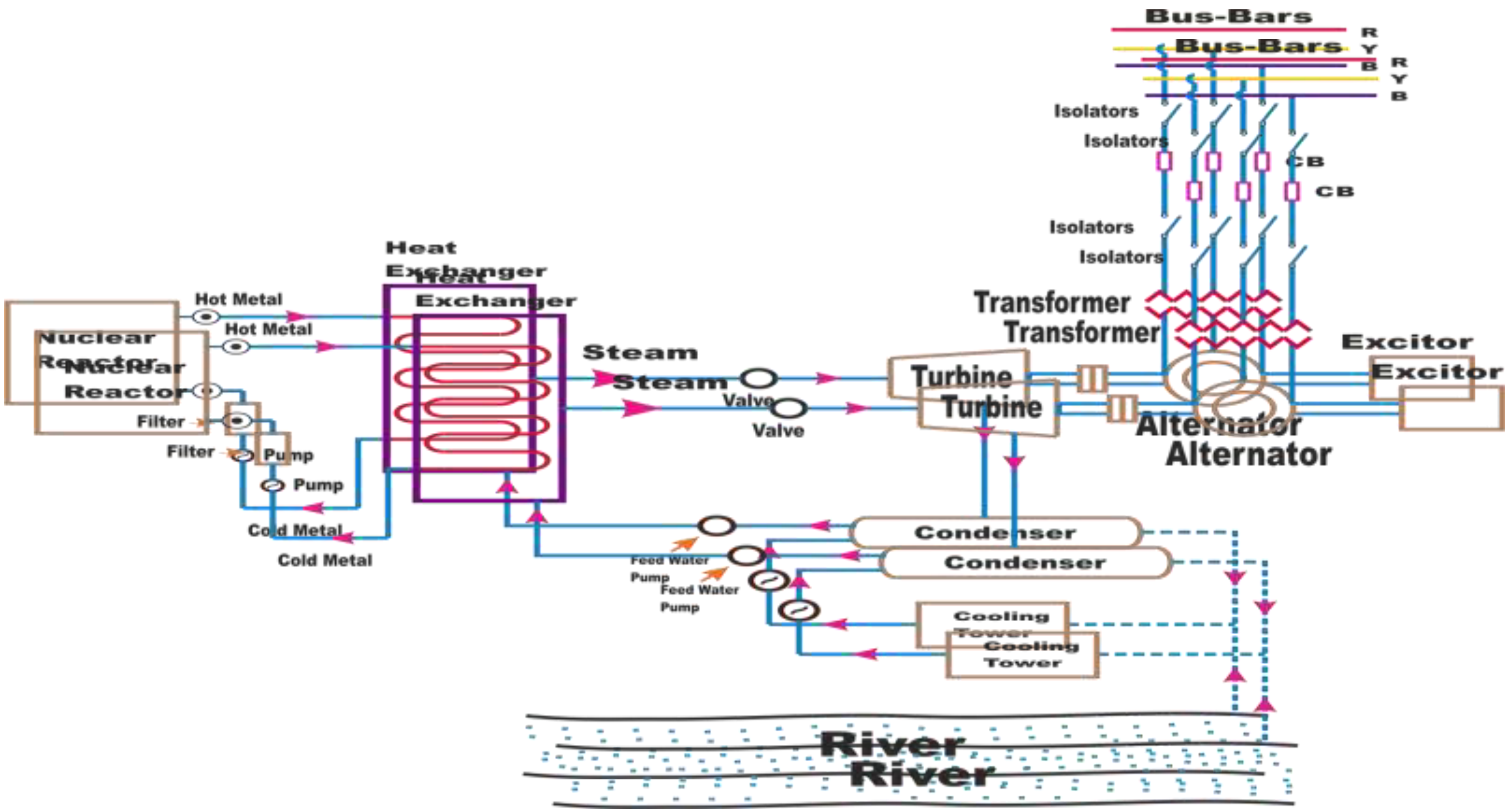
Intake structure is a structure which collects the water from the forebay and directs it into the penstocks.

11. **Surge Chamber**

A surge chamber or surge tank is a cylindrical tank which is open at the top to control the pressure in penstock

12. **Power House** Power house is a building provided to protect the hydraulic and electrical equipment. Generally, the whole equipment is supported by the foundation or substructure laid for the power house.

Nuclear Power Plant



Components of Nuclear Reactor

1.Core – Nuclear fuel + space for coolant

2.Moderator – reduce the speed of fast moving neutrons – E.g. Graphite, heavy water or Beryllium

3Control Rods- To start chain reaction and maintain the chain reaction at required level and to shut down during emergency

4.Coolant - to transfer the heat produced in the reactor to steam generator for raising steam

Components of Nuclear Reactor

4.Reflector – to reflect the escaping neurons back to core.

5. Reactor vessel – housing for all equipment designed to withstand high pressure

6.Steam Generator –to produce steam by absorbing heat from the hot coolant.

7.Turbain

8. Coolant and Feed pump is to pump the feed water to the steam generator.

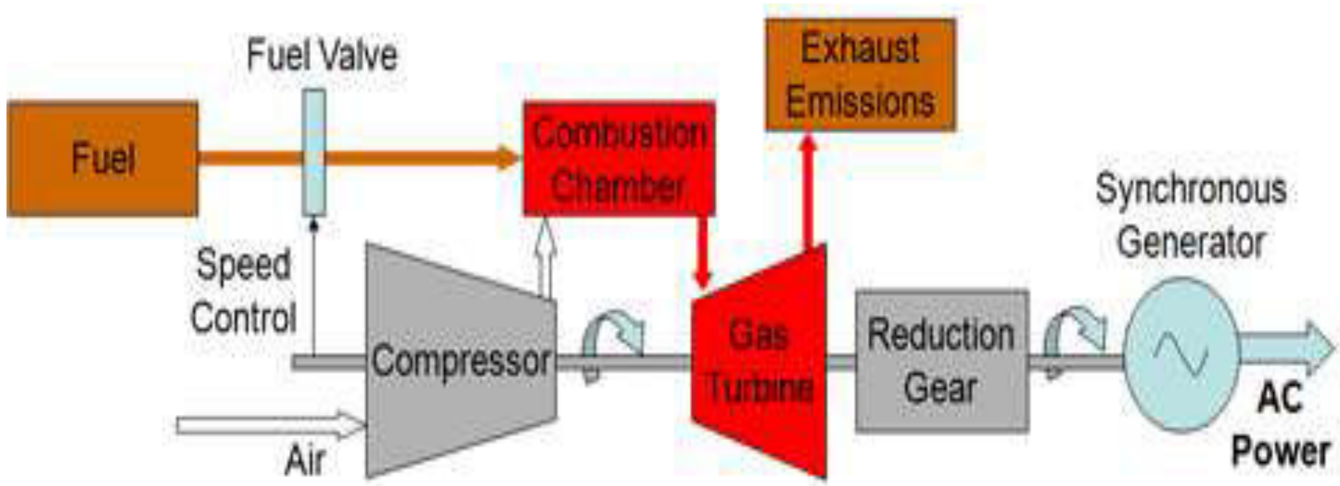
9.Biological shielding- Protection from alpha,beta ad gama rays

10. Generator

Site selection for Nuclear Reactor

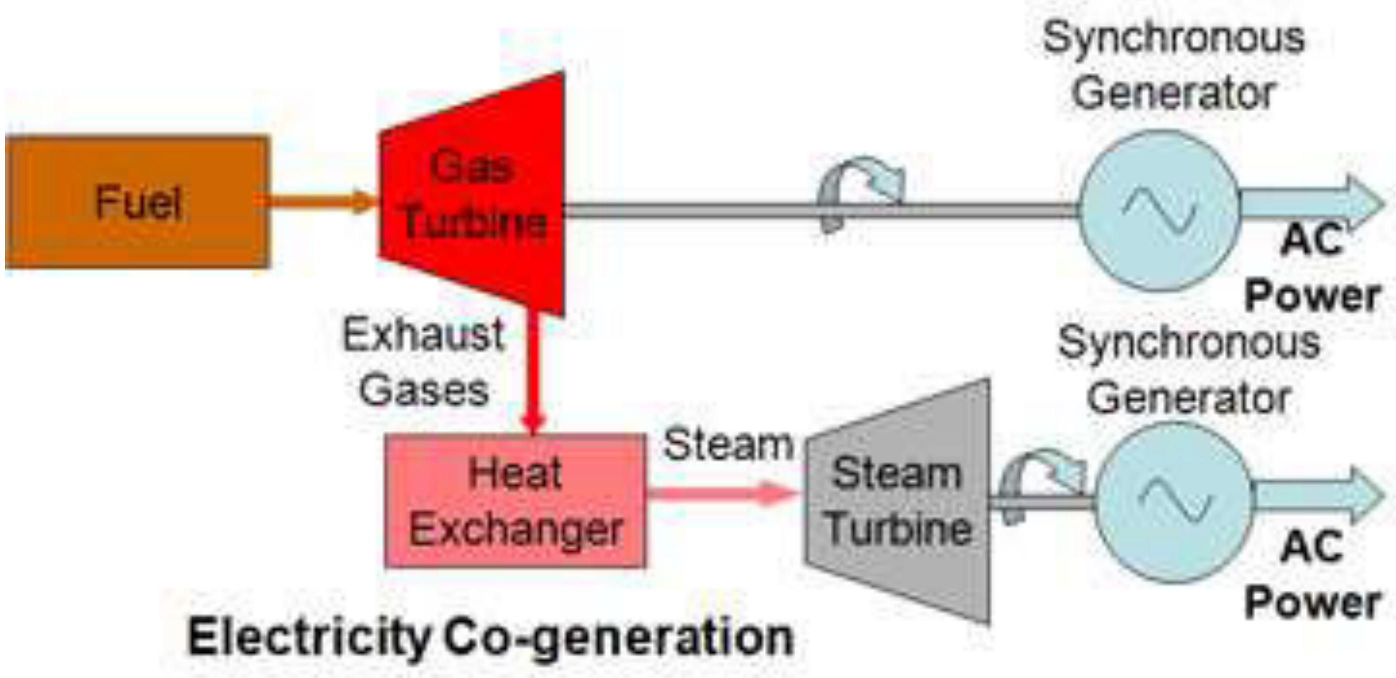
1. Water availability
2. Distance from load centers
3. Distance from populated areas
4. Transportation facility
5. Waste disposal
6. Cost of land
7. Nature of land
8. Future extension
9. Availability of workers
10. Size of the plant

Gas Turbine Power Plant



Gas Turbine Electric Power Generation

Gas Turbine Power Plant Co-Gen



Site selection

1. Transportation facility
2. Distance from load centre
3. Availability of fuel
4. Distance from the populated area

Application

1. Jet air crafts
2. Train
3. Ship
4. Electrical generating station

Classification

1.According to load – peak load, base load plant stand by

2.Cycle of operation – Open, closed semi closed

3. According to fuel – Liquid, Solid Gaseous

4. No of shaft – Single and Multi shaft

Working of Gas Turbine

Starter motor – Air from atmosphere – Low Pressure compressor (LPC) – intercooler – High Pressure Compressor (HPC) for further compression of air- heat exchanger(pick up the heat from exhaust gas from turbine) – Combustion chamber (CC) ,mix with air and fuel, burnt gas to high pressure turbine(HPT)

Further un-burned fuel to another CC – then to LPT

Fuel

Gaseous:

Natural gas, LPG, Refinery gas, Coke oven gas, Coal gas Hydrogen

Liquid :

Diesel, Kerosene, Naphtha, Ethanol & Methanol,

Condensates, Heavy residual grade oil & crude oil.

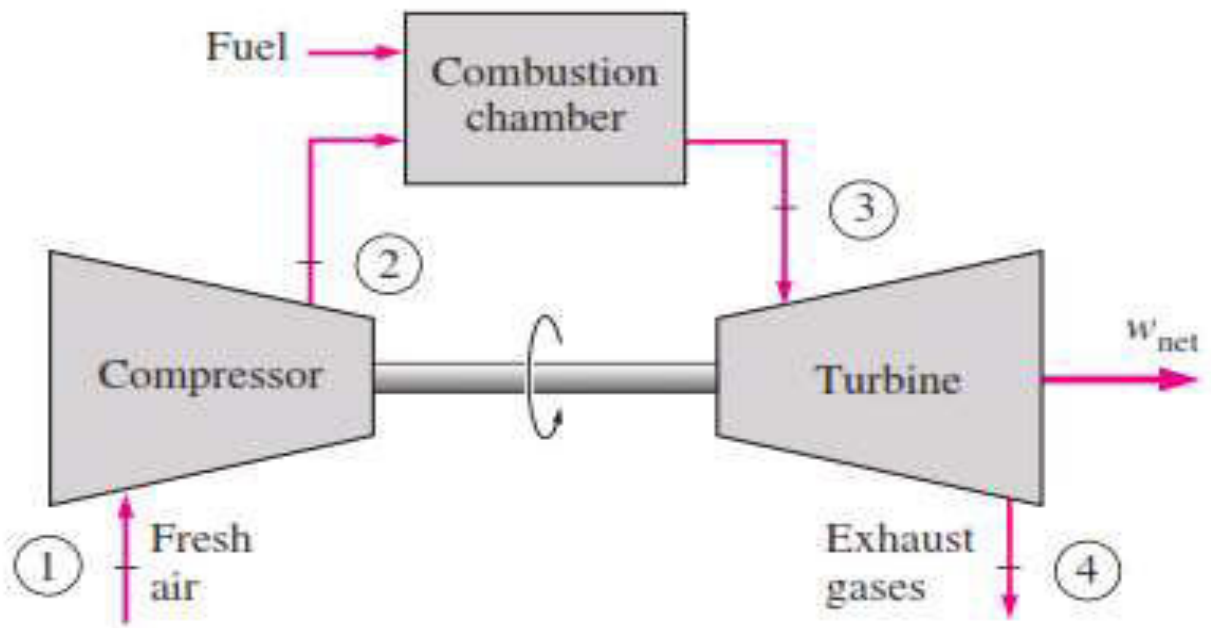
Fuel Qualities

- Volatility – should be highly desirable during cold conditions
- Combustion products – Less
- Energy contents – higher heating value
- Lubricating Properties
- Availability

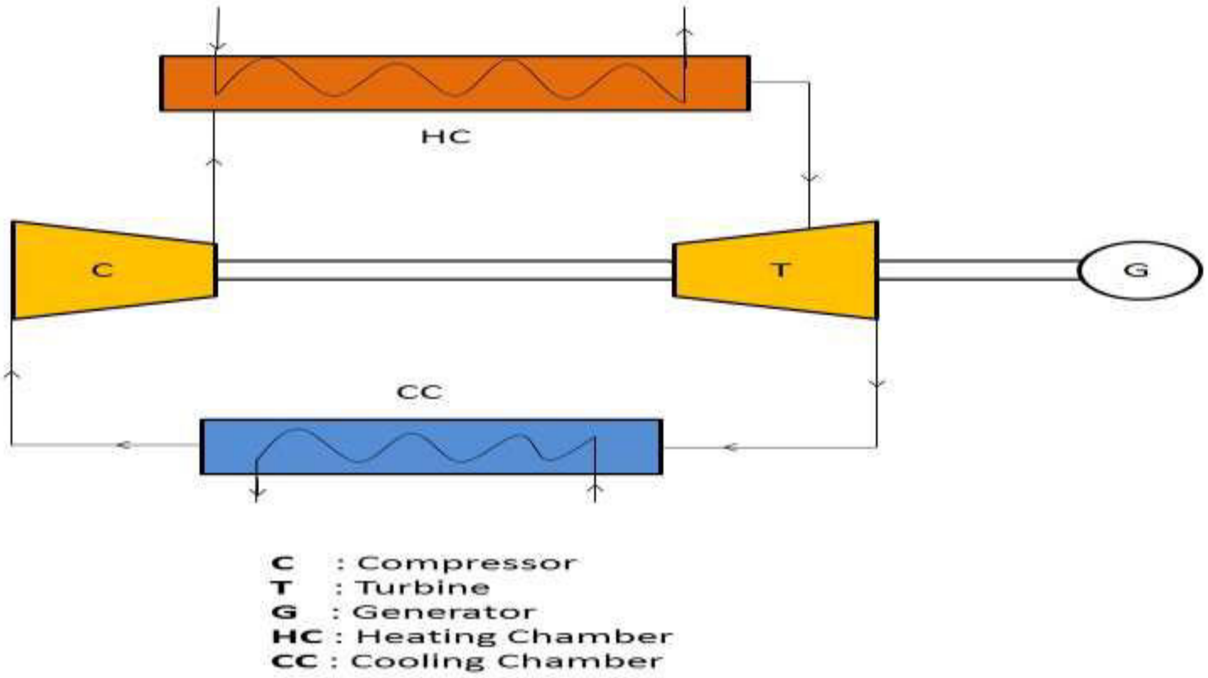
Materials Used

- Special steel
- Titanium Alloys
- Super Alloys

Types of Gas Turbine – Open Cycle

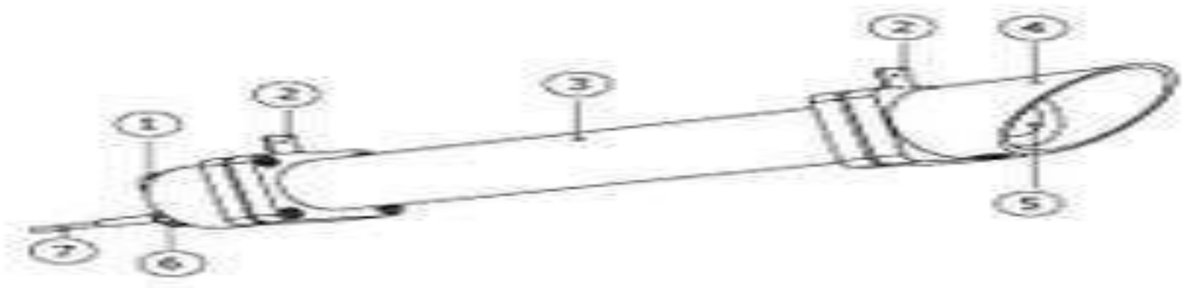


Types of Gas Turbine – Closed Cycle



Module II
SOLAR ENERGY

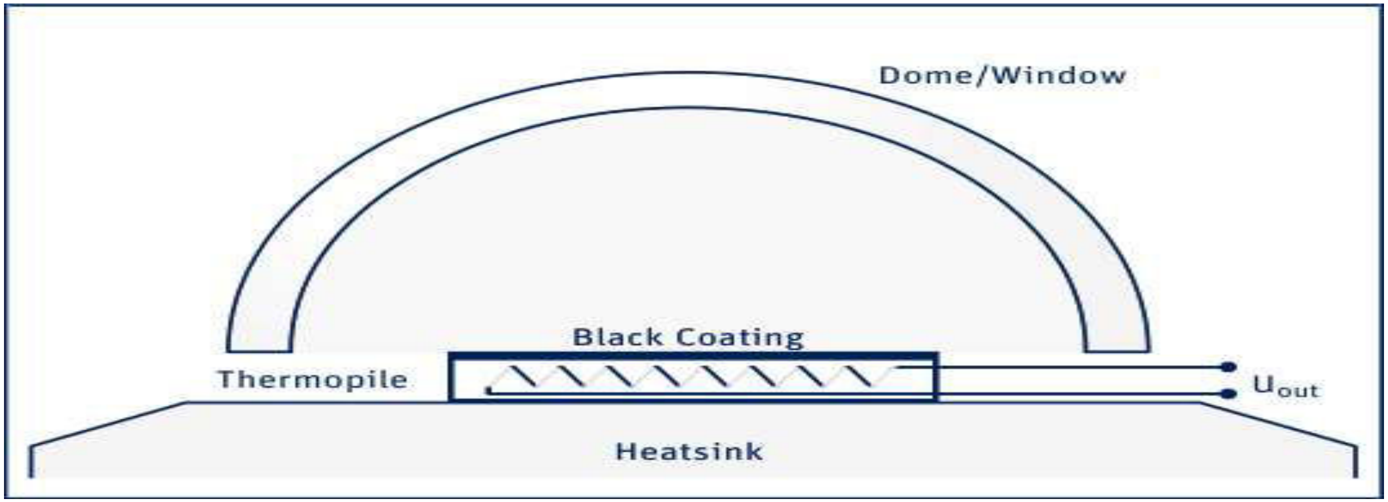
Measurements of Solar Radiation



Pyrheliometer: (3) body, (4) protection cap, (5) window with heater, (2) sight, (1) humidity indicator, (7) cable

pyrheliometer is an instrument for measurement of direct beam solar irradiance. Sunlight enters the instrument through a window and is directed onto a thermopile which converts heat to an electrical signal that can be recorded.

Pyranometer



- The active (hot) junctions are located beneath the blackened receiver surface and are heated by the radiation absorbed in the black coating. The passive (cold) junctions of the thermopile are in thermal contact with the pyranometer housing, which serves as a heat-sink.

Solar Collectors

A **solar collector** is a device that collects and/or concentrates **solar** radiation from the Sun. These devices are primarily used for active **solar** heating and allow for the heating of water for personal use.

Flat Plate Collector

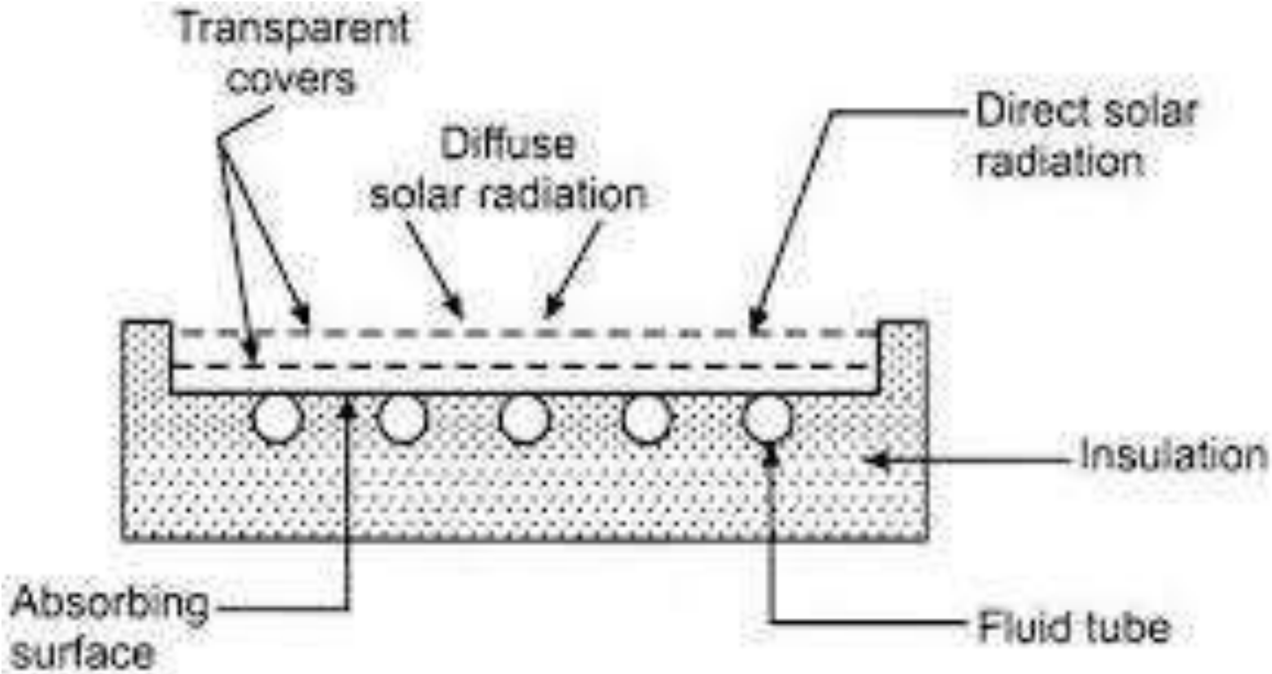


Fig. 3.3. Flat-plate solar collector.

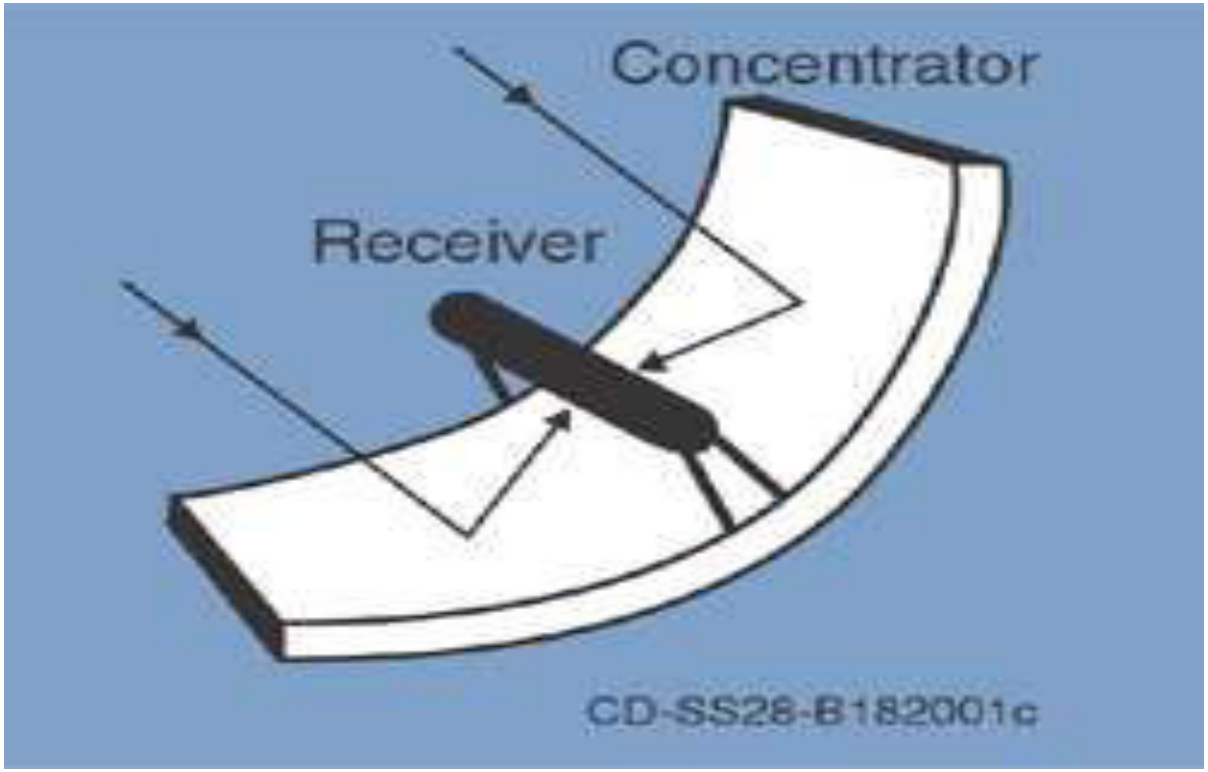
Working Principle

WORKING PRINCIPLE OF FLAT PLATE COLLECTORS

In FLAT PLATE COLLECTORS Sunlight passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. Thus the heat is transferred to the fluid {liquid (water or oil) or gas(air) } passing through pipes attached to the absorber plate by means of convective heat transfer.

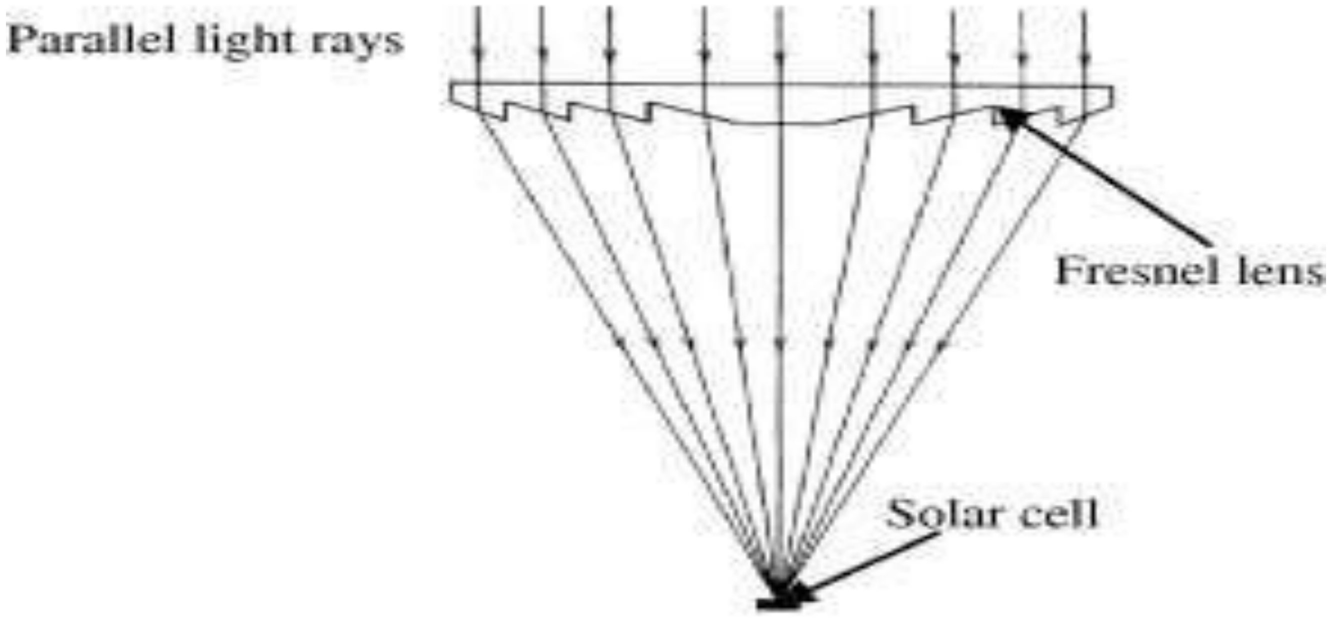
- Absorber plates are commonly painted with "selective coatings," which absorb and retain heat better than ordinary black paint.

Parabolic Through Collector



Mirror Strip Collector

Fresnel Lens Collector



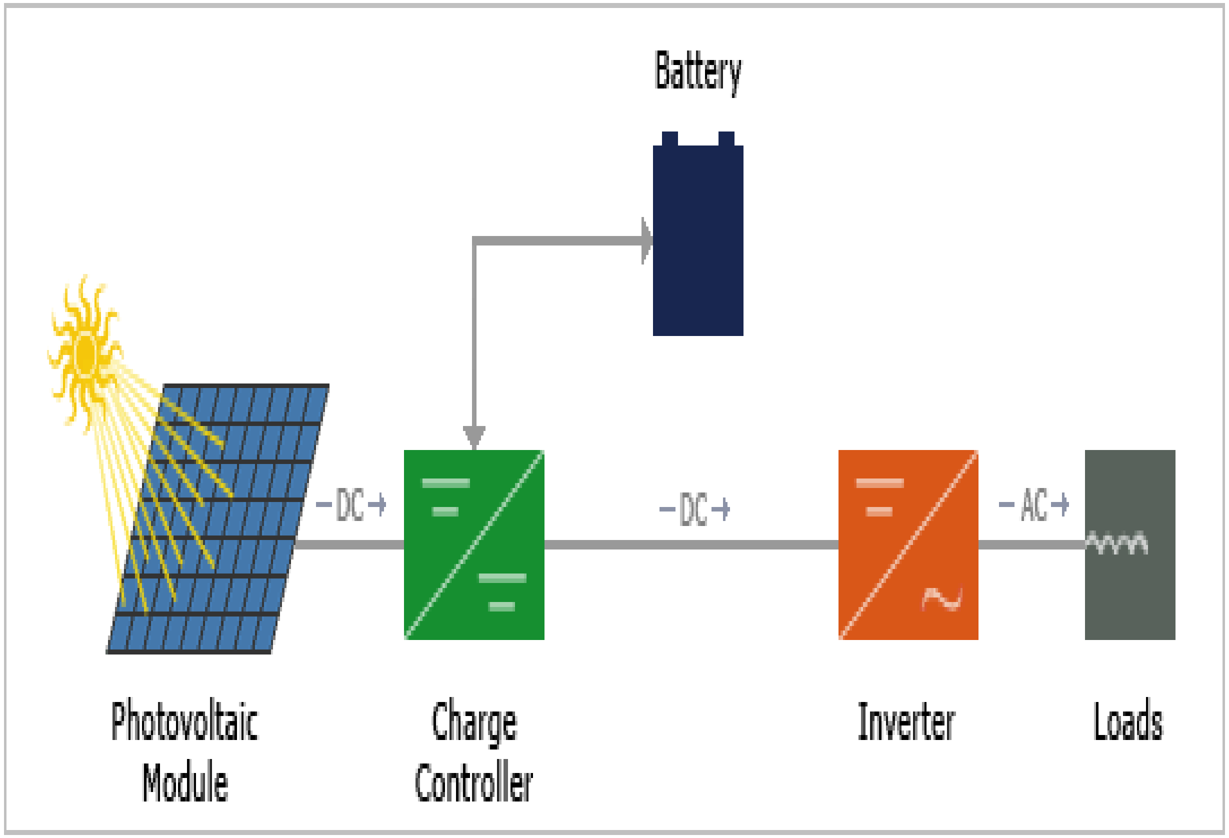
Application

1. Hot water
2. Furnace
3. Distillation
4. Cooking
5. Pump

Photovoltaic System

Photovoltaics are best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons by the **photovoltaic** effect. Solar cells produce direct current electricity from sunlight which can be used to power equipment or to recharge a battery.

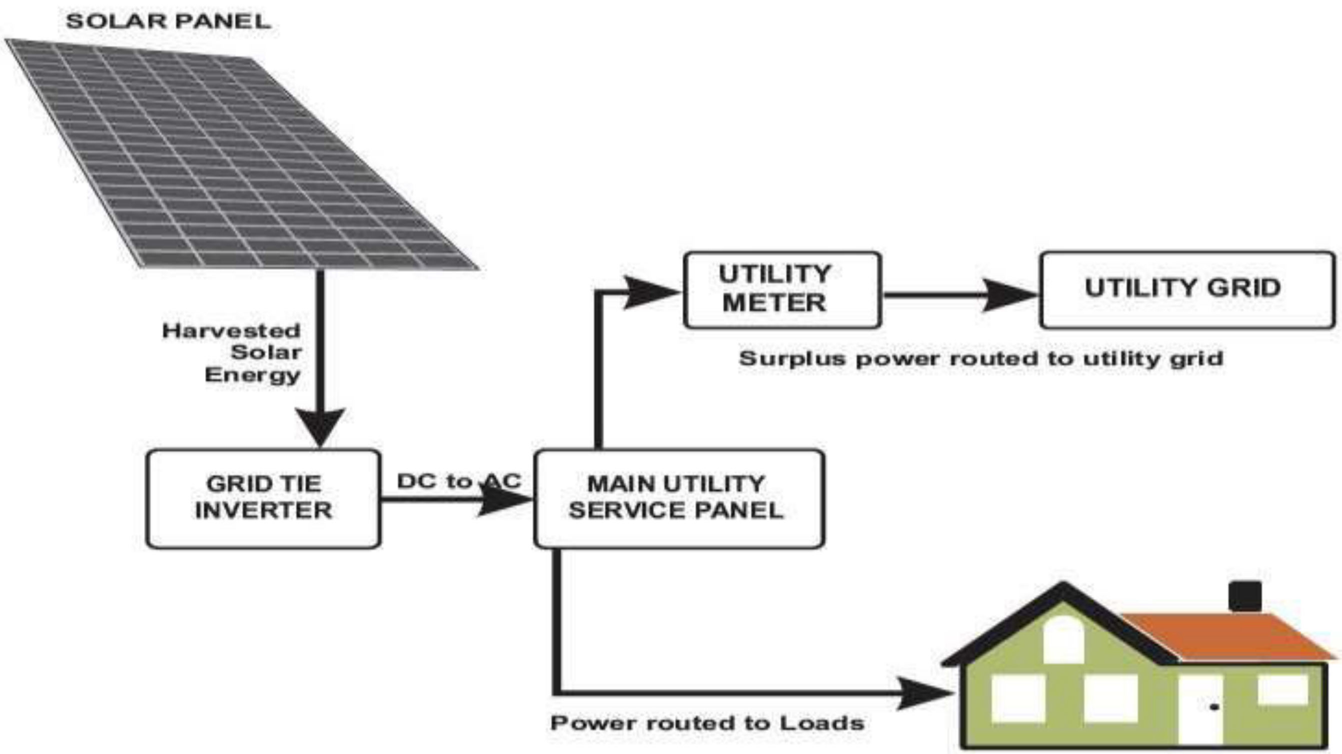
Photovoltaic System Diagram/Stand Alone



Photovoltaic System Types

1. Stand Alone
2. Grid Tied

Grid Tied


SOLAR PANEL
Harvested
Solar
Energy
GRID TIE
INVERTER
DC to AC
MAIN UTILITY
SERVICE PANEL
UTILITY
METER
UTILITY GRID
Surplus power routed to utility grid
Power routed to Loads

Types of Solar Power Plant

1. Solar pond electric power plant(Aus:2000sqm-20Kw)
2. Low temperature solar power plant
3. Medium temperature system using focusing – Collector
4. High temperature systems (Solar farm and solar power plant)

Solar pond electric power plant

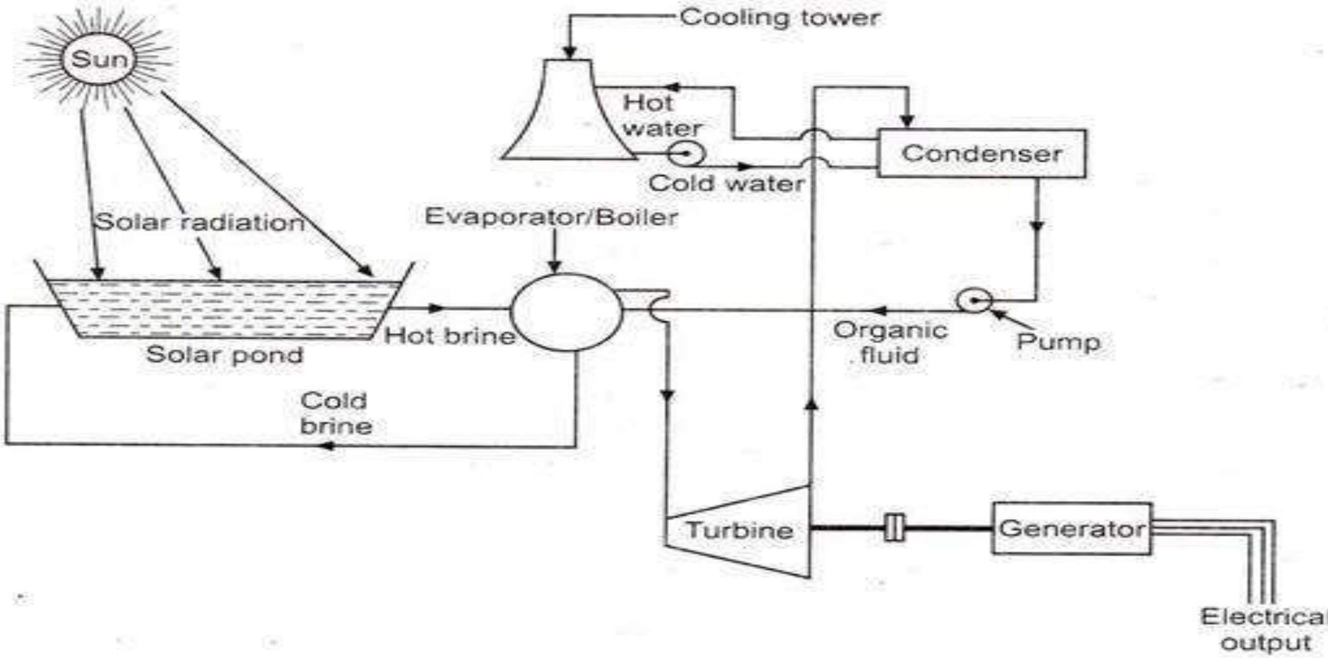
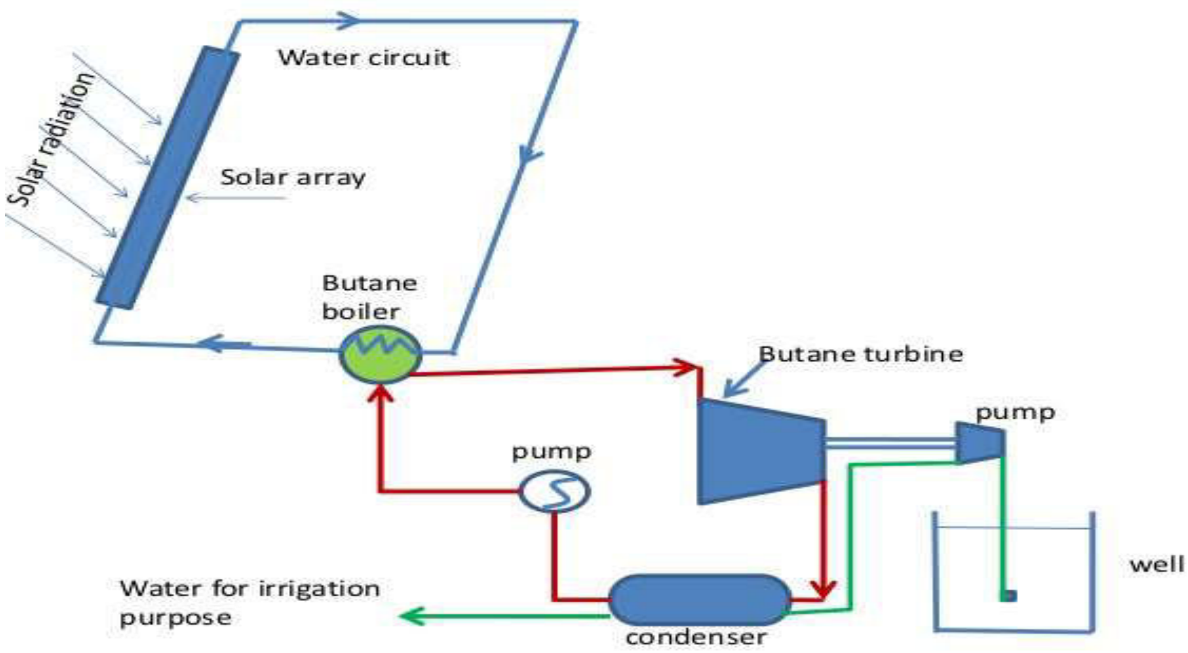


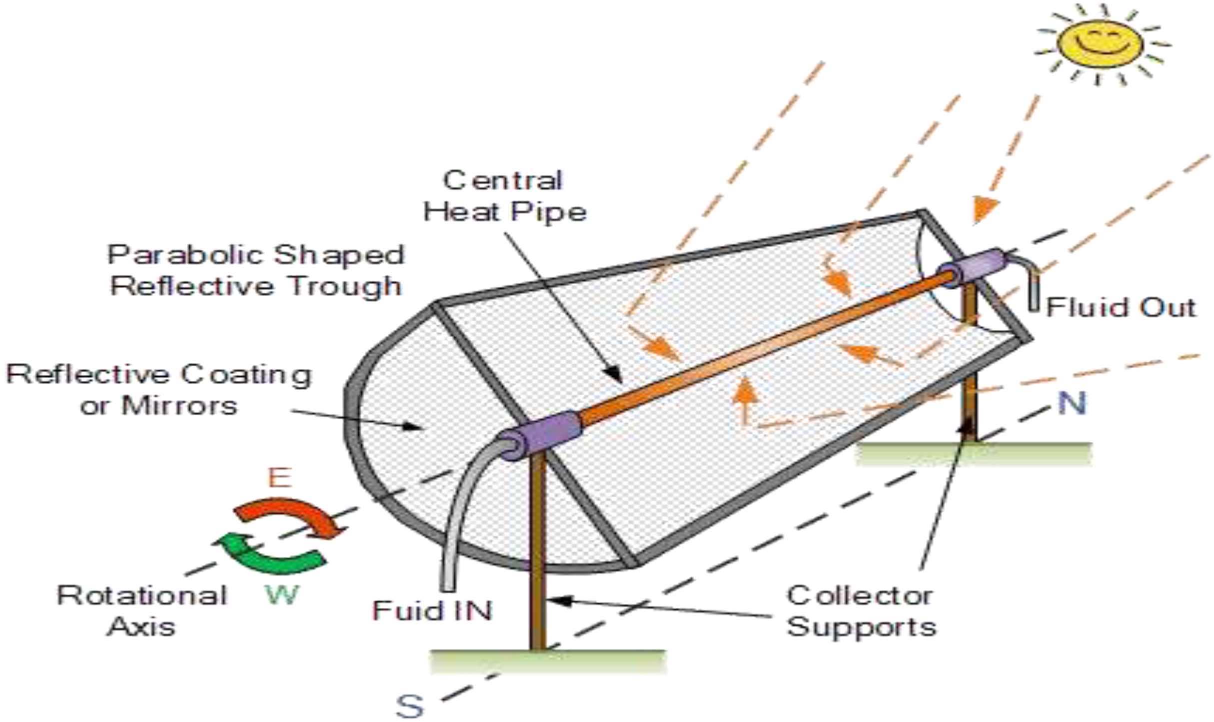
Fig. 4.4. Solar pond electric power plant.

Low temperature solar power plant



SCHEMATIC OF A LOW TEMPERATURE SOLAR POWER PLANT

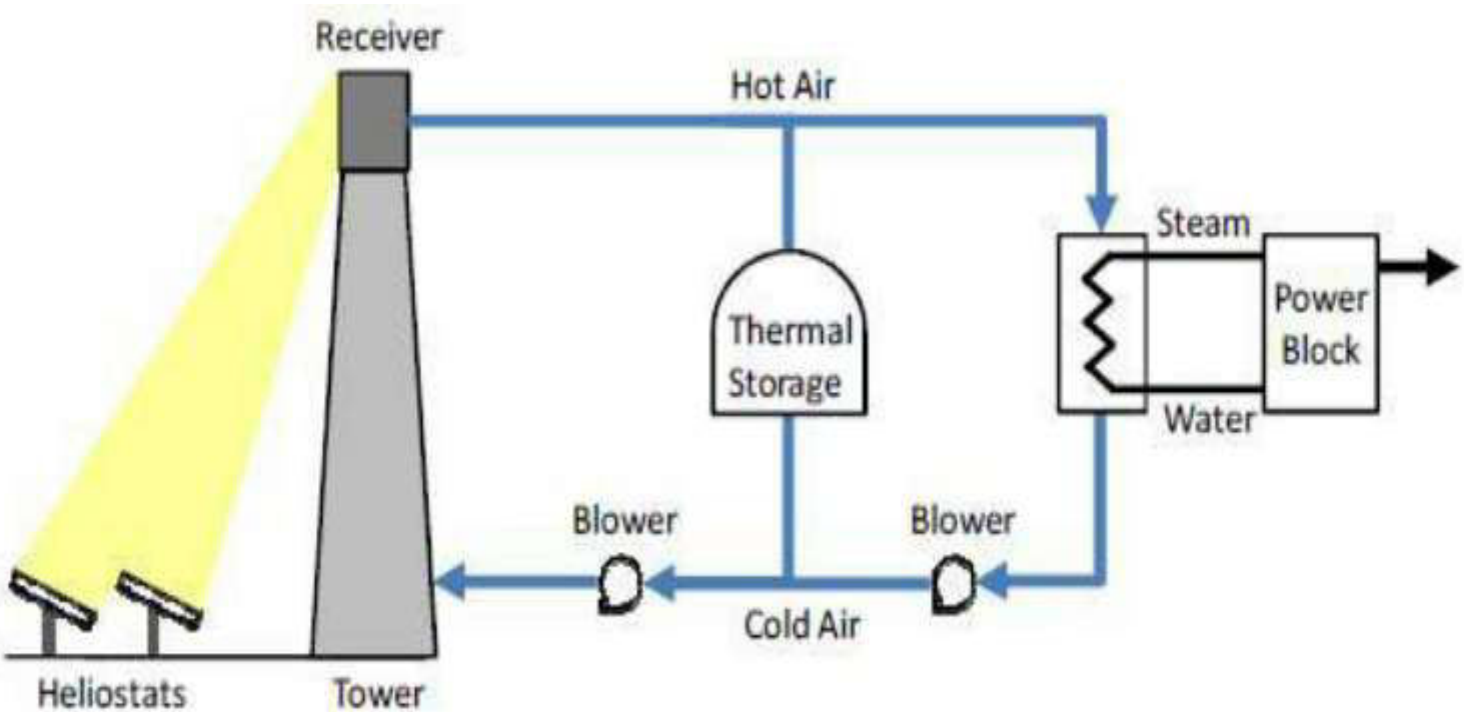
Medium Temperature System Using Focusing Collector



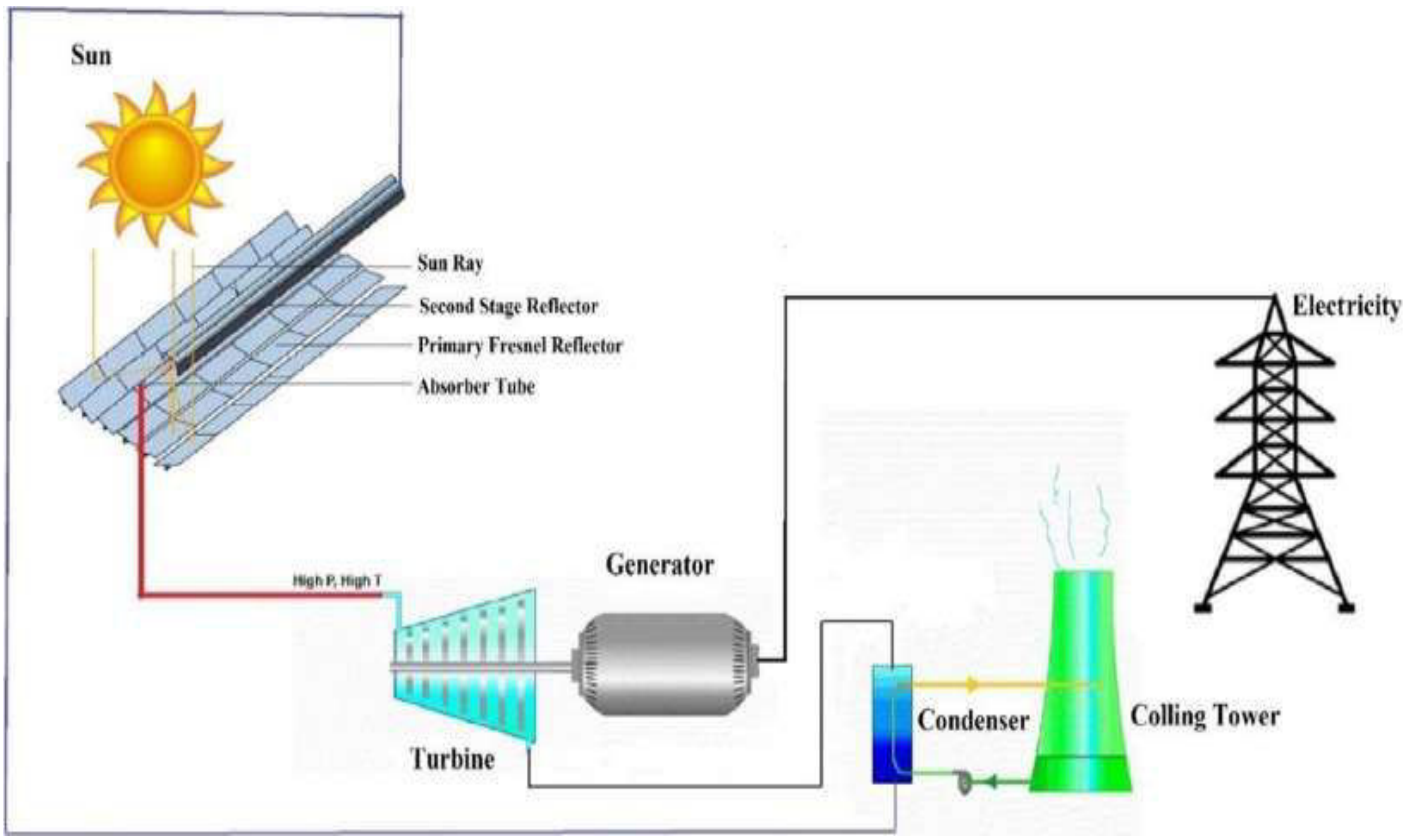
High Temperature System

1. Solar Farm – whole field – parabolic trough concentrators
2. Solar Tower - - central receiver on tower and whole field tracking

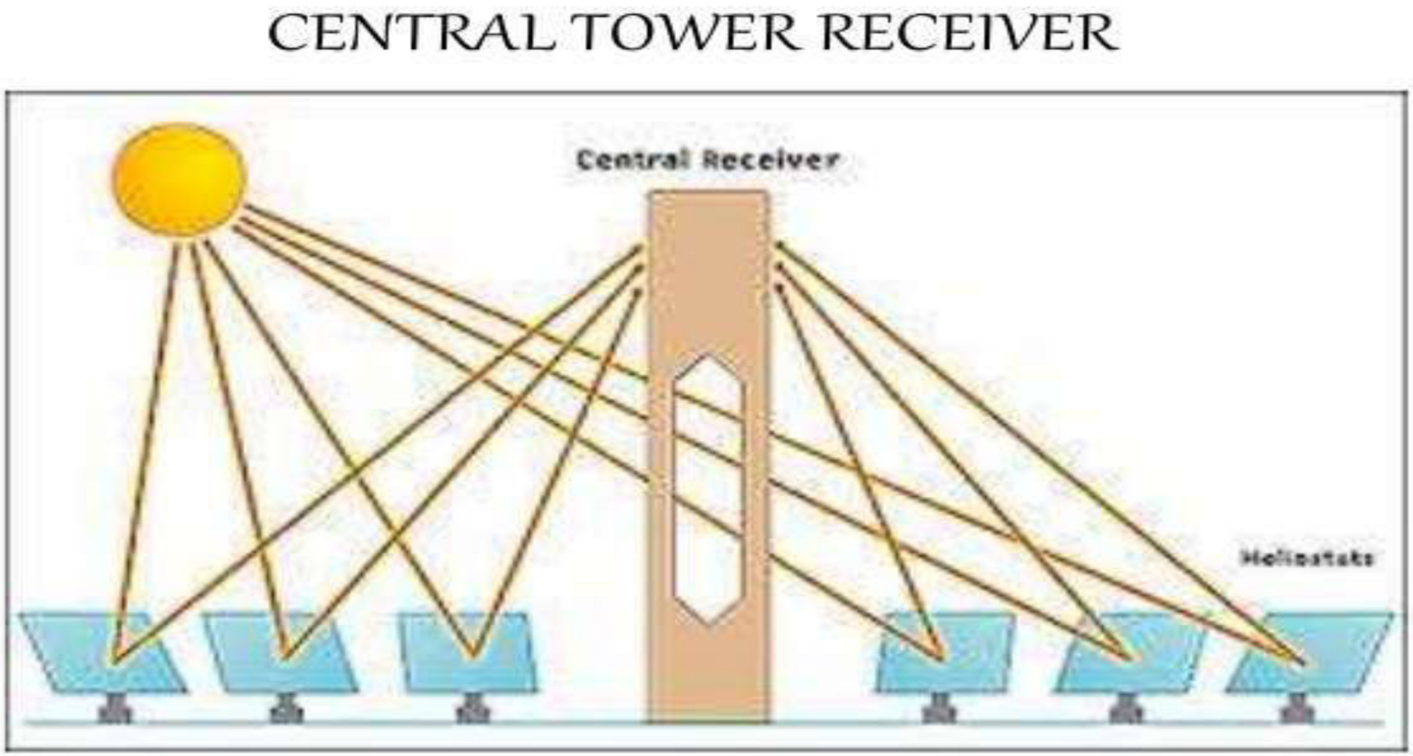
Solar Tower


Receiver
Hot Air
Steam
Thermal
Storage
Power
Block
Water
Blower
Blower
Cold Air
Heliostats
Tower

Solar Power Plant



Solar Central Receiving System



Components of Solar Central Receiving System

1. Tower with central receiver
2. Heat conversion system
3. Heat storage devices
4. Heliostats (Mirrors)

Economics of Solar Energy

- The **Economics Of Solar Power**. Fossil fuels, namely crude oil, natural gas and coal, are the world's number one source of **energy**. ... While wind **energy** is predominantly used for commercial means, such as wind farms, **solar energy** has both commercial and residential uses
- By the end of 2020, global installed solar capacity could be 20 to 40 times its present level.

Sustainability Attributes

- **Solar energy** is a renewable free source of **energy** that is **sustainable** and totally inexhaustible, unlike fossil fuels that are finite. It is also a non-polluting source of **energy** and it does not emit any greenhouse gases when producing **electricity**. Using **solar power** means reducing your **energy** bills and saving money.

Module III
WIND ENERGY

Principle of WE

- Large masses of air moving over the surface of earth.
- Transforms this Kinetic Energy to mechanical form then to Electrical energy.
- Efficiency depends on rotor interacts with wind stream.

Application

- Pumping
- Grinding grains
- Drainage
- Power generation
- Saw mill

Wind Availability and Measurement

Depends on terrains and speed of wind

<u>Recording Wind</u>

- Human observation and log book
- Mechanical cup-counter anemometer
- Data logger
- Continuous record of velocity and direction

Source/Origin of Wind

- Local wind

- Planetary wind

<u>Advantage and Limitations</u>

?

Wind Power

Power density in moving air,

$P_w = K * U_w^3$ W/m^2

$K = 1.3687 * 10^{-2}$ (Constant)

U_w = Wind Speed in km/hr.

Available Power

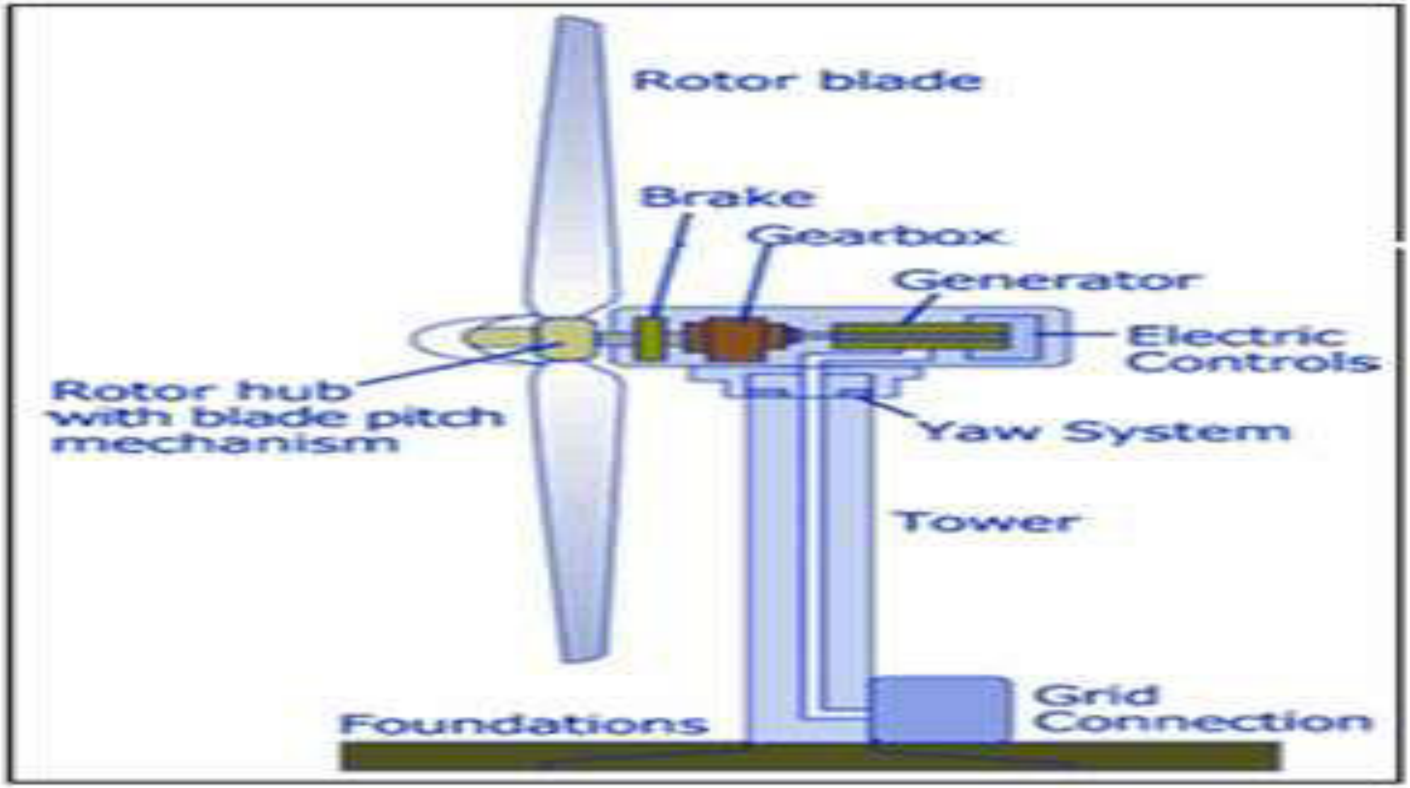
$P_a = (\pi/8) * \rho D^2 U_w^3$ Watts

ρ Density of air at sea level ; D Diameter of turbine horizontally

Terms

- Wind
- Wind mill
- Wind turbine
- Wind turbine generator unit
- Nacelle (Housing)
- Propeller
- Hub
- Pitch angle(Ļ wind direction and direction ⊥r to the plane of blade)

Controls Continued…



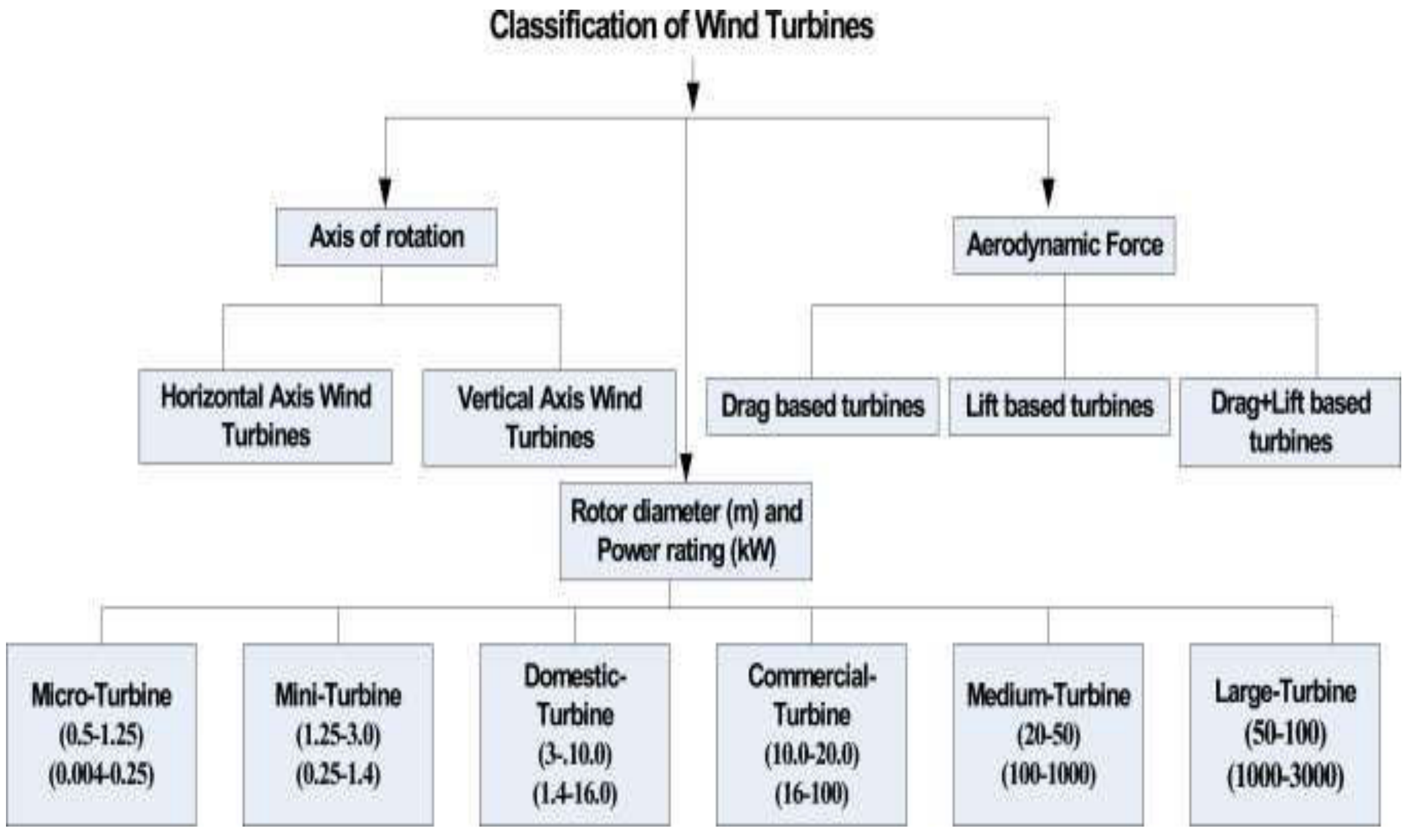
Wind Speed

1. Cut- in speed – speed at which the turbine start delivering shaft power (min 7m/s)
2. Mean wind speed Uwm=

$$U_{wm} = \frac{U_{w1} + U_{w2} + \ldots\ldots U_{wn}}{n}$$

3. Rated wind speed : The velocity at which turbine generator deliver rated power
4. Furling wind Velocity: Speed at which power conversion is cut off

Classification of Wind Turbine



Horizontal Axis Wind Turbine

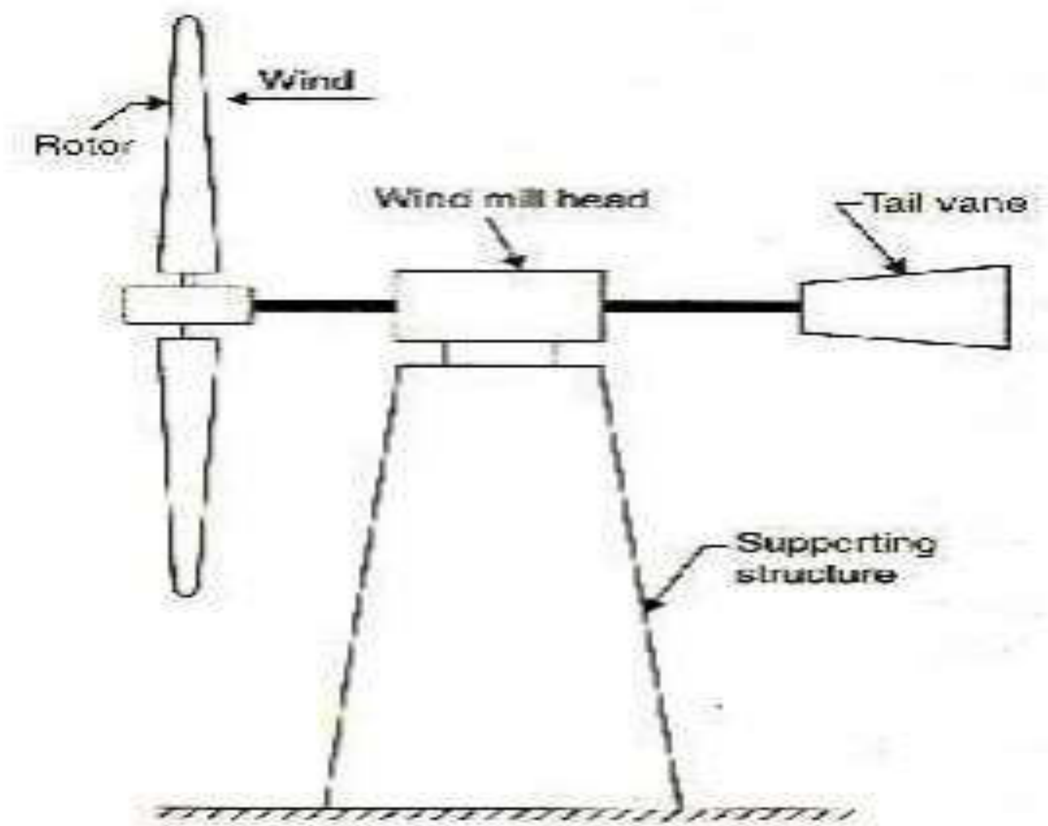
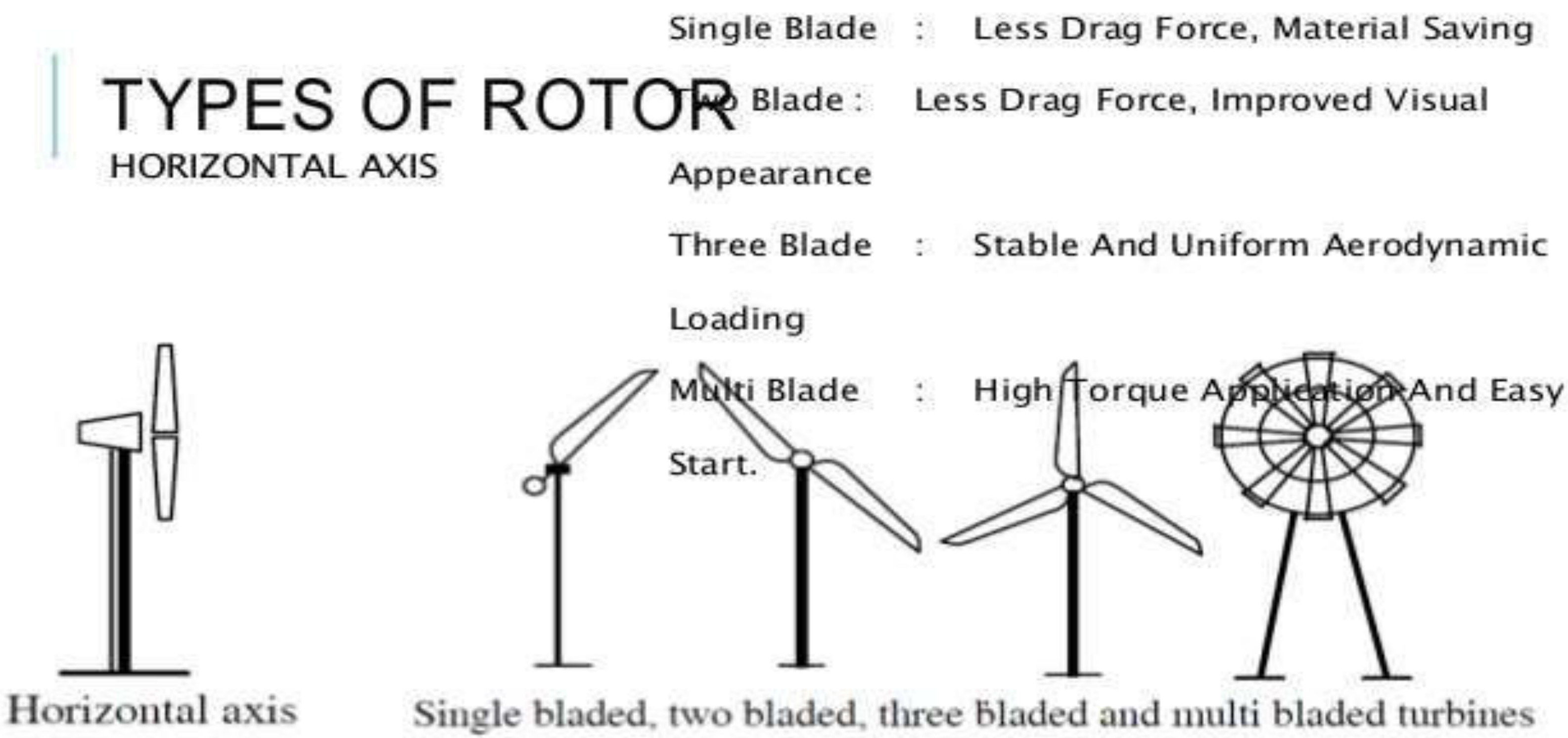


Figure: Horizontal axis wind machine.

Types of Horizontal Axis Wind Turbine

1.Multi Blade – 15 -20 Blades



Single Blade : Less Drag Force, Material Saving

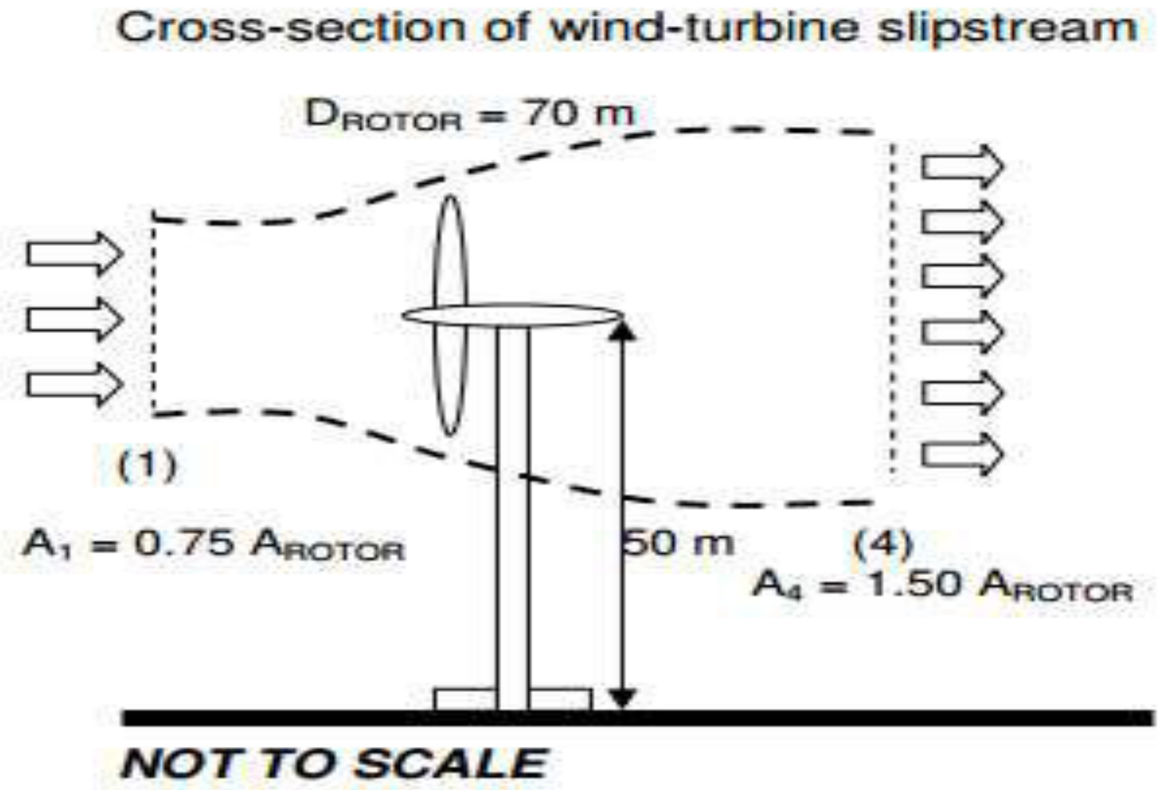
Two Blade : Less Drag Force, Improved Visual Appearance

Three Blade : Stable And Uniform Aerodynamic Loading

Multi Blade : High Torque Application And Easy Start.

Types of Horizontal Axis Wind Turbine Continued..

2. Propeller Type Wind Mill Speed : 300 - 400 rpm



Types of Horizontal Axis Wind Turbine Continued..

3.

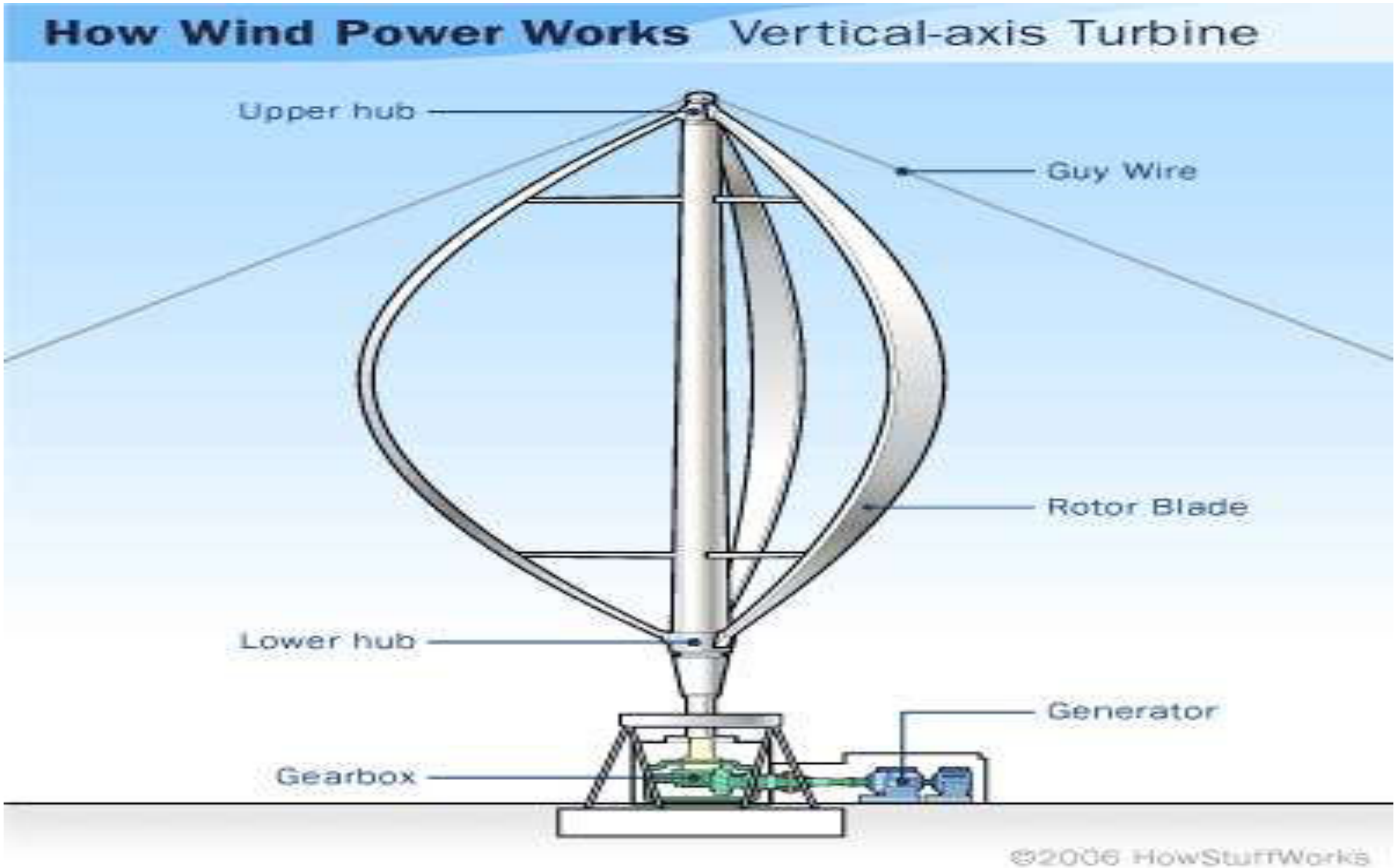
Horizontal Axis Wind Turbine Advantages and Limitation

Horizontal-axis wind turbines

- **Advantages:**
- Blades are to the side of the turbine's center of gravity, helping stability.
- Tall tower allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up, the wind speed can increase by 20% and the power output by 34%.
- Tall tower allows placement on uneven land or in offshore locations.
- Can be sited in forests above the tree line.
- Most are self-starting.
- Can be cheaper per unit of output because of higher production volume, larger sizes and, in general, higher capacity factors and efficiency.

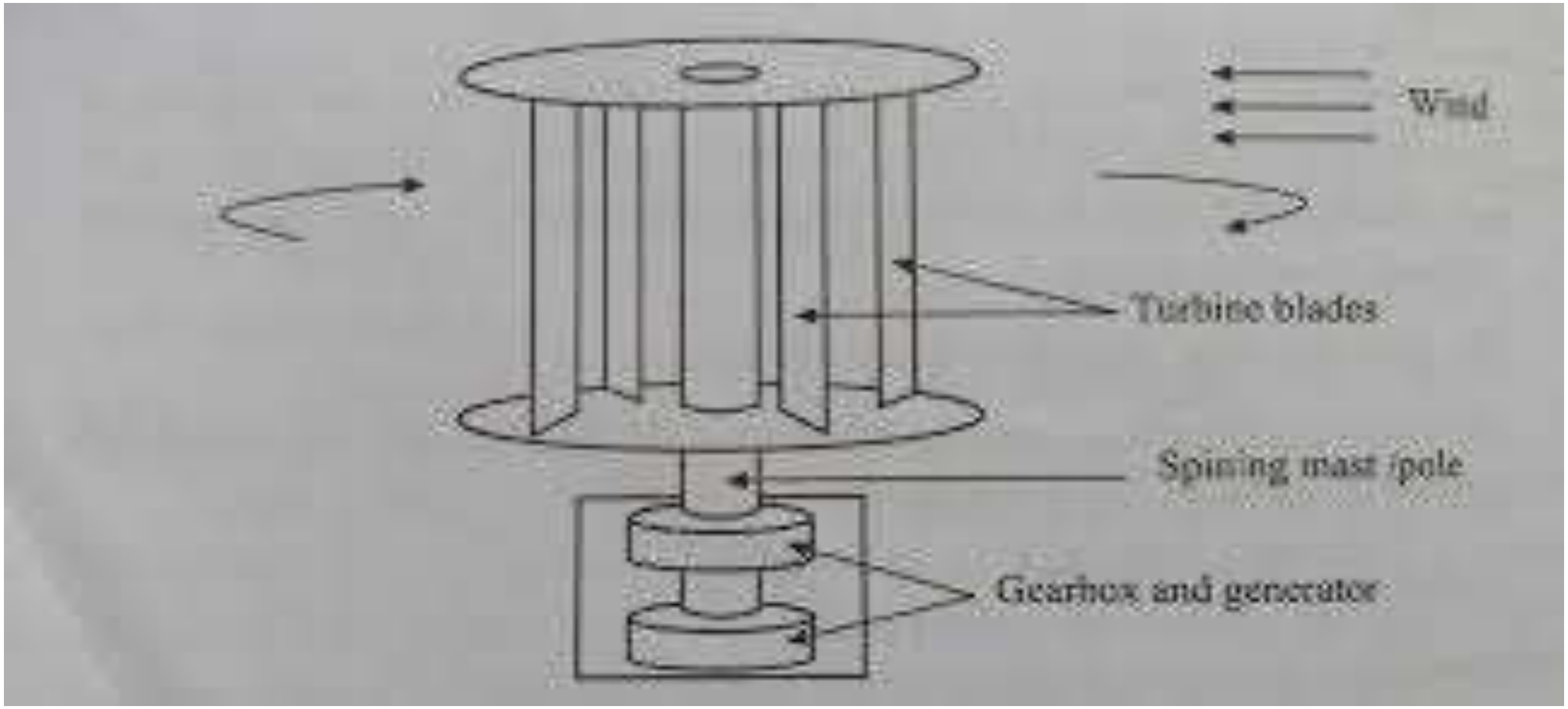
- **Disadvantages:**
- HAWTs have difficulty operating in near ground, turbulent winds.
- The tall towers and long blades (up to 180 feet (55 m) long) are difficult to transport on the sea and on land. Transportation can now cost 20% of equipment costs.
- Supply of HAWTs is less than demand and between 2004 and 2006, turbine prices increased up to 60%. At the end of 2006, all major manufacturers were booked up with orders through 2008.
- The FAA has raised concerns about tall HAWTs effects on radar near Air Force bases.
- Their height can create local opposition based on impacts to viewsheds.

Vertical Axis wind Turbine



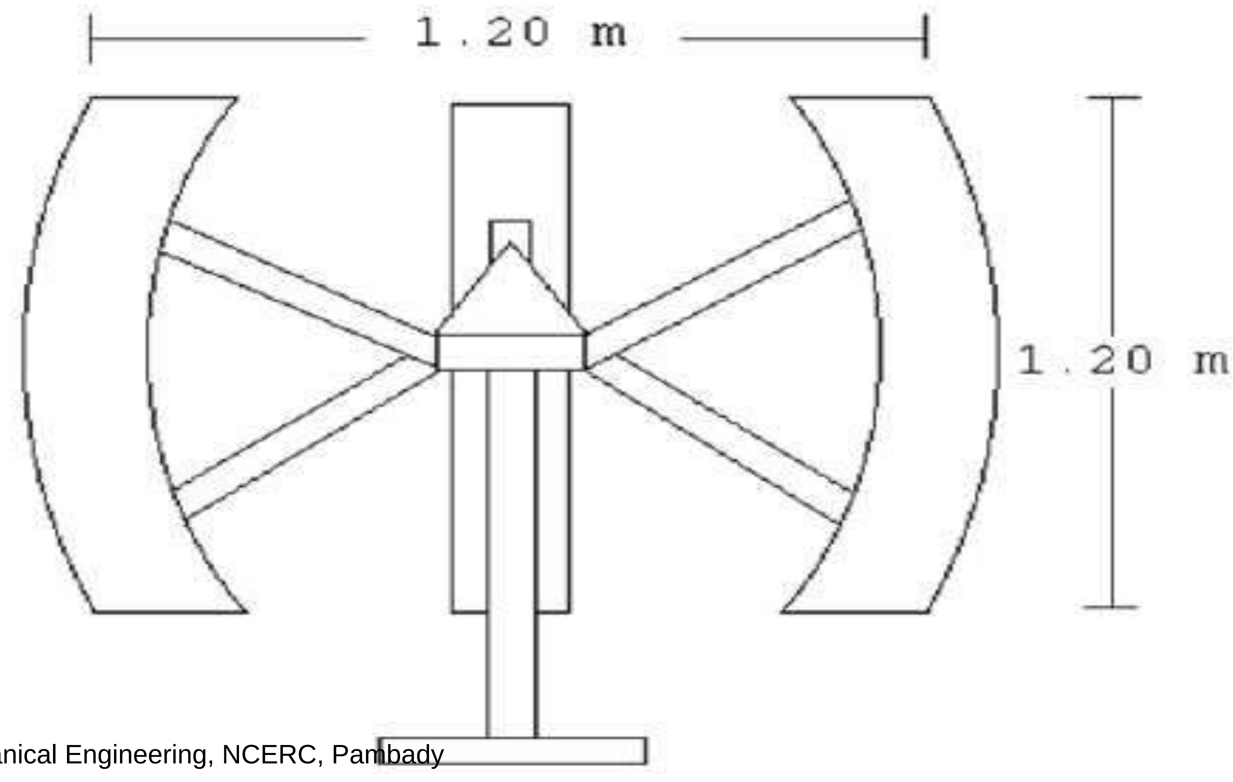
Types of Vertical Axis Wind Turbine

1. Savonius Type V W T - Self Staring , Low speed , Low efficiency

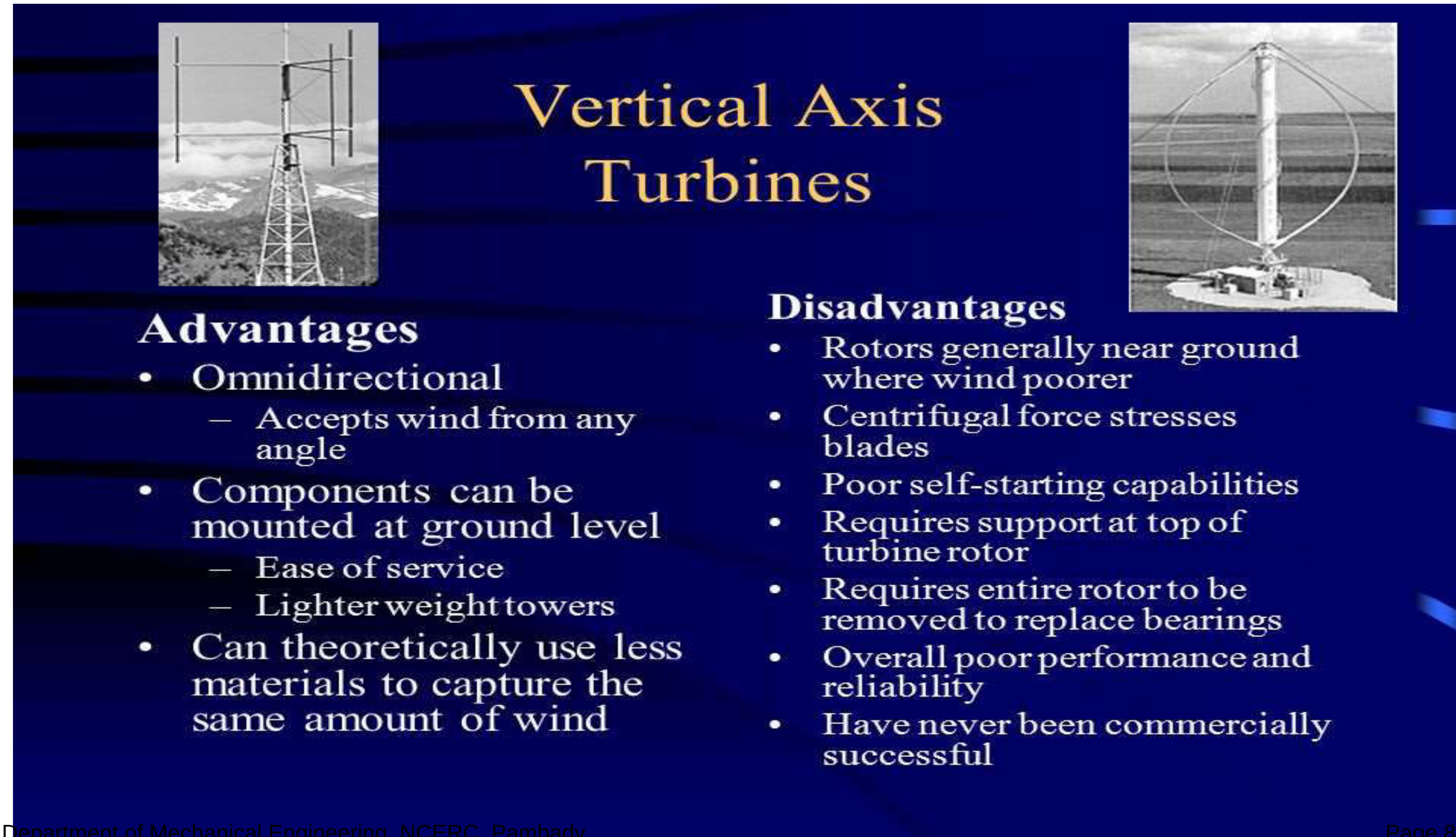


Types of Vertical Axis Wind Turbine Continued..

2.Darricus Type- Not self starting - High Speed - High efficiency - Potentially low capital cost



Vertical Axis Wind Turbine Advantages and Limitation



Performance of Wind Mill

Wind mill performance is defied as “ Coefficient of performance”

$$Kp = \frac{\text{Power outcome from rotor}}{\text{Max available power from wind}}$$

Kp= P/Pmax

= P /(1/2) *ρ A Uw^3

Where A= Sweep area Uw wind velocity

Aerodynamics of Wind Turbine

The two primary **aerodynamic** forces at work in **wind**-**turbine** rotors are lift, which acts PERPENDICULAR to the direction of **wind** flow; and drag, which acts PARALLEL to the direction of **wind** flow. **Turbine** blades are shaped a lot like airplane wings -- they use an airfoil design.

Aerodynamics of Wind Turbine continued…

- Lift force is formed by varying the velocity of air stream flowing over the aerofoil.
- Velocity of air is inversely proportional to pressure and vice versa.
- For a good aerofoil – should have a HIGHER LIFT/DRAG Ratio. i.e. for a efficient performance the wind power must have High lift force and less drag force.

Aerodynamics of Wind Turbine continued..

Force acting on blade:

1. Circumferential force (Torque) in the direction of wheel rotation
2. Axial force in the direction of wind stream.

Site Selection

1. Land topography and geology
2. Grid structure and distance
3. Size of turbine

Economical Consideration

1. Capital cost
2. Land Cost
3. Operational and management cost
4. Environmental consideration

- Visual Impact
- Electromagnetic interference
- Noise impact
- Social Consideration

    Land use

    Distance from residential area

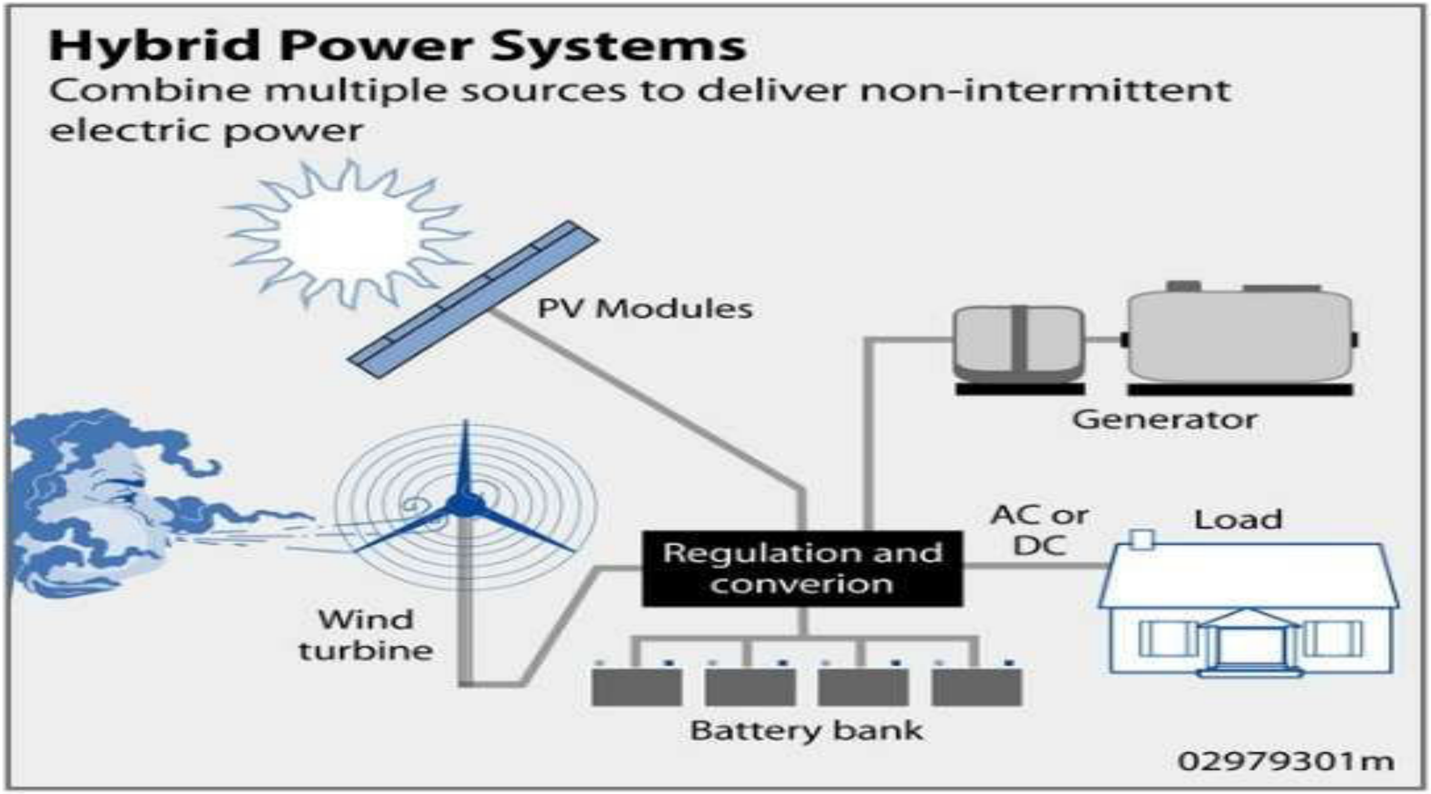
Wind Power Economics

- Wind Free (So wind-generated electricity is free?)
- A modern wind turbine, which can generate 2 megawatts of electricity (MWe)
- Costs of installation is about $3.5 million.(Five hundred of these turbines installed at a wind farm, to be able to generate 1000 MWe, would cost $1.75 billion.) PLUS O&M and transmission lines, and the total sum could match the approximate $4 billion required to build a nuclear plant.

Problems in Operating Large Wind Power Generators

1. Location of site
2. Constant angular velocity
3. Variation of wind velocity
4. Need of storage system
5. Strong supporting structures
6. Occupation of large areas of land

Introduction to Solar- Wind Hybrid Energy Systems.



Module IV
BIOMASS ENERGY

What is Biomass Energy?

Biomass is organic material that comes from plants and animals, and it is a renewable source of **energy**. **Biomass** contains stored **energy** from the sun. Plants absorb the sun's **energy** in a process called photosynthesis and convert carbon dioxide and water into nutrients (carbohydrates). When **biomass** is burned, the chemical **energy** in **biomass** is released as heat or converted to electricity. Biomass can be burned to create heat (direct), converted into electricity(direct), or processed into biofuel (indirect).

Source of Biomass

- The main waste energy feed stocks(Obtained from primary treatment of waste) are wood waste, agricultural waste, municipal solid waste, manufacturing waste, and landfill gas. Sewage sludge is another source of biomass.

PROBLEMS

Toxicity (Presence of H_2S) – Explosive –

Leakage of Biogas

Site Selection

1.Distance – Plant and Site of Gas consumption – For 2 cum plant 10 m distance is optimum

2.Minimum Gradient – For gas conveying, minimum 1% gradient must be available for the line

3.Open space – Sunlight should fall on the plant – temperature 15 to 30 deg C is essential for gas generation at higher rate

4.Water Table – prevent seapage of water – plant should not be constructed if the water table is above/more than 10ft (3m)

5.Seasonal run off – proper care has to be taken to prevent the interference of rain water during the monsoon.

Site Selection Continued..

- 6.Distance from wells – the seapage of fermented slurry may pollute the well water. Minimum 15m from the well
- 7.Space requirements – 10 to 12 sqm area is needed per one cum of the gas
- 8.Availability of water – plenty of water must be available as the cowdung slurry with a solid concentration of 7 to 9% is used
- 9.Source of materials for Biogas (cowdung/Biomass) – to economise the transportation cost

Advantages

1. Biogas is Eco-Friendly
2. Biogas Generation Reduces Soil and Water Pollution
3. Biogas Generation Produces Organic Fertilizer
4. It’s A Simple and Low-Cost Technology That Encourages A Circular Economy
5. Healthy Cooking Alternative For Developing Areas

Biomass Conversion Process

1. Thermo- Chemical Conversion

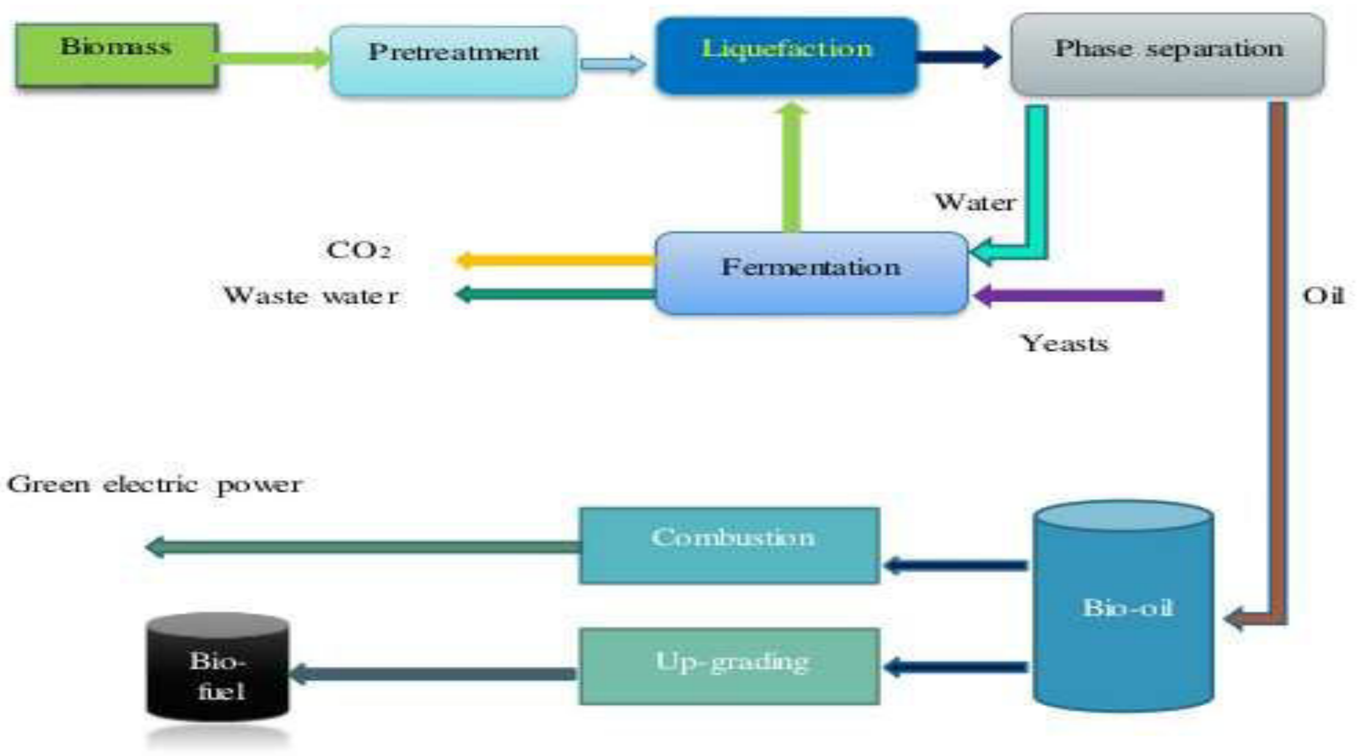
- Gasification – Heating biomass with limited oxygen to produce low heating value
- Liquefaction- converting to methanol or ethanol of high heating value

THERMO- CHEMICAL CONVERSION

Liquefaction OF BIOMASS

Hydrothermal **liquefaction** of **biomass** is the thermo-chemical conversion of **biomass** into liquid fuels by processing in a hot, pressurized water environment for sufficient time to break down the solid bio-polymeric structure to mainly liquid components.

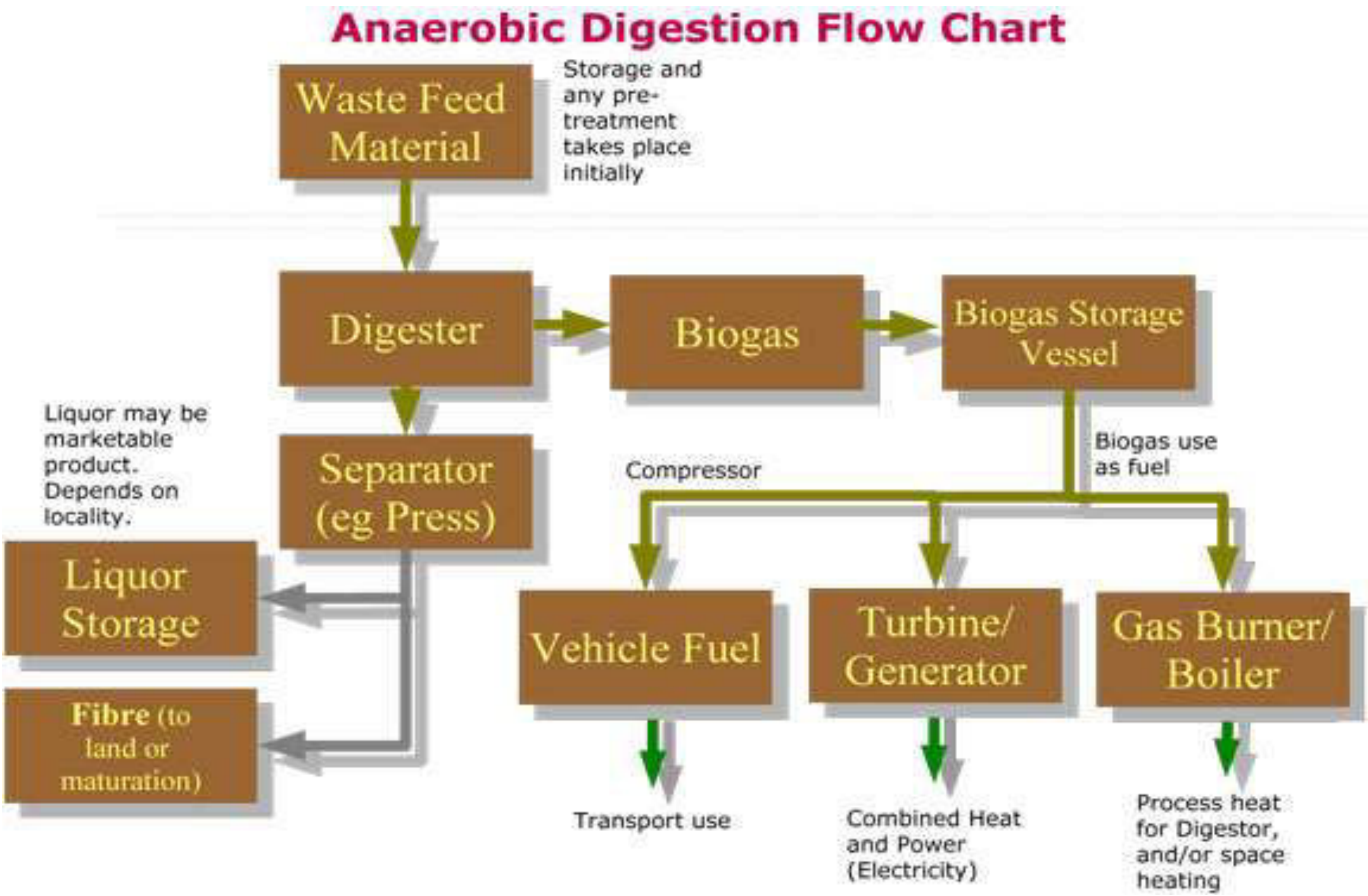
Liquefaction process of Biomass



Biochemical Conversion

1. **Anaerobic digestion** is a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen. One of the end products is biogas, which is combusted to generate electricity and heat, or can be processed into renewable natural gas and transportation fuels.

Anaerobic digestion

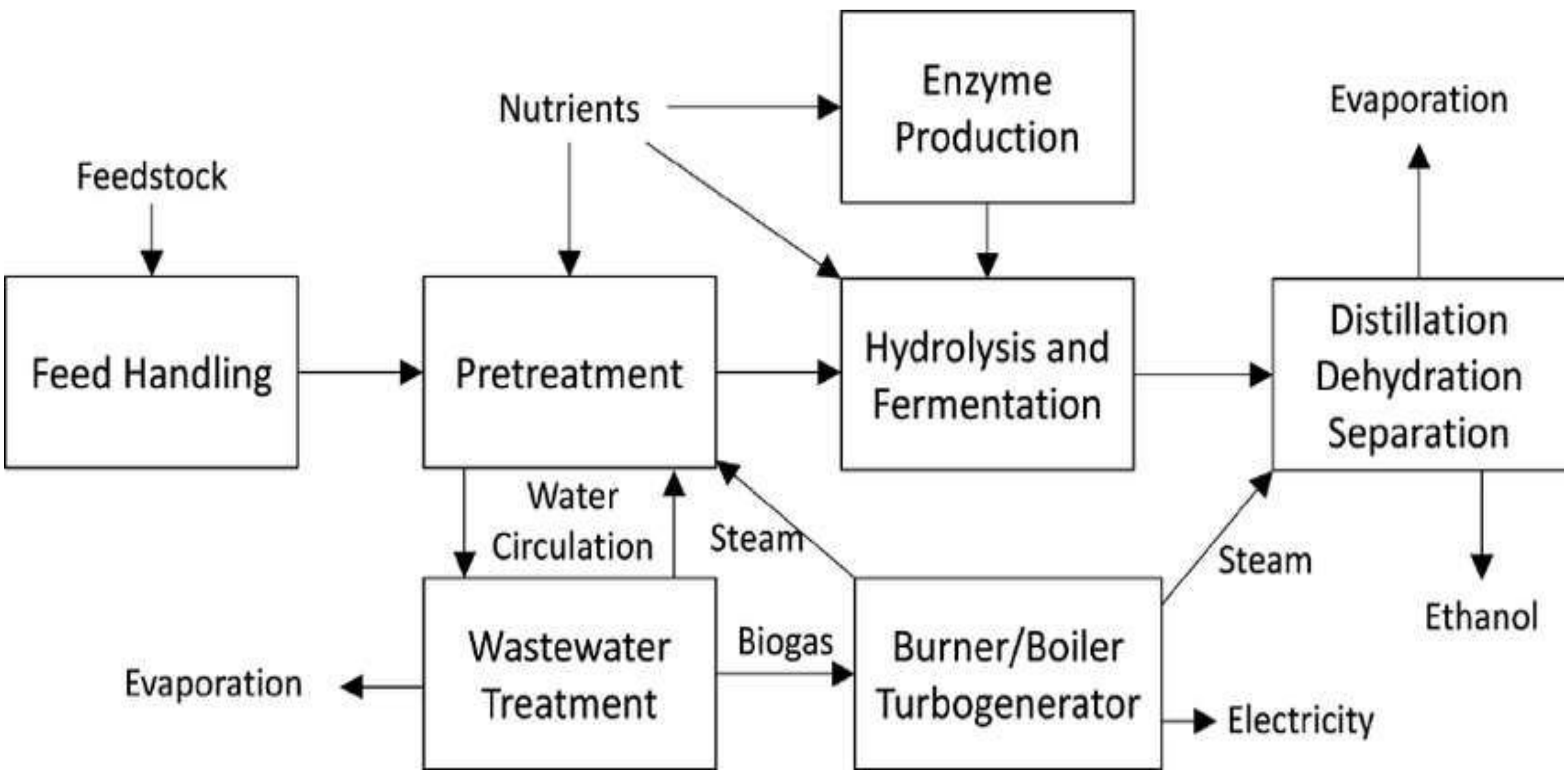


Biochemical Conversion Continued..

2) Fermentation

Fermentation is a metabolic process in which an organism converts a carbohydrate, such as starch or a sugar, into an alcohol or an acid. For example, yeast performs *fermentation* to obtain energy by converting sugar into alcohol. Bacteria perform *fermentation*, converting carbohydrates into lactic acid.

Fermentation



DIRECT COMBUSTION

The basis thermal conversion direct combustion can be classified as:

a) Combustion

b) Pyrolysis and

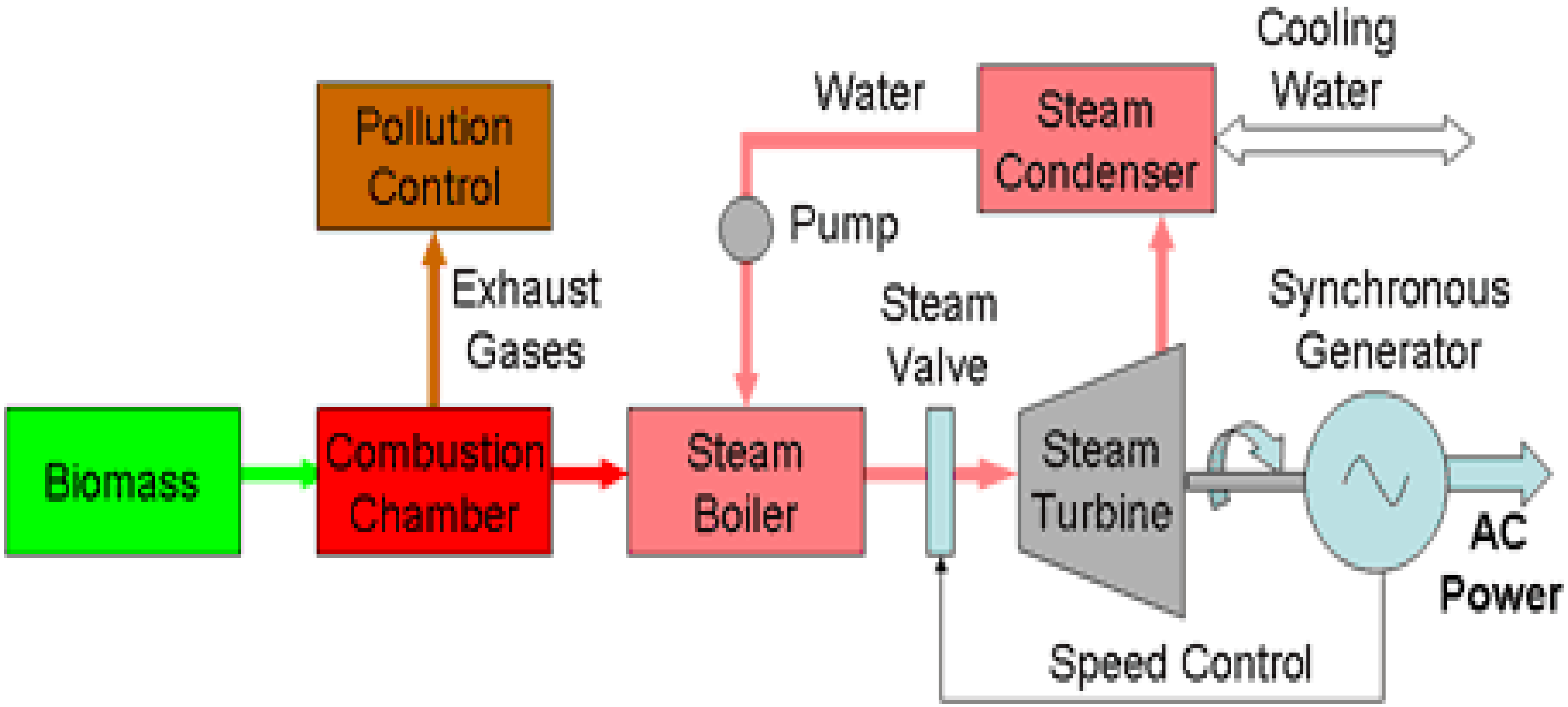
c) Gasification

a) Combustion

Combustion is the best established and most commonly used technology for converting ***biomass*** to heat.

During ***combustion***, ***biomass*** fuel is burnt in excess air to produce heat. The first stage of ***combustion*** involves the evolution of combustible vapours from the ***biomass***, which burn as flames.

a) Combustion

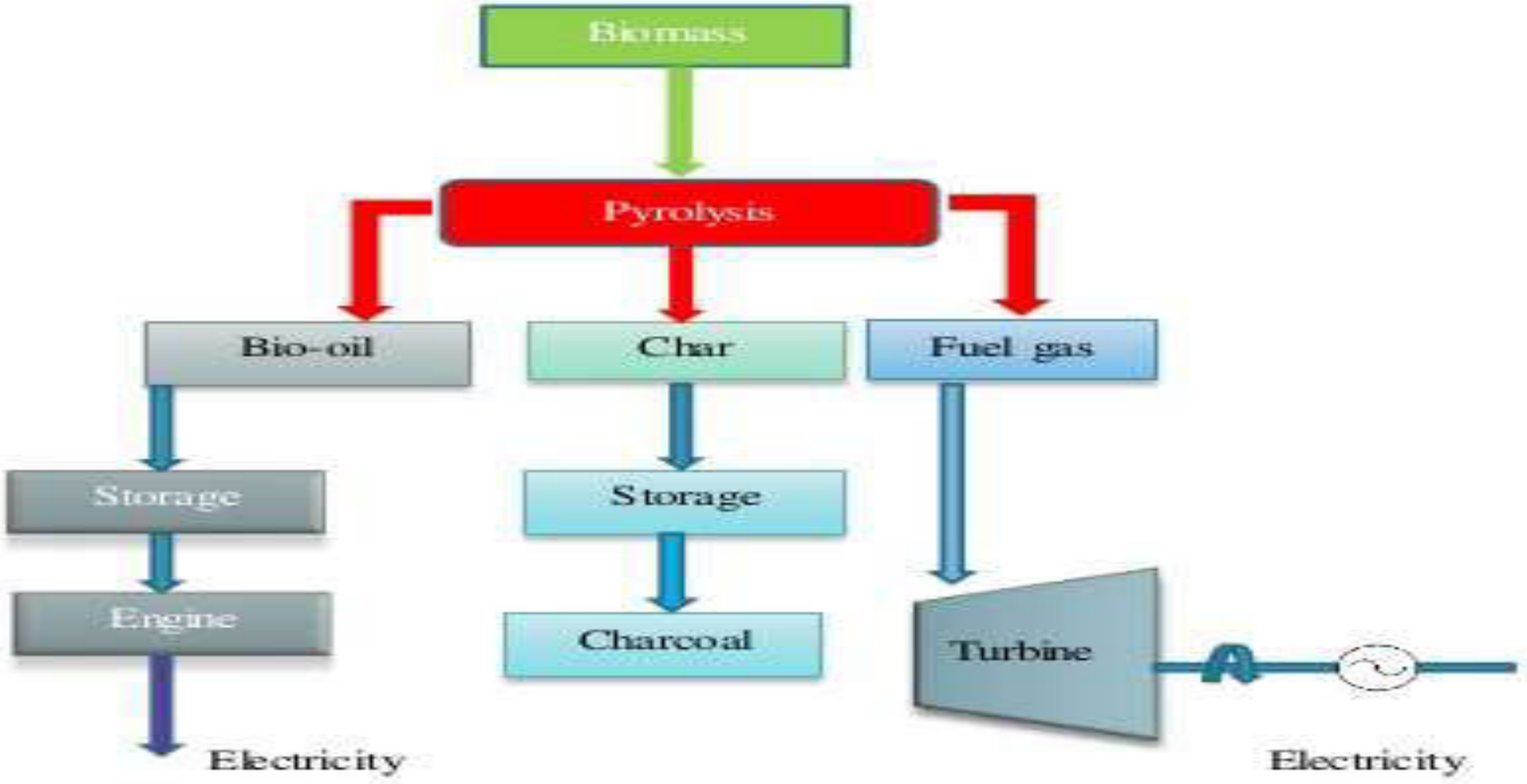


Electricity Generation Powered by Biomass

b) Pyrolysis

Biomass pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen. It is the fundamental chemical reaction that is the precursor of both the combustion and gasification processes and occurs naturally in the first two seconds.

b) Pyrolysis

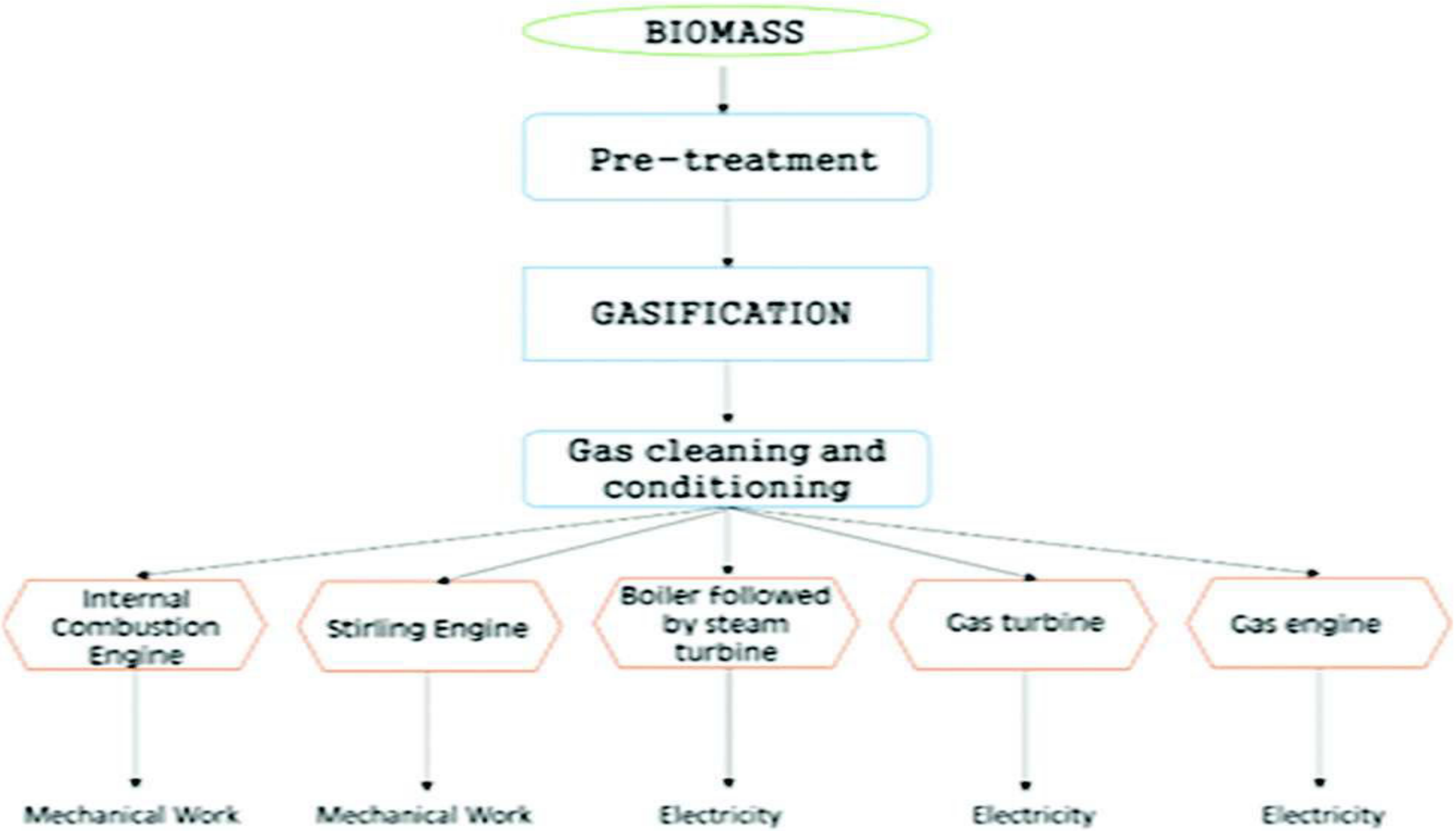


Biomass
Pyrolysis
Bio-oil
Char
Fuel gas
Storage
Storage
Engine
Charcoal
Turbine
Electricity
Electricity

c) Gasification

Biomass gasification involves burning of **biomass** in a limited supply of air to give a combustible gas consisting of carbon monoxide, carbon dioxide, hydrogen, methane, water, nitrogen, along with contaminants like small char particles, ash and tars.

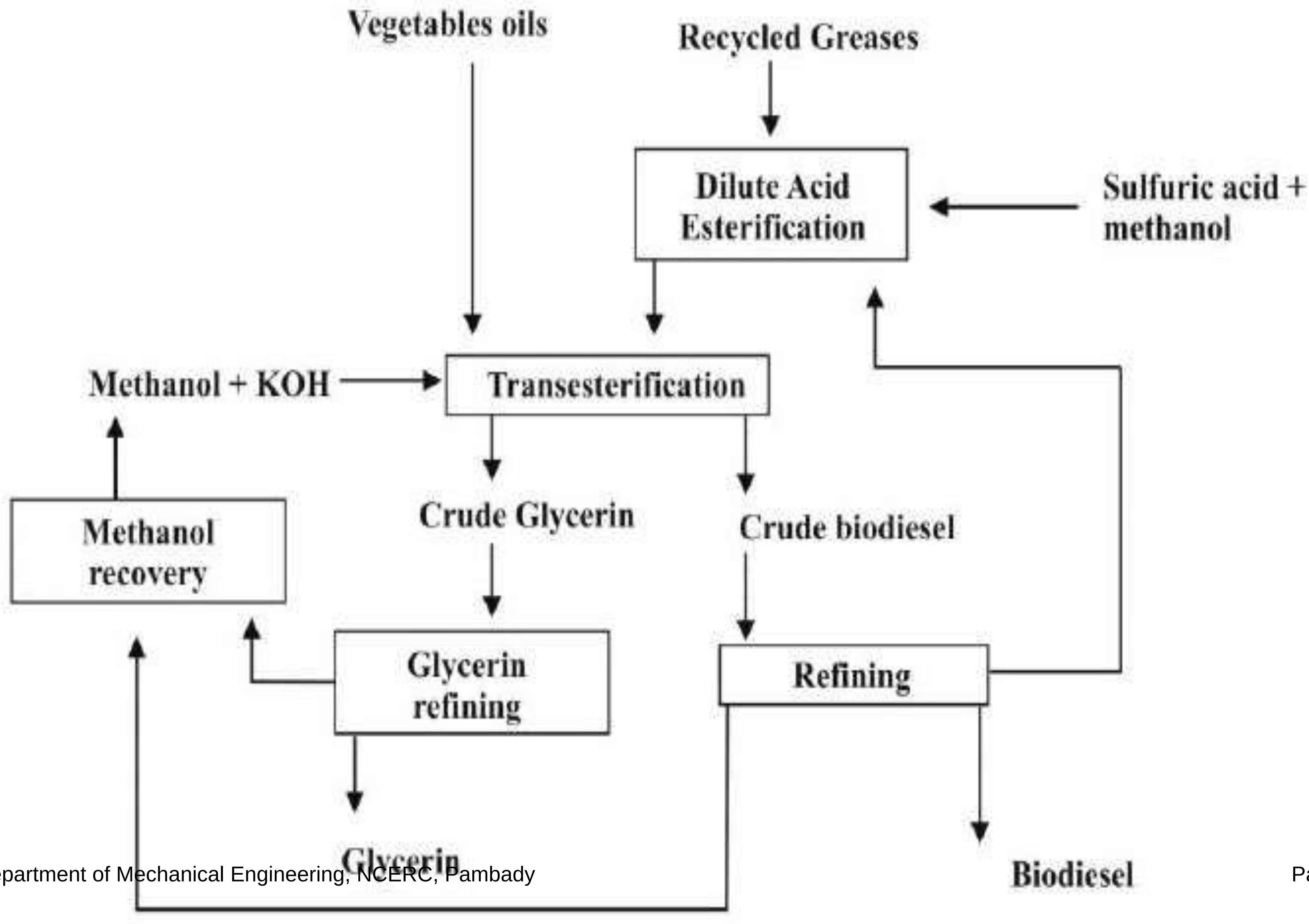
c) Gasification



TRANSESTERIFICATION

Transesterification process a glyceride reacts with an alcohol (typically methanol or ethanol) in the presence of a catalyst forming fatty acid alkyl esters and an alcohol.

Transesterification



BIOGAS PLANT

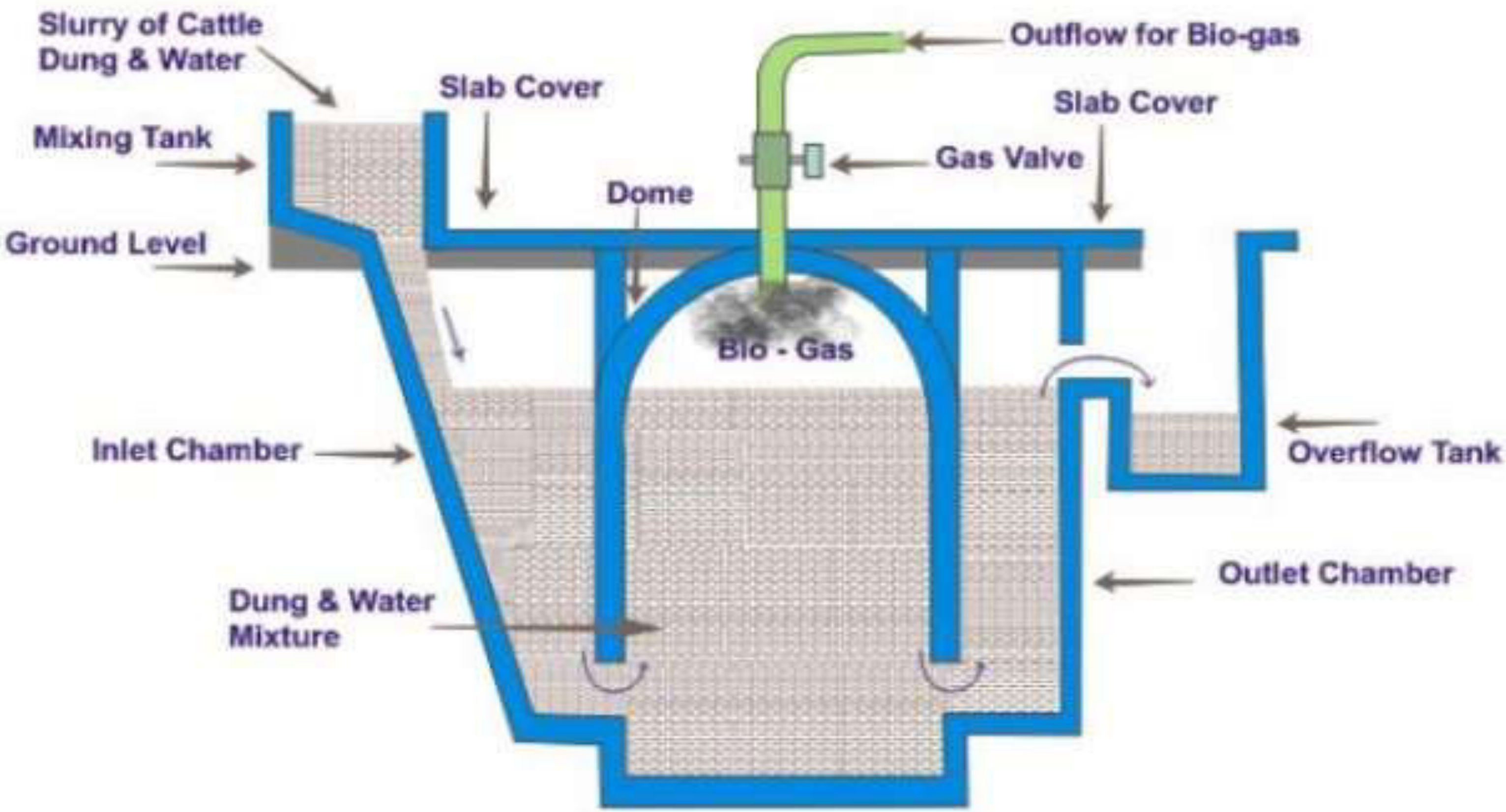
Biogas is the mixture of gases produced by the breakdown of organic matter in the absence of oxygen. ***Biogas*** can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. This fuel consists of CH_4,CO_2, H_2, H_2S.

Type of Biogas Plant

a) Fixed-Dome Type

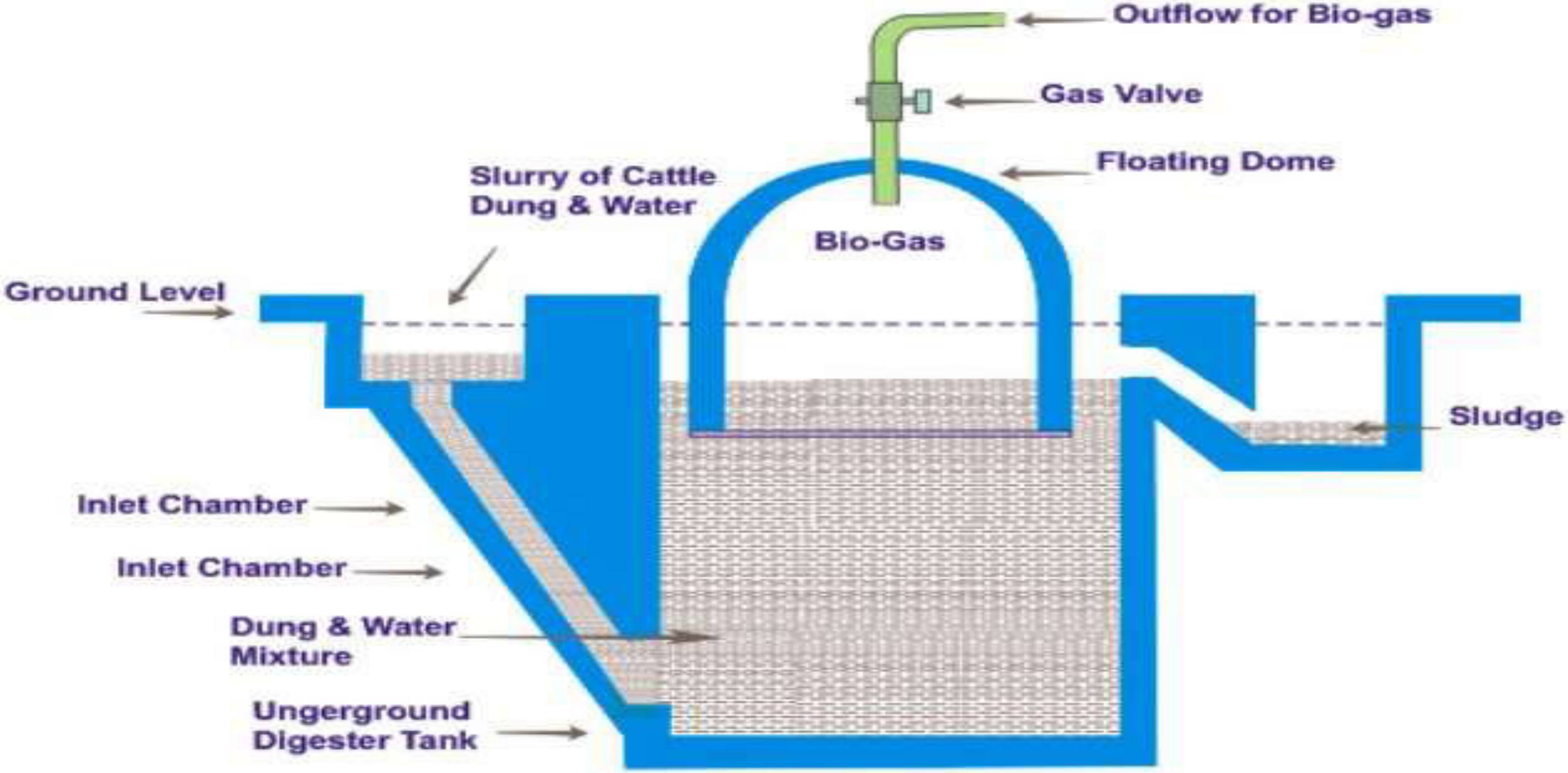
b) Floating gas holder type

a) Fixed-Dome Type



Fixed Dome type Bio-gas Plant

b) Floating gas holder type



Floating Dome type Bio-gas Plant

ECONOMICS OF BIOMASS POWER GENERATION

1. **Cost of installation**
   - **Equipment arrangement**
   - **Plant size**
   - **Geographical factors**
2. **Permitting , equipment, engineering, construction, commissioning, development and cost of financing.**

Economics Of Biomass Power Generation Continued …

3. The economics of bio-power system

- Incentive
- Plant cost
- Labour cost
- Biomass resource cost
- Sale rate of electricity
- Thermal energy

4. Cost of Labour (depends on size)

Module V

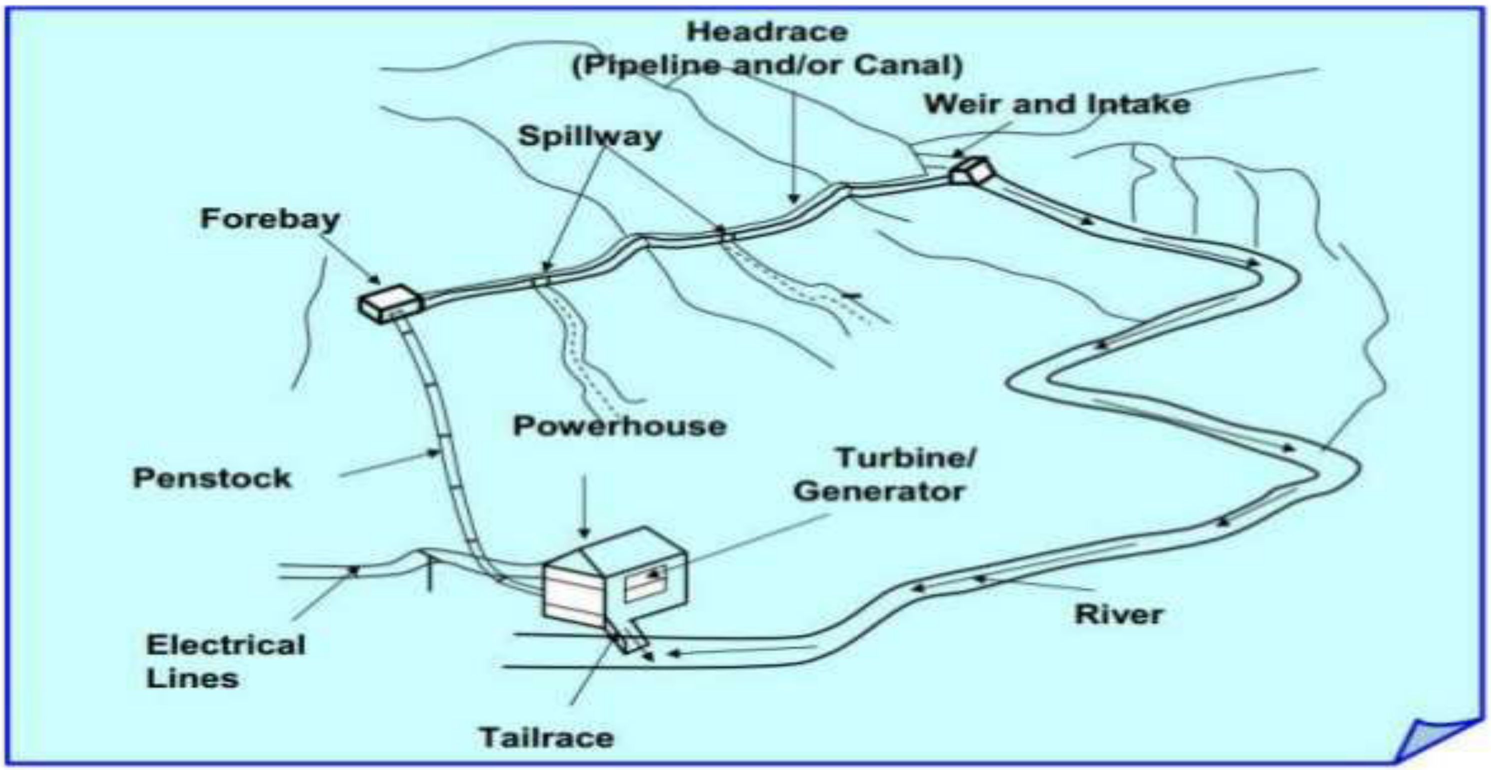
Other Renewable Energy Sources and Economics

Types

Type	Description
Large Hydro	All installations with an installed capacity of **more than 1000 kW** (according to some definitions more than 10,000 kW)
Medium Hydro	Installations of **15 - 100 MW** (usually feeding the grid)
Small Hydro	Installations of **1-15 MW** (usually feeding into the grid)
Mini Hydro	Capacity **between 100 - 500 kW** (either as stand-alone schemes or more often feeding into the grid)
Micro Hydro	Installations with power output of **5 - 100 kW** (usually provided power for small community or rural industry in remote areas away from the grid)
Pico Hydro	From a few hundred watts **up to 5 kW**

Components of Micro Hydo power plant

COMPONENTS OF MICRO-HYDRO POWER PLANT



Suitable conditions for micro-hydro power

The ideal geographical areas for exploiting small scale hydro schemes is where there are steep rivers flowing all year round. Islands with moist marine climates are also suitable. Low-head turbines have been developed for small-scale exploitation of rivers or irrigation canals where there is a small head but sufficient flow to provide adequate power.

Types of Turbines for micro hydro power

Type	high head	medium head	low head
Impulsive turbines	▪ Pelton ▪ Turgo	▪ cross-flow ▪ multi-jet Pelton ▪ Turgo	▪ cross-flow
Reaction turbines		▪ Francis	▪ propeller ▪ Kaplan

Types of Turbines for micro hydro power Continued ..

- **Impulse Turbine :** the turbine runner operates in air and is turned by one or multiple jets of water which make contact with the runner blades.
- **Reaction Turbine** : the turbine runner is fully immersed in water and is enclosed in a pressure casing, the runner blades are angled so that pressure differences across them create lift forces, like those on aircraft wings, which cause the runner to rotate.
- **Load Factor** : Average Load /Maximum load in given time period
- Load control governors: The ELC prevents speed variations by continuously adding or subtracting an artificial load to maintain the turbine speed.

Economics of Micro Hydro Power Plants

1. Cost
2. Environmental Impact
3. Initial cost
4. Construction cost
5. O & M
6. Revenue
7. Project financing
8. Profitability – ROI – ROE – NPV - IRR

Low cost Grid Connection

1. Load limited supply
2. Reduced service connection costs
3. Pre-fab wiring systems
4. Credits
5. Community involvement

TIDEL POWER PLANT

For utilization of tidal energy, water must be trapped at high tide behind a dam or barrage and then made to drive turbine coupled to an electric generator as it returns to sea during low tides. The available energy is proportional to the square of the amplitude.

Tidal Power Plant Components

(i) Dam

(ii) Sluice ways from basin to sea and vice versa

(iii) Power house.

Tidal Power Plant Components Continued..

- The function of a dam is to form a barrier between the sea and the basin or between one basin to the other basin in case of multiple basins. The most suitable word for tidal power plant is barrage. Barrages have to resist waves whose shock can be severe and where pressure changes sides continuously.
- The sluice ways are gate controlled devices. They are employed to fill the basin during the high tide or empty the basin during low tide. In existing plants, vertical lift gates have been employed. Flap gates are also used. The flap gates allow only in the direction of sea to basin. Therefore, the level of the basin rises.
- Auxiliary equipments, turbines and generators are the main components of the power house. Large sized turbines are used because of low head available. Bulb types and rim type turbines are commonly used.

Classification of Tidal Power Plants

There are two types of basin systems viz.:

1. Single Basin System

i) Single Ebb-Cycle System,

(ii) Single Tide-Cycle System,

(iii) Double Cycle System.

2. Double Basin System.

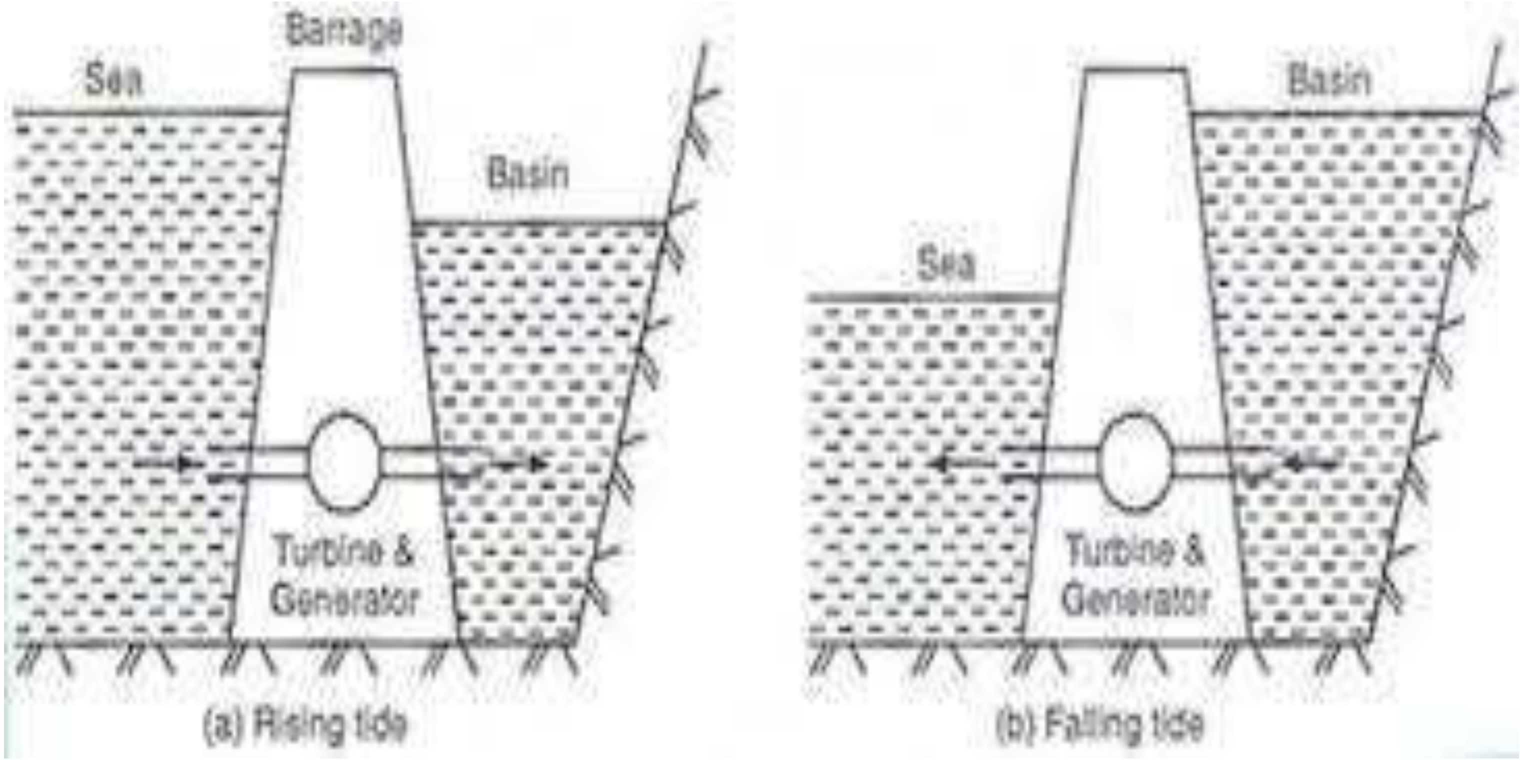
1 **(i) Single Ebb-Cycle System:**

In single ebb-cycle system, when the high tides (flood side) are falling, sluices are opened to permit the sea water to enter the basin, while the turbine sets are shut. The level of the basin begins increasing. The energy is stored in the form of tidal range. Tidal range provides water head during low tides. **The generation of power takes place, when the water from the basin flows over the turbine into the low level sea water.** The turbines are designed for single way operation. The power output from such system is intermittent in nature and highly variable.(Fig b)

1 (ii) Single Tide-Cycle System:

In single tide cycle system, the generation is affected when the sea is at flood tide. The sea **water is admitted into the basin over the turbines**. As the flood tide period is over and the sea level begins falling again, the generation is stopped. The basin is drained into the sea through the sluice ways. In this system also the power output is intermittent.(Fig a)

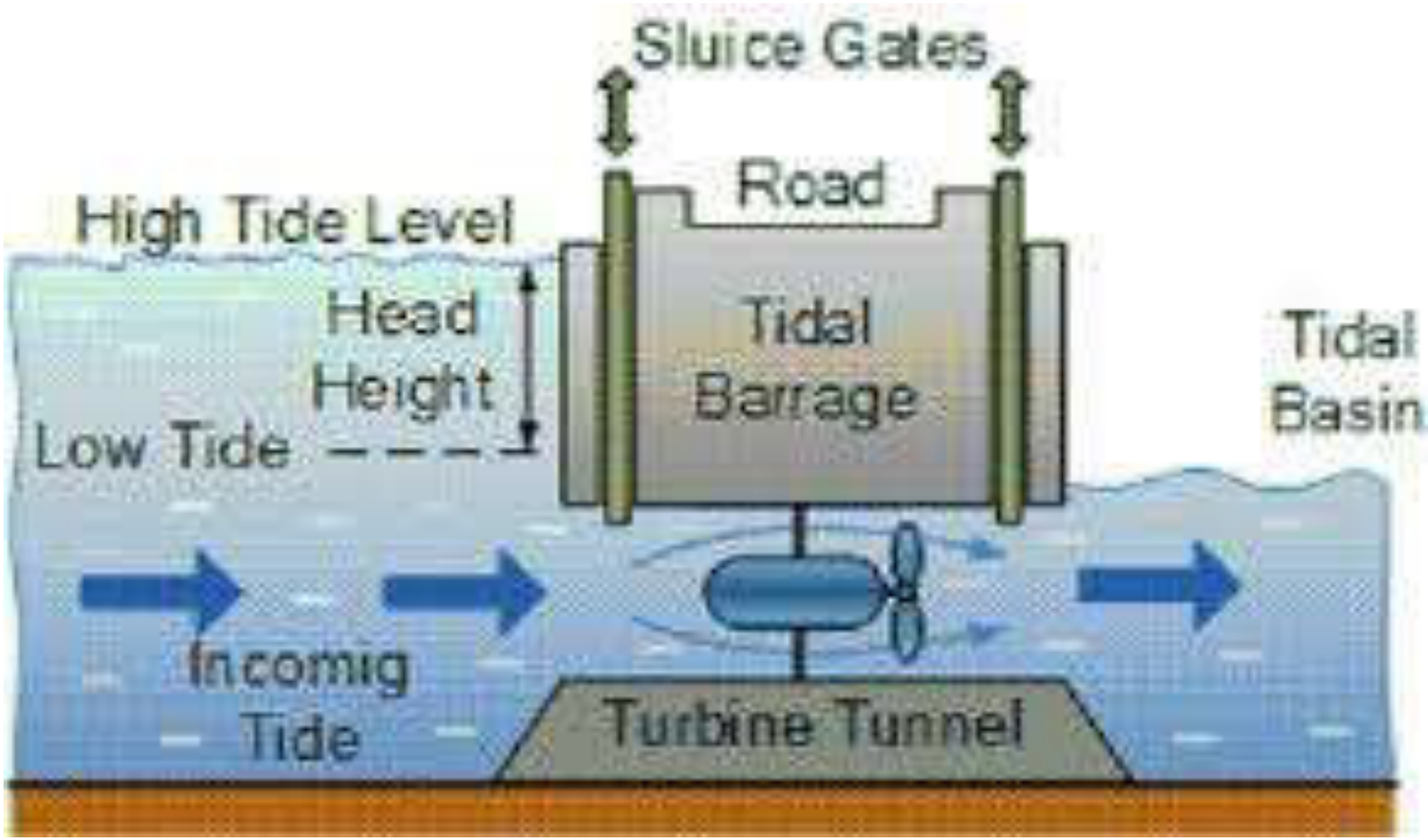
Single Basin System Continued..



1(iii) Double Cycle System:

In double cycle system, the reversible turbines are installed and power is generated during filling and emptying of basin. Filling process occurs when the ocean is at high tide while the water in basin at low tide level, the emptying occurs when the ocean is at low tide and basin at high tide level.

Single Basin System Continued..



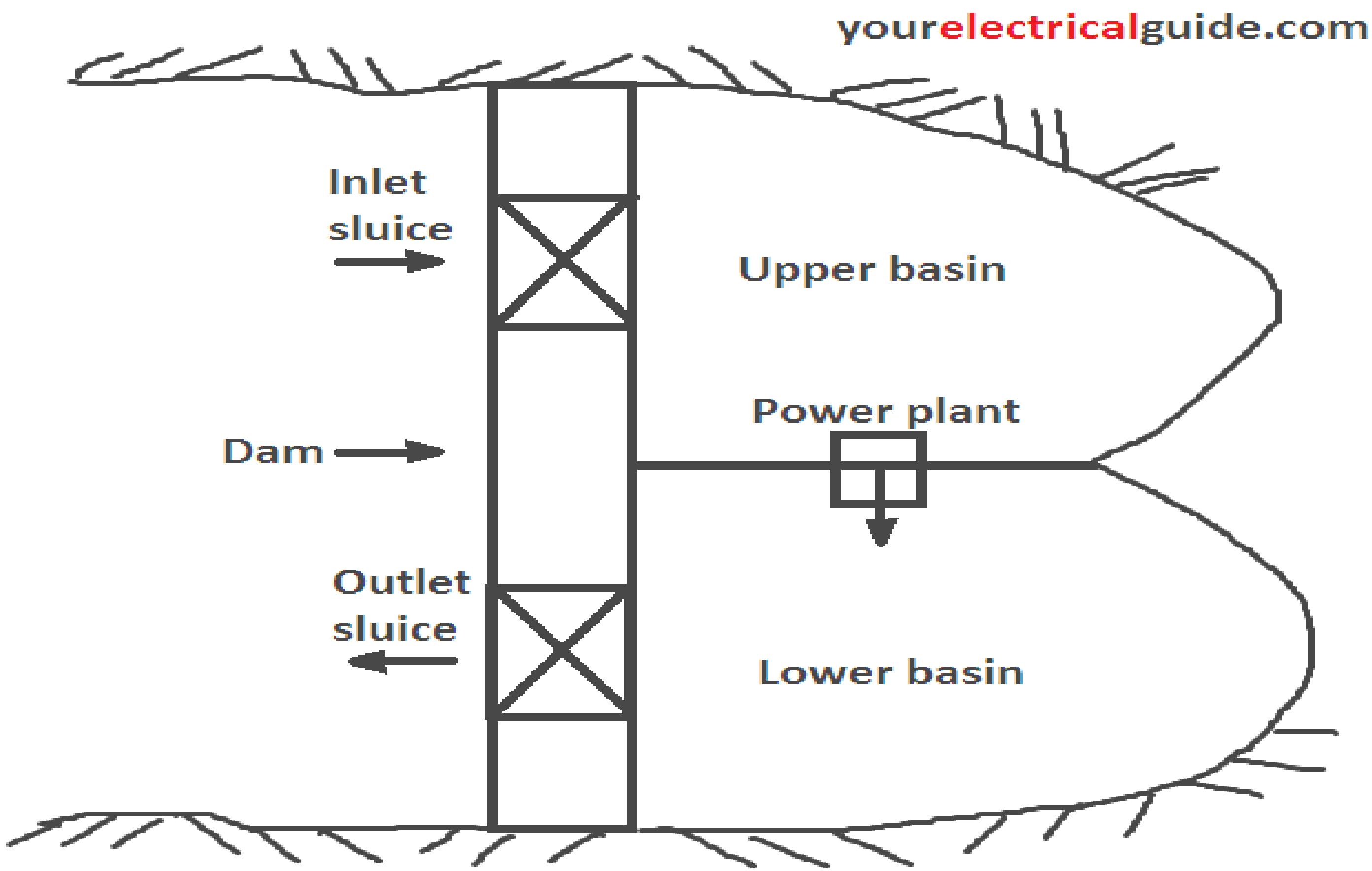
2. Double Basin System:

There are two basins at different levels. A dam is provided between two basins. The turbines are located in the dam. The sluice gates are provided in the dam. One basin is called the upper basin; the water level is maintained above that in the other, the low basin. The high level basin gates are called the inlet gates and low level gates as outlet gates. The upper basin is filled with water.

When the water level in upper basin A provides a sufficient difference of head between the two basins, the turbines are started. The water flows from basin A to basin B through the turbines and the power is generated. The power generation thus continues simultaneously along with filling up of water in basin A. When the tide attains its peak value, the water level in basin A is maximum; the inlet sluices are then closed. The water flows from the upper basin to the lower basin through the turbines.

Thus, the water level in the upper basin falls and that in the lower basin rises. When the rising level in lower basin B becomes equal to the level of the falling tide, the outlet sluices are opened. When the tide reaches its lower most level, the outlet gates are closed. After some time the tide rises. When its level becomes equal to low level of the upper basin, the inlet gates are opened. Consequently the level of water in basin A starts rising. Thus, the cycle is repeated.

Double Basin System



Tidal power plant : Double basin system

Advantages

- It is pollution free.
- Energy is freely available.
- Power is ensured around the year.
- It is unaffected by the unpredictability of monsoon.
- Large area of valuable land is not required

Limitations

- The capital cost of the plant is high.
- Every location is not suitable for installing such a system.
- Sedimentation of basins is a problem.
- Sea water is very corrosive.
- Marine life is affected.
- Output not uniform due to variation of tidal range
- M/c are corroded due to sea water

Geo Thermal Power Plant

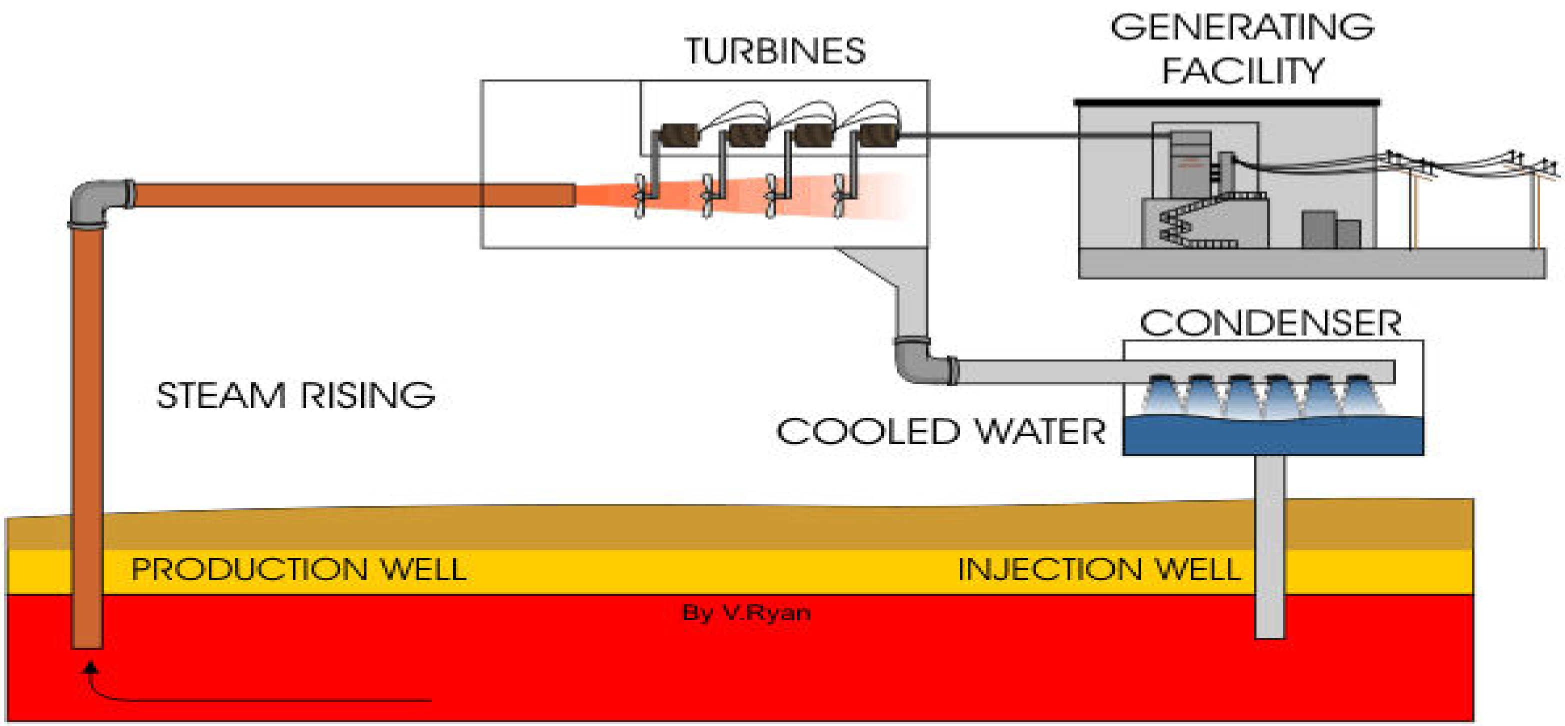
Geothermal power stations are similar to other steam turbine thermal **power stations** in that **heat** from a fuel source (in **geothermal's** case, the Earth's core) is used to **heat** water or another **working** fluid. The working fluid is then used to turn a turbine of a generator, thereby producing electricity.

Types of Geo thermal sources

There are three **types of geothermal power plants**: dry steam, flash steam, and binary cycle.

Dry steam **power plants** draw from underground resources of steam. The steam is piped directly from underground wells to the **power plant**, where it is directed into a turbine/generator unit.

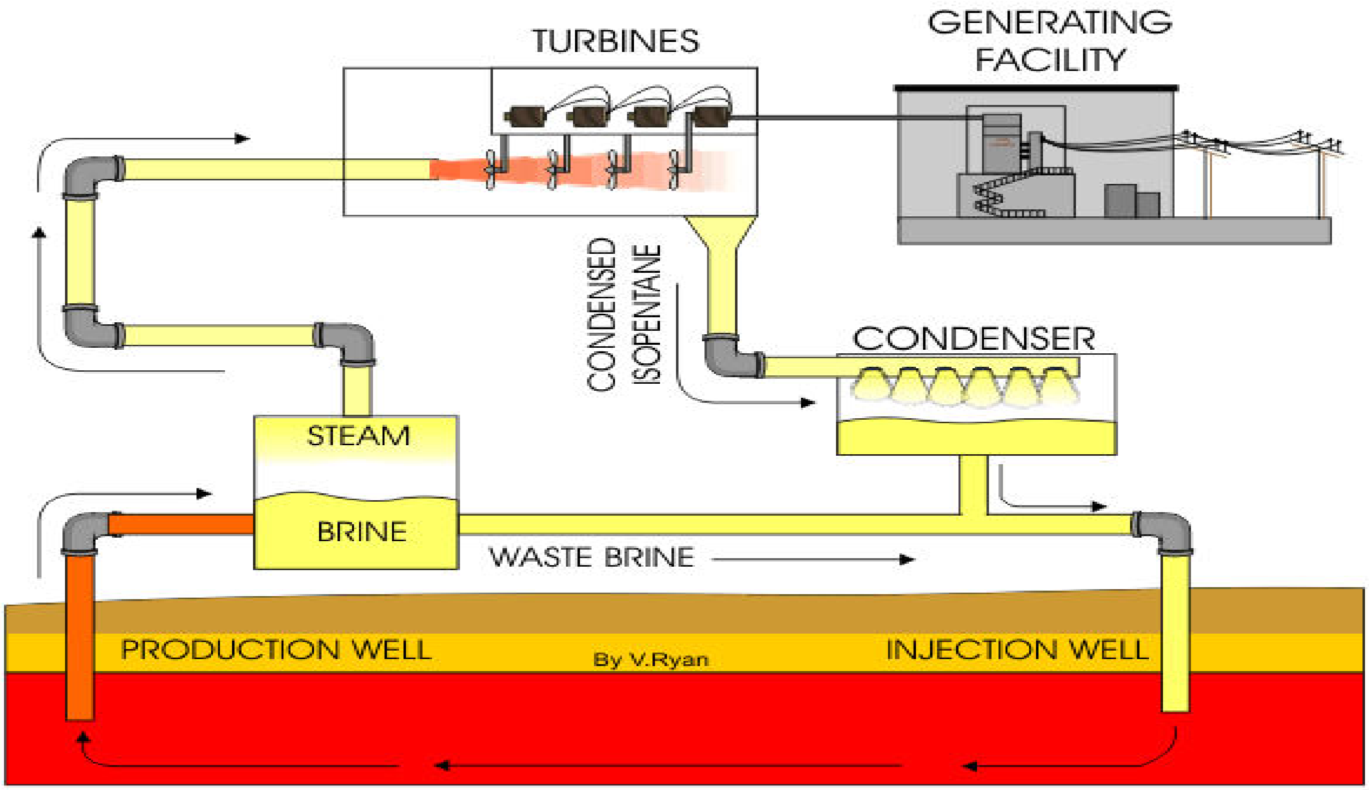
Dry SteamSystem



Flash steam plants

Flash steam plants take high-pressure hot water from deep inside the earth and convert it to **steam** to drive generator turbines. When the **steam** cools, it condenses to water and is injected back into the ground to be used again. Most **geothermal power plants** are **flash steam plants**

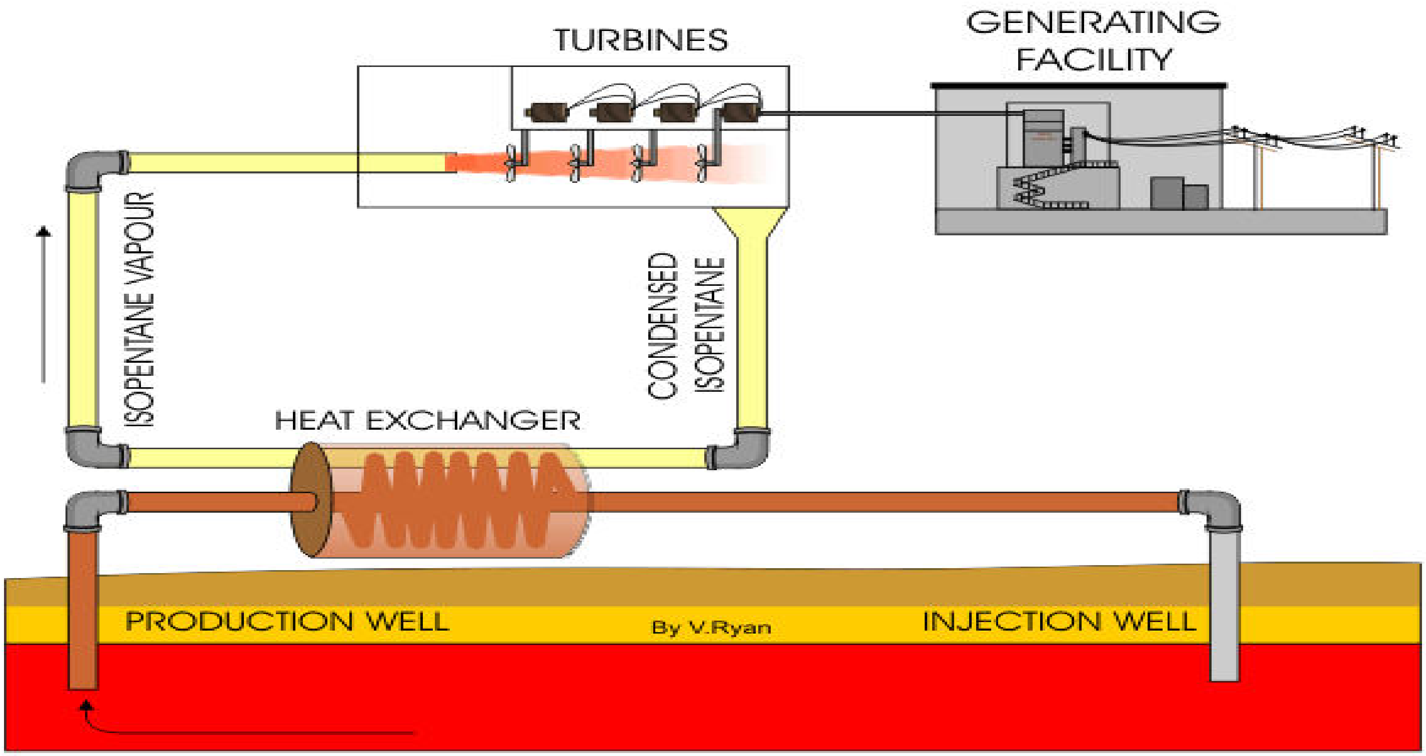
FlashSteam Plant



Binary Steam Geothermal Power Plant

- Binary plants specifically use a second working fluid (hence, "binary") with a much lower boiling point than water. The binary fluid is operated through a conventional Rankine cycle. Generally, the working fluid is a hydrocarbon such as isopentane, or a refrigerant. The geothermal fluid (predominantly water vapour) and working fluid pass through a heat exchanger, where the working fluid flashes to vapour and drives the turbines.

Binary System



Advantages

Advantages of Geothermal power plant

- Unlike solar energy or wind energy, it is not dependent on the weather conditions.
- Clean source of power.
- Less area is required.
- Unhindered production of power.
- Additional capacity can be added to produce more power and is thus flexible.
- Maintenance cost of geothermal power plants is very less.

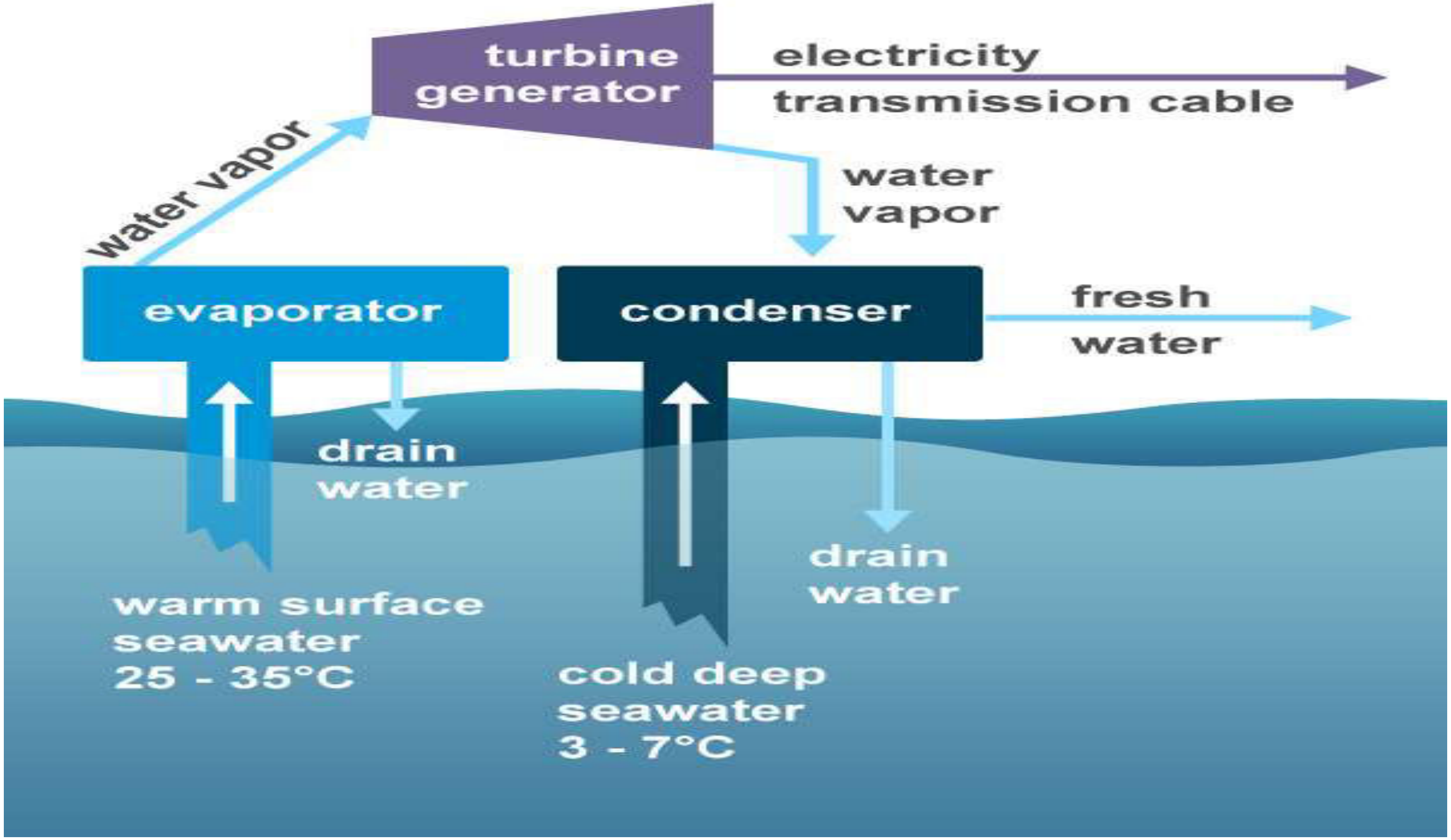
Limitations

- Not widespread source of energy
- High installation costs
- Can run out of steam
- May release harmful gases
- Transportation
- Earthquakes

OCEAN THERMAL ENERGY CONVERSION (OTEC) PLANT

Introduction

Energy from the sun heats the surface water of the ocean. In tropical regions, surface water can be much warmer than deep water. This temperature difference can be used to produce electricity and to desalinate ocean water. Ocean Thermal Energy Conversion (OTEC) systems use a temperature difference (of at least 77° Fahrenheit) to power a turbine to produce electricity. Warm surface water is pumped through an evaporator containing a working fluid. The vaporized fluid drives a turbine/generator. The vaporized fluid is turned back to a liquid in a condenser cooled with cold ocean water pumped from deeper in the ocean. OTEC systems using seawater as the working fluid can use the condensed water to produce desalinated water.


turbine
generator
electricity
transmission cable
water vapor
water
vapor
evaporator
condenser
fresh
water
drain
water
drain
water
warm surface
seawater
25 - 35°C
cold deep
seawater
3 - 7°C

TYPES OF OTEC PLANT

1) Closed cycle

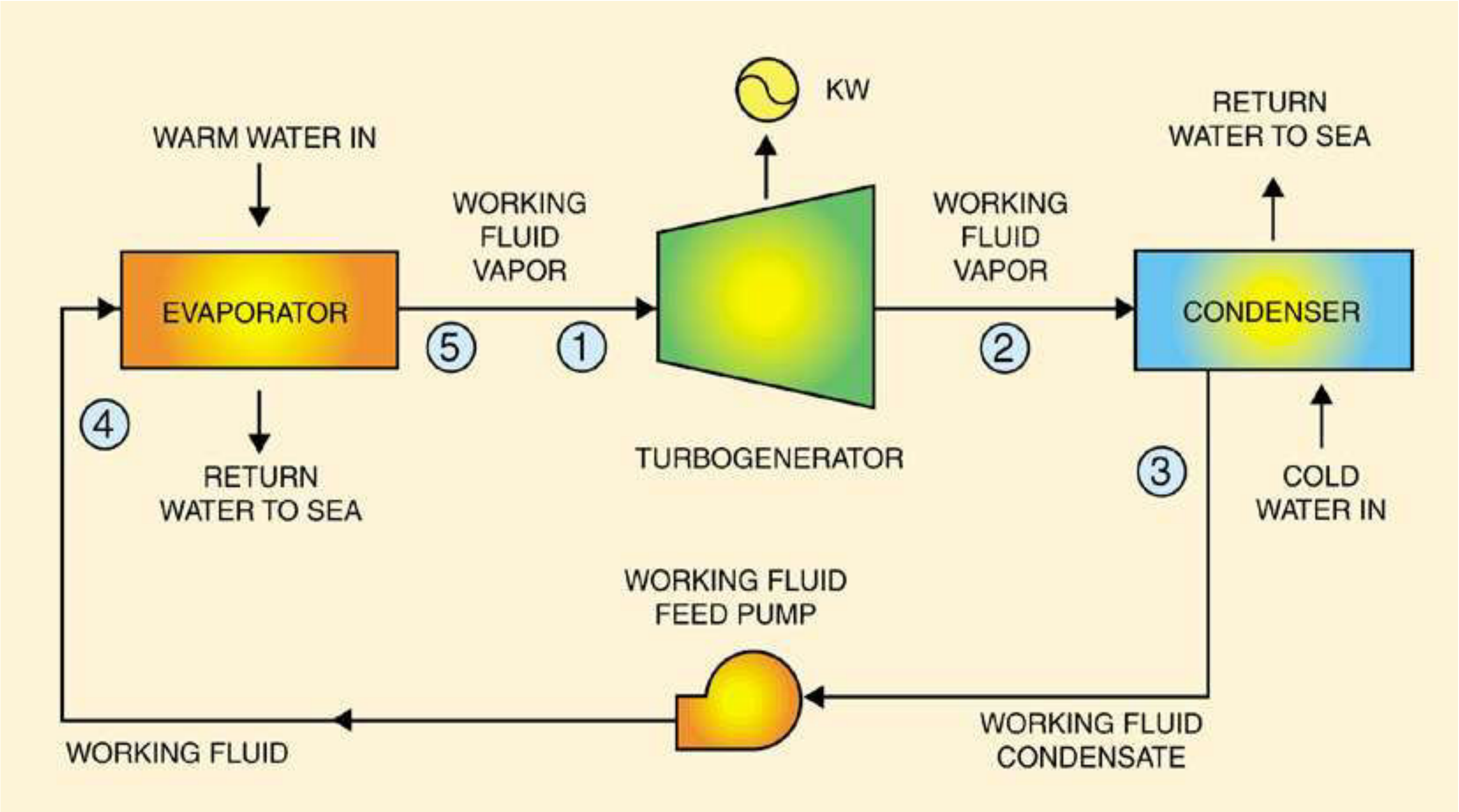
2) Open cycle

3) Hybrid Cycle

Closed Cycle OTEC System

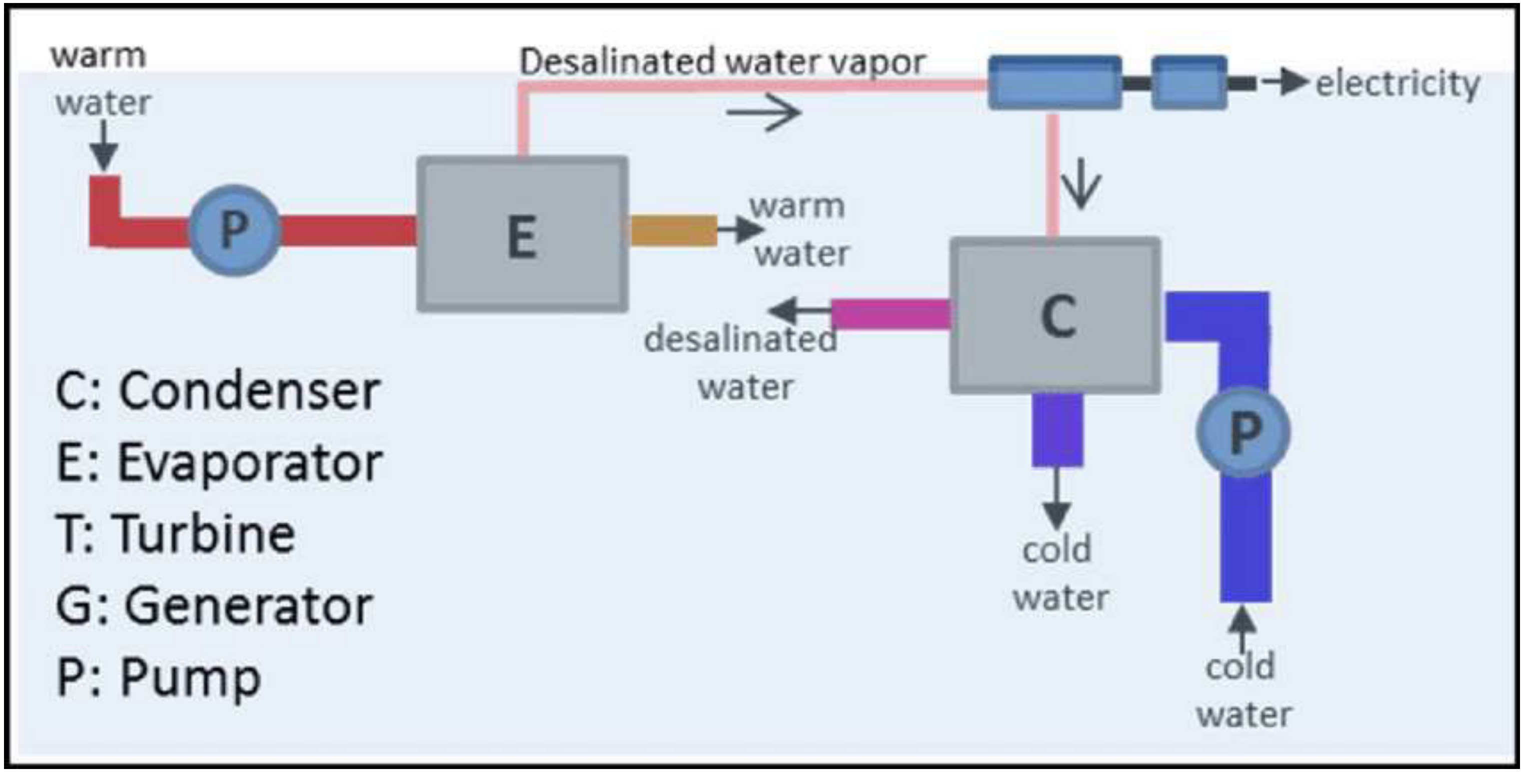
OTEC is a heat engine system with a heat source (i.e., warm water) and a heat sink (e.g., cold water). The warm water evaporates the working fluid (Ammonia or R 134a –Tetrafluoroethane-) into a vapour which expands and drives a turbine. The turbine, connected to a generator, is the source of mechanical energy.

Closed Cycle OTEC System



Open Cycle

In an open cycle OTEC system the sea water itself is used to provide the thermodynamic fluid.

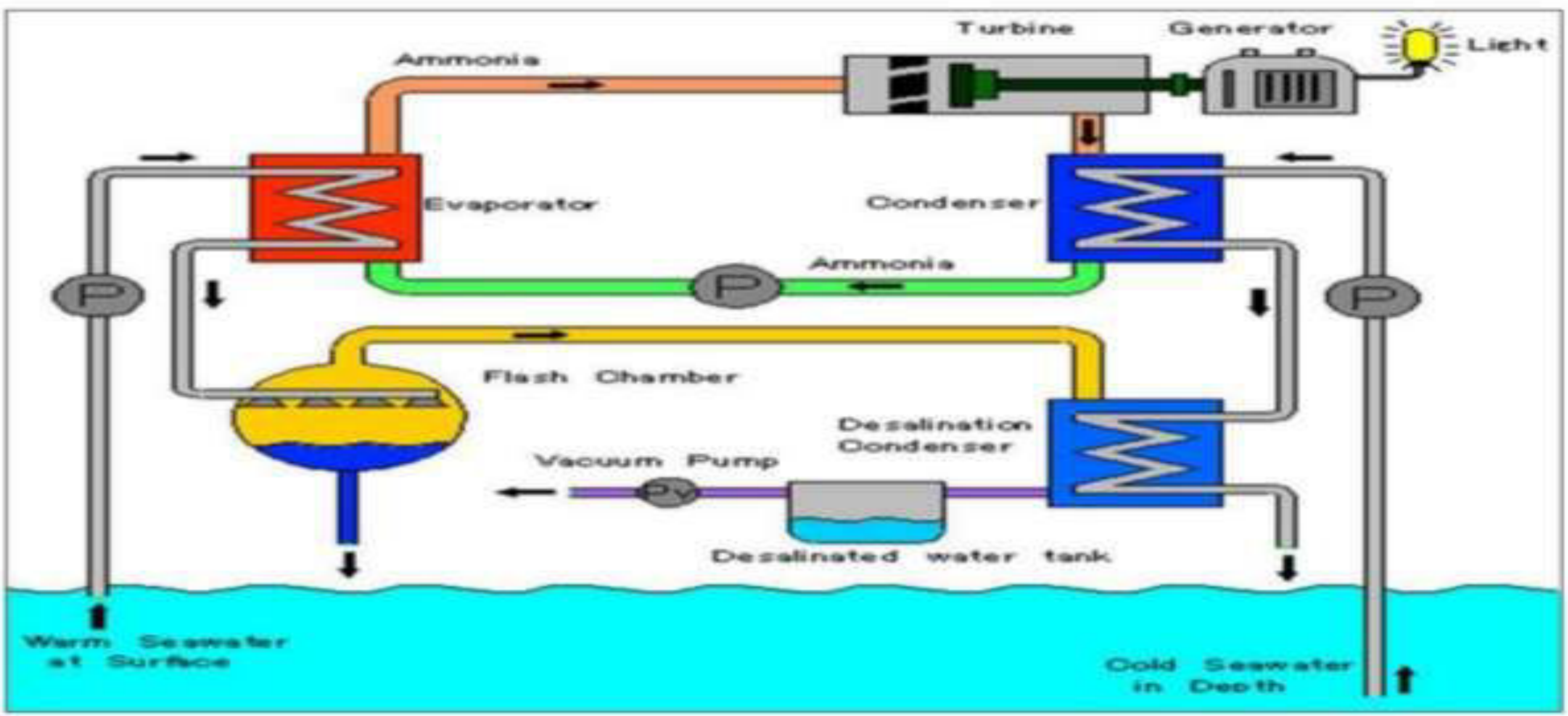


Hybrid Cycle

In a hybrid, warm seawater enters a vacuum chamber and is flash-evaporated, similar to the open-cycle evaporation process. The steam vaporizes the ammonia working fluid of a closed-cycle loop on the other side of an ammonia vaporizer. The vaporized fluid then drives a turbine to produce electricity.

Hybrid Cycle

HYBRID CYCLE



Advantages of OTEC

- Power developed is continuous and it is independent of weather.
- There is a small variation in power output from season to season.
- The system uses conventional power plants needing only small changes in design.
- It can produce simultaneously the desalinated water and nutrients for agriculture.

Limitations of OTEC

- Capital cost is very high.
- Efficiency of energy conversion is very low.
- Needs very large sized turbines due to use of low pressure of steam having high specific volume in case of open cycle.
- It uses expensive power working fluids in case of closed cycle.
- Cost of electric power generation per kWh is very high.

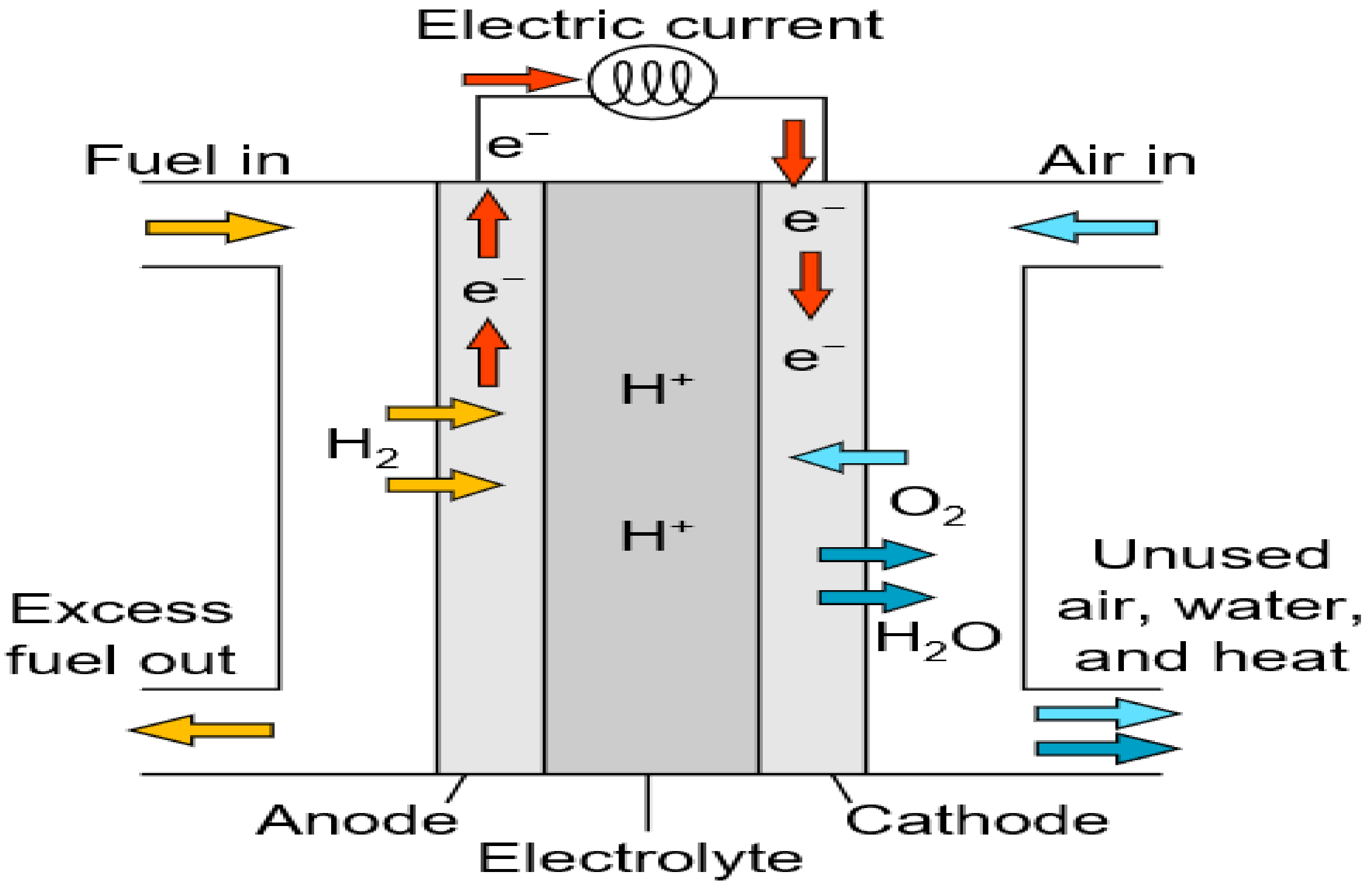
FUEL CELL

A ***fuel cell*** is an electrochemical ***cell*** that converts the chemical energy of a ***fuel*** (often hydrogen) and an oxidizing agent (often oxygen) into electricity through a pair of redox reactions.

FUEL CELL

A fuel cell resembles a battery in many respects, but it can supply electrical energy over a much longer period of time. This is because a fuel cell is continuously supplied with fuel and air (or oxygen) from an external source, whereas a battery contains only a limited amount of fuel material and oxidant that are depleted with use. For this reason fuel cells have been used for decades in space probes, satellites, and manned spacecraft. Around the world thousands of stationary fuel cell systems have been installed in utility power plants, hospitals, schools, hotels, and office buildings for both primary and backup power; many waste-treatment plants use fuel cell technology to generate power from the methane gas produced by decomposing garbage.

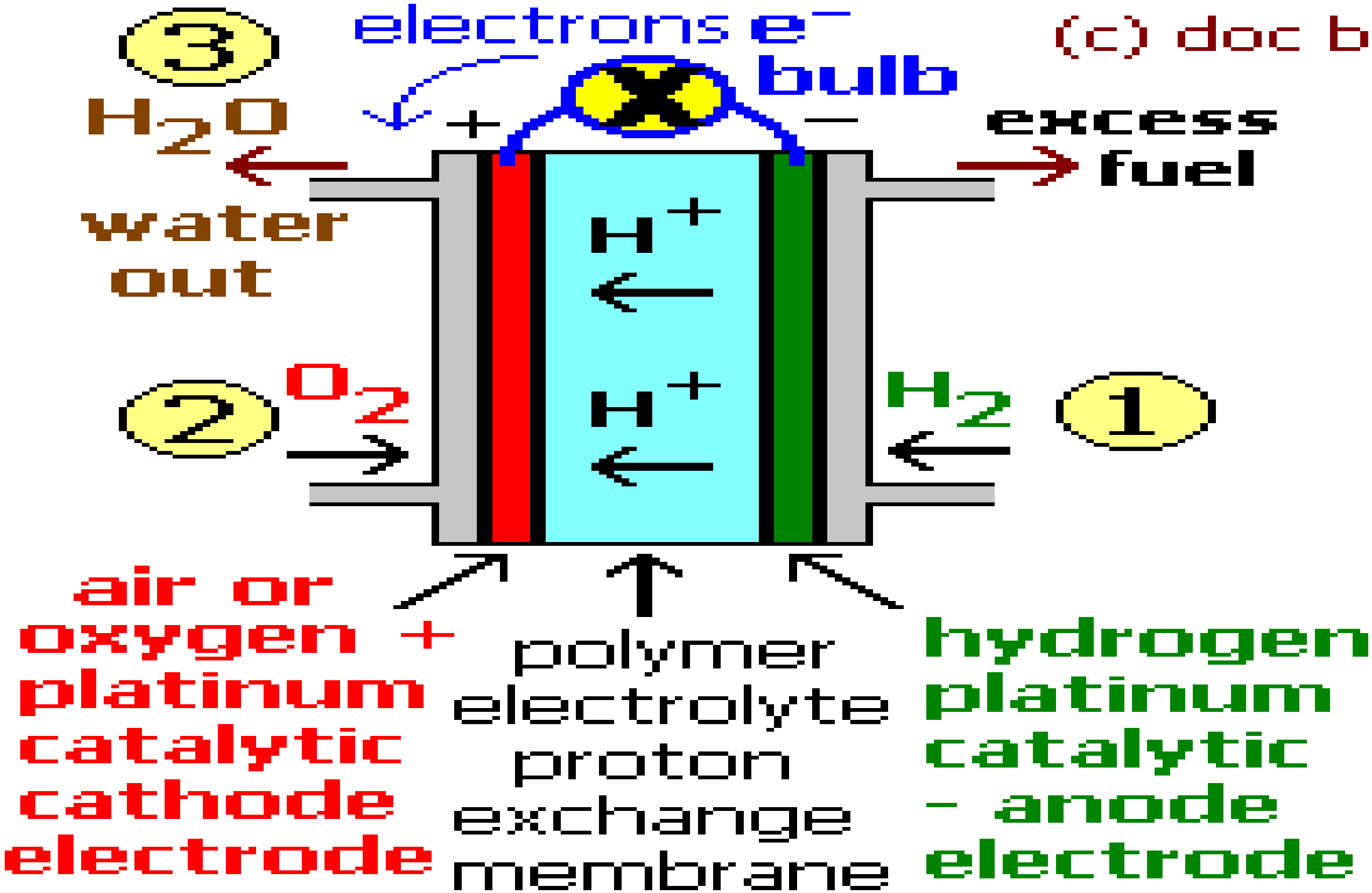
Fuel Cell Continued ..



Hydrogen Energy Conversion System

Hydrogen do not freely available as a gas in the earth. It always combines with other elements like,H_2O, CH_3OH (MeOH) Methanol,C_3H_8(Propane), C_4H_{10}(Butane)

Hydrogen fuel cells **power** the shuttle's electrical **systems**, producing a clean by product – pure water, which the crew drinks-. A **fuel** cell combines **hydrogen** and oxygen to produce **electricity**, heat, and water. Both **convert** the **energy** produced by a chemical reaction into usable electric **power**.


3
electrons e⁻
(c) doc b
bulb
H2O
+
−
excess fuel
water out
H+
H+
2
O2
H2
1
air or oxygen + platinum catalytic cathode electrode
polymer electrolyte proton exchange membrane
hydrogen platinum catalytic − anode electrode

Advantages of Hydrogen Fuel Cells

1. It is readily available.
2. It doesn’t produce harmful emissions.
3. It is environmentally friendly.
4. It can be used as fuel in rockets.
5. It is fuel efficient.
6. It is renewable.
7. Quick operation
8. Less space
9. Easy installation
10. No Noise

Limitations

1. It is expensive.
2. It is difficult to store.
3. It is not easy to replace existing infrastructure.
4. It is highly flammable.
5. It is dependent on fossil fuels.
6. Low voltage output

Application

1.Commercial, industrial , residential primary and backup power generation.

2. As power sources for remote locations, such as spacecraft, remote weather stations, large parks, communications centres, rural locations including research stations.

3.For certain military applications

4. Automotive vehicles

MHD (Magneto Hydro Dynamic) Power Plant

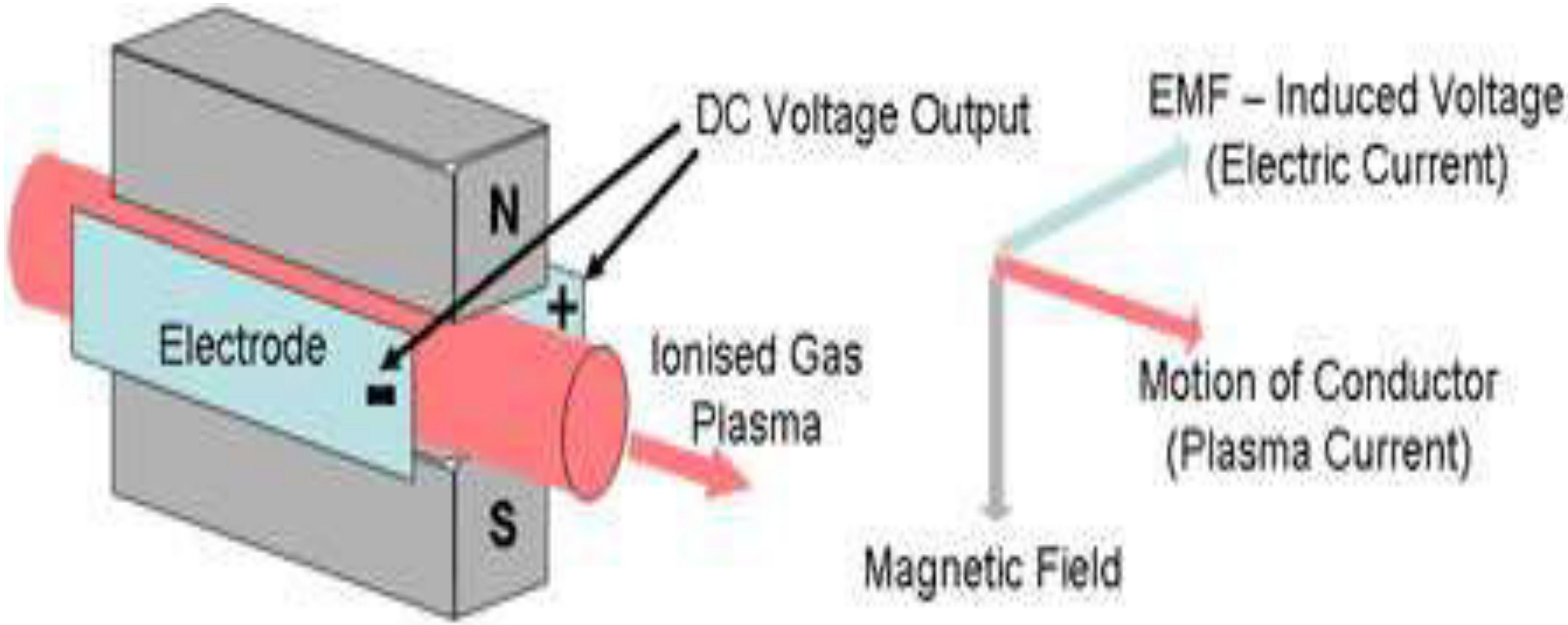
Methodology

This power plant works in the principle of Faraday's law of electromagnetic induction (Faraday's law of electromagnetic induction is a basic law of electromagnetism predicting how a magnetic field will interact with an electric circuit to produce an electromotive force (EMF)).

Working Principle

The MHD generator can be considered to be a fluid dynamo. This is similar to a mechanical dynamo in which the motion of a metal conductor through a magnetic field creates a current in the conductor except that in the MHD generator the metal conductor is replaced by a conducting gas plasma.

When a conductor moves through a magnetic field it creates an electrical field perpendicular to the magnetic field and the direction of movement of the conductor



Magnetohydrodynamic Power Generation (Principle)

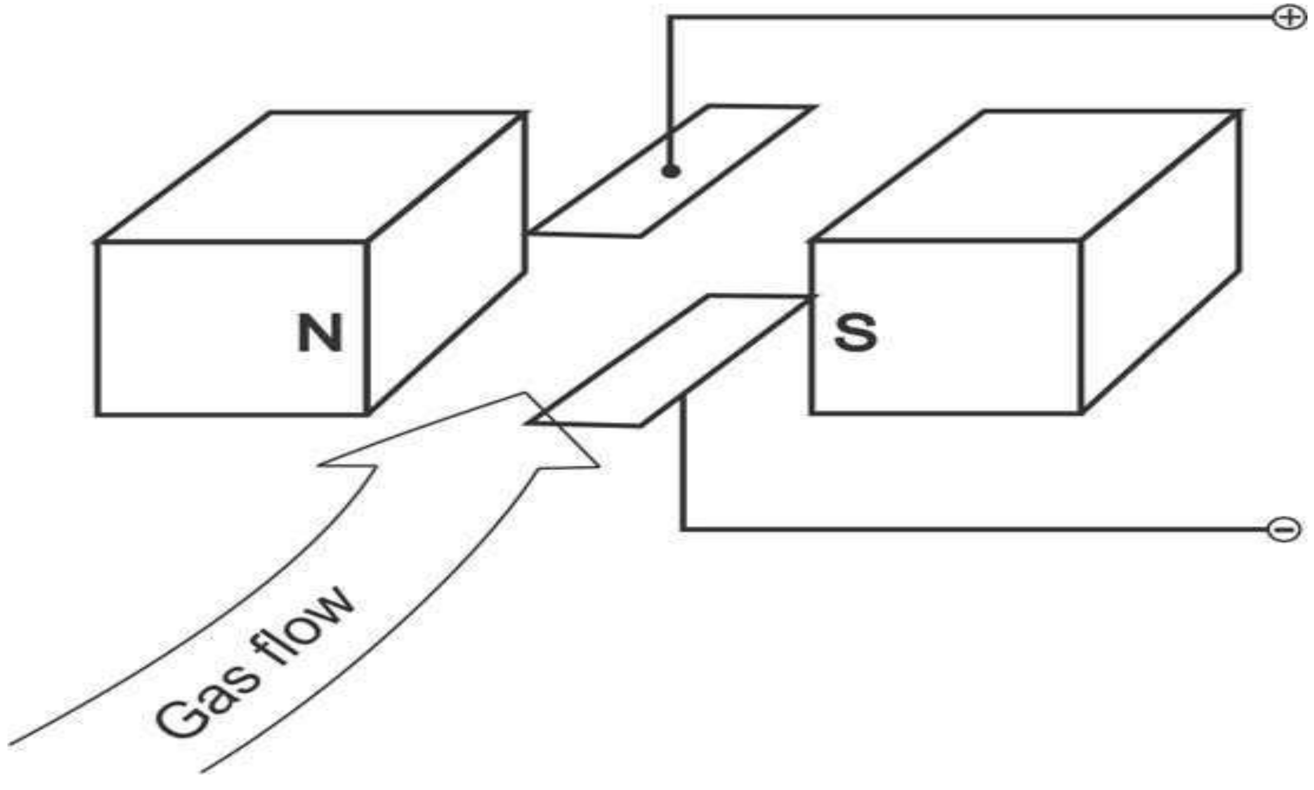
The MHD System

The MHD generator needs a high temperature gas source, which could be the coolant from a nuclear reactor or more likely high temperature combustion gases generated by burning fossil fuels, including coal, in a combustion chamber. To achieve thermal ionization very high required in the tune of 2000 to 3000 K (1727deg C to 2727deg C)

MHD Generator

A magnetohydrodynamic generator (MHD generator) is a magnetohydrodynamic converter that utilizes a Brayton cycle to transform thermal energy and kinetic energy directly into electricity.

MHD Generator Continued..



Types of MHD Generators

The MHD cycles can be of three types, namely

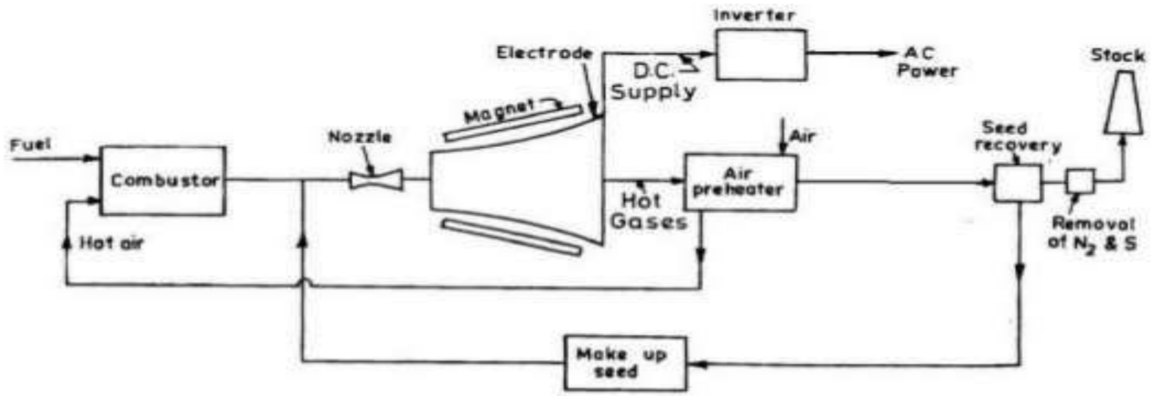
1. Open Cycle MHD.
2. Closed Cycle MHD.
3. Closed cycle MHD with liquid metal

1.Open Cycle MHD.

In open cycle MHD system, atmospheric air at very high temperature and pressure is passed through the strong magnetic field. Coal is first processed and burnet in the combustor at a high temperature of about 2700 Deg C and pressure about 12 ATP with pre-heated air from the plasma. Then a seeding material such as potassium carbonate is injected to the plasma to increase the electrical conductivity. The resulting mixture having an electrical conductivity of about 10 Siemens/m is expanded through a nozzle, so as to have a high velocity and then passed through the magnetic field of MHD generator. During the expansion of the gas at high temperature, the positive and negative ions move to the electrodes and thus constitute an electric current. The gas is then made to exhaust through the generator. Since the same air cannot be reused again hence it forms an open cycle and thus is named as open cycle MHD.

1.Open Cycle MHD Continued..

OPEN CYCLE MHD SYSTEM



Open cycle MHD System

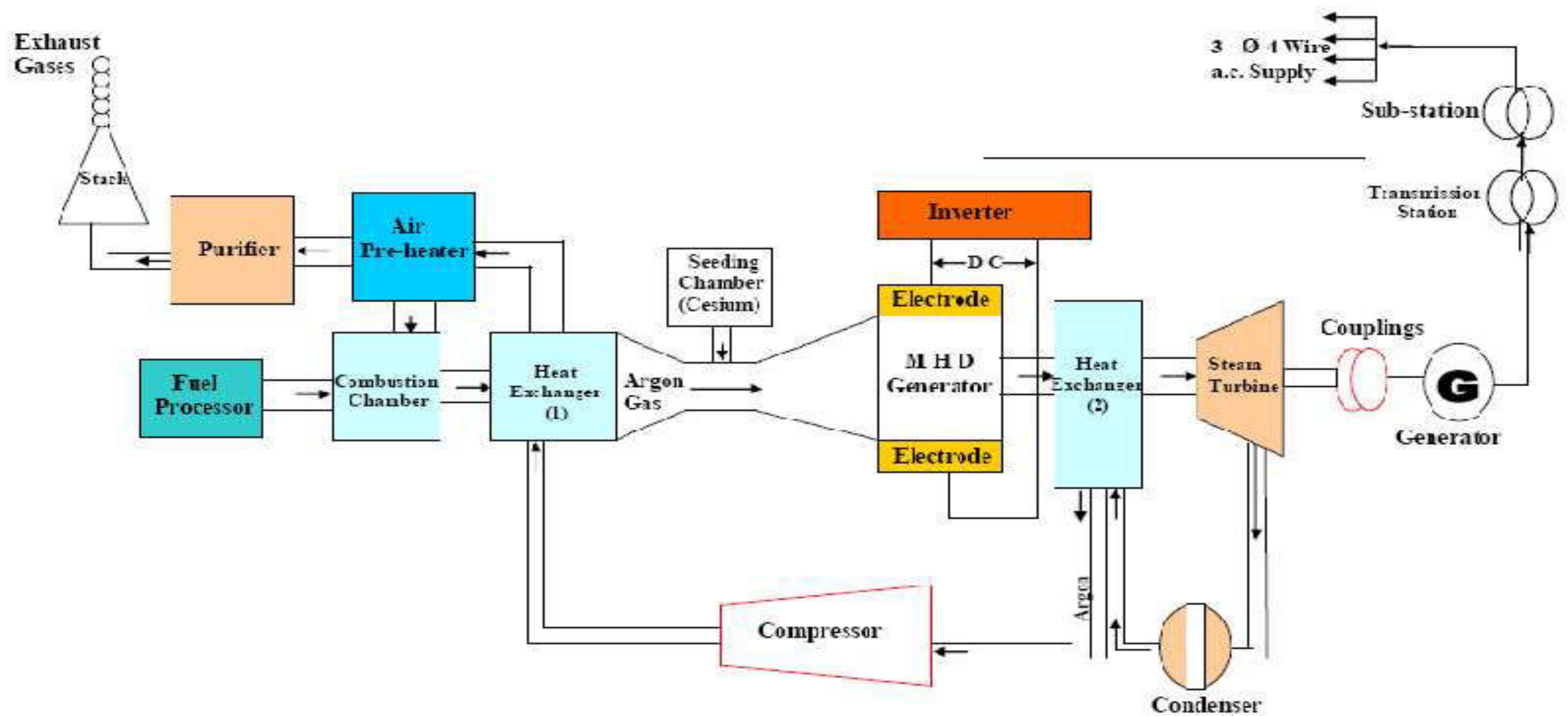
1.Open Cycle MHD Continued..

Practically, ionization temperature of gases in pure form is very high. Handling of these high temperatures is very difficult. To reduce the temperature, the gas is seeded with a small quantity of alkaline metals like sodium and potassium.

2. Closed Cycle MHD.

Here the working fluid in a closed cycle MHD is circulated in a closed loop. Hence, in this case inert gas or liquid metal is used as the working fluid to transfer the heat. The liquid metal has typically the advantage of high electrical conductivity, hence the heat provided by the combustion material need not be too high. Contrary to the open loop system there is no inlet and outlet for the atmospheric air. Hence, the process is simplified to a great extent, as the same fluid is circulated time and again for effective heat transfer.

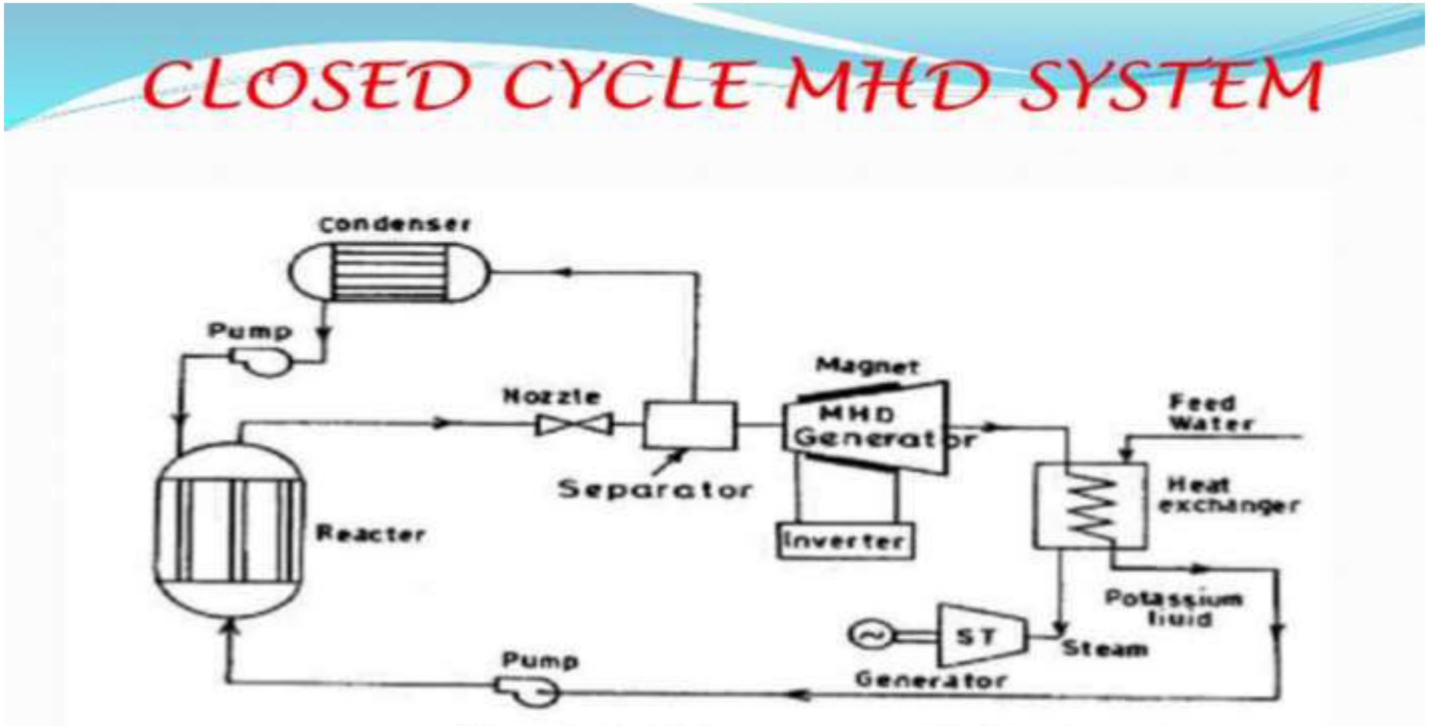
2. Closed Cycle MHD Continued..



3. Closed cycle MHD with liquid metal

It is similar to the inert gas system except that it uses liquid metal (potassium) in place of helium gas as the working fluid. Liquid potassium is heated in the nuclear reactor and is passed through the nozzle to increase its velocity

3. Closed cycle MHD with liquid metal Continued..



Closed cycle MHD generator using liquid metal as working fluid coupled with steam generator.

Economics In Plant Selection

1. General

In all engineering works question of cost is of first importance. While designing electrical power generating stations and other systems efforts are made to achieve overall economy so that the per unit cost of generation is the lowest possible. This will enable supplier to supply electrical energy to its consumers at reasonable rates. In every system, economy plays an important role. A saving in cost of generation of electrical power represents a significant reduction in the operating cost as well as fuel cost. The electrical engineer has to adopt a cheapest and most convenient scheme.

Economics In Plant Selection Continued..

2. PLANT LOCATION AND SITE SELECTON

1. Raw material availability.
2. Location (with respect to the marketing area.)
3. Availability of suitable land.
4. Transport facilities.
5. Availability of labors.
6. Availability of utilities (Water, Electricity).
7. Environmental impact and effluent disposal.
8. Local community considerations.
9. Climate.
10. Political strategic considerations.
11. Taxations and legal restrictions

Economics In Plant Selection Continued..

3. PLANT LAYOUT

The economic construction and efficient operation of a process unit will depend on how well the plant and equipment specified on the process flow sheet is laid out and the principal factors that are considered are listed below:

Economics In Plant Selection Continued..

- Economic considerations: construction and operating costs.
- Process requirements.
- Convenience of operation.
- Convenience of maintenance.
- Health and Safety considerations.
- Future plant expansion.
- Modular construction.
- Waste disposal requirements

Economics In Plant Selection Continued..

4. SELECTION OF TYPES OF EQUIPMENT

- Selection of boilers
- Super heaters
- Economizer and air pre-heater
- Condenser
- Prime-movers
- Selection of size and number of generating units

Economics In Plant Selection Continued..

5. SELECTION OF BOILERS "Boiler or steam generator basically convert water into steam." Boilers are of two types:

1. Fire tube boilers
2. Water tube boilers Advantage of water tube boiler over gas tube boiler- a) High evaporation capacity due to large heating surface. b) High pressure due to small size of drum. c) Safe in operation. d) Occupy less space.

Economics In Plant Selection Continued..

6.SUPER HETERS AND REPEATERS "A super heater is a device which removes the traces of moisture from saturated steam and helps in increasing the temp. of steam." Super heater is used in plant to increase the efficiency of plant by- 1. As the steam is dry , turbine blades remain dry so mech. Resistance is less. 2. Due to dryness of steam no corrosion occurs on blades of turbine.

Economics In Plant Selection Continued..

7.ECONOMIZER AND AIR PRE-HEATER

Economizer and air pre-heater are devices which recover the heat from the flue gases on their way to chimney and raise the temp. of feed water and air supply for combustion. Economizer raise the boiler efficiency by (10-12%) and saves the fuel consumption by (5-10%).

Economics In Plant Selection Continued..

8.CONDENSER: Condenser are used to condense the exhaust steam and it also removes air and other non-condensable gases from steam. There are of two types- Jet or contact condenser Contact condensers In modern power plants mostly surface condensers are used because in this condensate can be used as a feed water to the boiler.

Economics In Plant Selection Continued..

9. PRIME-MOVERS

“Prime movers are used to convert the stored energy into rotational mechanical energy” While selecting a prime-mover the initial cost of plant taken into consideration. As the efficiency of plant increases but there is a reduction in the floor space of plant. For industrial purpose non condensing type and for central generation condensing type steam turbine should be used.

Economics In Plant Selection Continued..

10. SELECTION OF SIZE AND NUMBER OF GENERATING UNITS Selection of units and their operation plays an important role in the working of power station and economics of power generation. The size and number of units is decided from the load curves.

Economics In Plant Selection Continued..

11. FACTORS AFFECTING THE SIZE NO. OF UNITS IN A GENERATING STATION Demand of power Max. efficiency Growth of demand in near future Capacity of plant should be 15 or 21% more than the expected maximum demand.

Important Terms and Definitions

1. **Connected Load**: the total electric power-consuming rating of all devices (as lamps or motors) connected to a distribution system.
2. **Maximum demand** is the highest level of electrical demand monitored in a particular period usually for a month period
3. **Demand Factor**: Ratio of maximum demand to connected load.
4. **Load Curve**: It is the graphical representation between load in kW and time in hours.

Important Terms and Definitions Continued..

5. Average Load: Area under the load curve divided by tie period (24 Hrs)

6. **Load Factor:** Is the ratio of average load to the peak load/maximum demand

7. **Base load and Peak load power plants:**

Base load is the minimum level of electricity demand required over a period of 24 hours. It is needed to provide power to components that keep running at all times (also referred as continuous load).

Peak load is the time of high demand. These peaking demands are often for only shorter durations.

Important Terms and Definitions Continued..

8.Plant Capacity Factor: The capacity factor is defined as the ratio of the total actual energy produced or supply over a definite period, **to** the energy that would have been produced if the plant (generating unit) had operated continuously at the maximum rating.

9. Plant Use Factor: is the ratio of the time that a plant/equipment is in use **to** the total time that it could be in use. It is often averaged over time in the definition such that the ratio becomes the amount of energy used divided by the maximum possible to be used.

Important Terms and Definitions Continued..

10.Diversity Factor: is the ratio of the sum of the individual maximum demands of the various subdivisions of a system (or part of a system) to the maximum demand of the whole system (or part of the syst Diversity is usually more than one.) under consideration.

11. Variable Load Operation: The load on a power station varies from time to time due to uncertain demands of the consumers and is known as the variable load on the station. This will affect the power plant design, operation and cost of generation of power. Also the prime mover and generator must be capable to adjusting the varying load in order to deliver a stable voltage and frequency.

Economics of Power Generation

Objective: To design a power plant to generate power at a low cost and supply the same to the consumers accordingly.

Total Cost = FC + VC (Inc. of OMC)

Economics of Power Generation Continued..

Fixed Cost

1. Land and Building
2. Equipment and Installation
3. Interest, Depreciation and Insurance
4. Overhead (Management Cost)

Variable Cost

1. Fuel, Labor
2. Maintenance and materials
3. Consumables

Factors affecting cost of power Generation

- Supply
- Demand.
- Gas Storage..
- Weather Forecasts.
- Generation charges
  - Nuclear.
  - Coal
  - Transport
- Global Markets.
- Imports and Exports.
- Government Regulation
- Financial Speculation.

Depreciation

Types of Depreciation

1.Sraght line method

2.Declining balance method

3.Sum of the year –digits

4. Sinking fund

5.Service output method.

Depreciation Continued..

1.Straght line method

Depreciation at the end of a period "t"

$D_t = (P-S)/n$

Book Value at the end of period "t"

$B_t = B_{t-1} - D_t$

Where P = First cost, S= Salvage value, n= life of asset

Depreciation Continued..

2.Declining (diminishing value) balance method

Depreciation at the end of a period "t"

$D_t = K * B_{t-1}$

Book Value at the end of period "t"

$B_t = B_{t-1} – D_t = B_{t-1} – (K * B_{t-1})$

$= (1- K) * B_{t-1}$

OR

In terms of P value

$D_t = K(1-K)^{t-1} * P$

$B_t = (1- K)^t * P$

Where P = First cost, S= Salvage value, n= life of asset, K = A fixed percentage which is limited at the most to 2/n

Depreciation Continued..

<u>3.Sum-of-the-years –digits</u>

Depreciation at the end of a period “t”

D_t = Rate * (P-S)

Where Sum of the year = n(n+1)/2

Book Value at the end of period “t”

$B_t = B_{t-1} – D_t$

Depreciation Continued..

4. Sinking fund

Depreciation at the end of a period “t”

$D_t = (P-S) * (r / (1+ r)^n -1)$

Book Value at the end of period “t”

$B_t = B_{t-1} – D_t$

Where r = rate of compound interest

Depreciation Continued..

5.Service output method.

Depreciation

$$D_t = \frac{P - S}{X} (x)$$

Where X = maximum capacity of service of an asset during its life time

x = quantity of service rendered in a period

POWER TARIFFS

Objective:

- Recovery of capital cost
- Recovery of OMC
- Net return + profit on capital cost

Selection of Tariffs

- Easy to understated
- Provide low rate for high consumption
- It should be uniform over large population
- Consider minimum demand charges and energy charges
- Provide low tariffs for lighting loads

Types of Tariffs:

- Flat demand
- Straight line
- Step meter rate
- Block meter rate
- Two part tariff or Hopkinson demand rate
- Three part tariff or Doherty rate
- Wright demand rate

Choice of Power Plant and its Site

- Power plant site
- Availability of fuel and type
- Type of load
- Generating unit efficiency
- Cost

An Electric Load or Power Distribution System

- Over head lines, Cable
- Direct to end consumer
- Ground connection (Earthing)

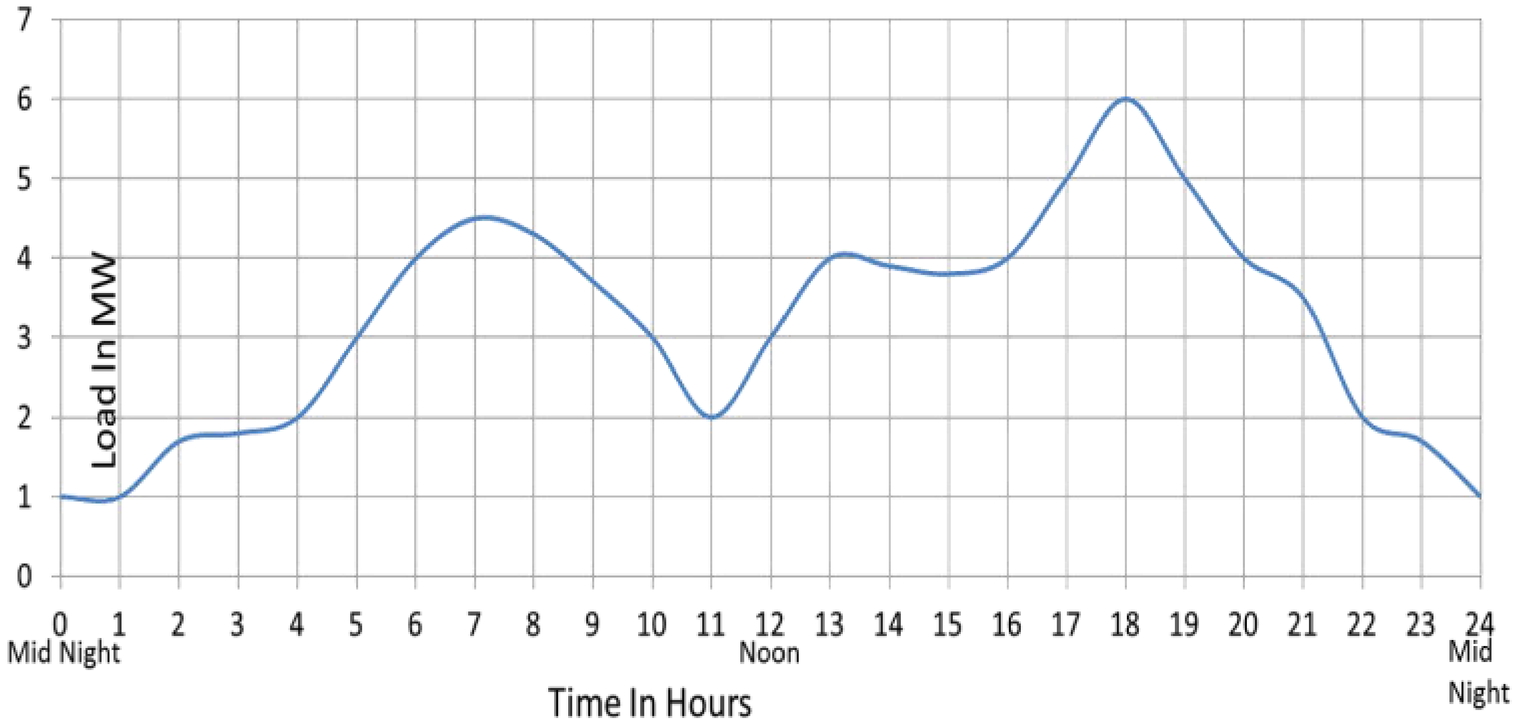
Parameters of Load Distribution

- AC/DC Supply
- Nominal voltage and tolerance
- Frequency and tolerance
- Phase configuration
- Maximum demand
- Power factor or connected load
- Earthing system
- Prospective short circuit current
- Maximum level and frequency of occurrence transients

Load Distribution Curve

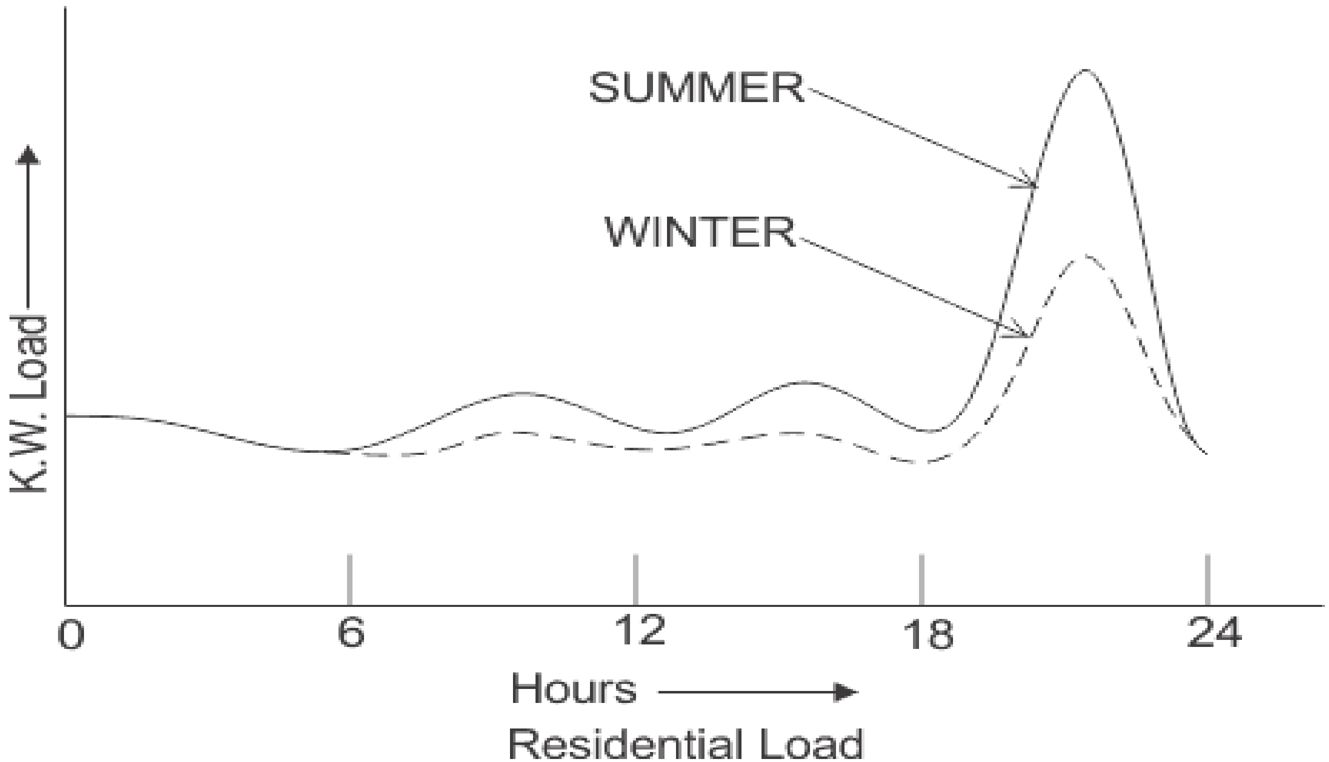
In a power system, a load curve or load profile is a chart illustrating the variation in demand/electrical load over a specific time. Generation companies use this information to plan how much power they will need to generate at any given time.

Load Curve

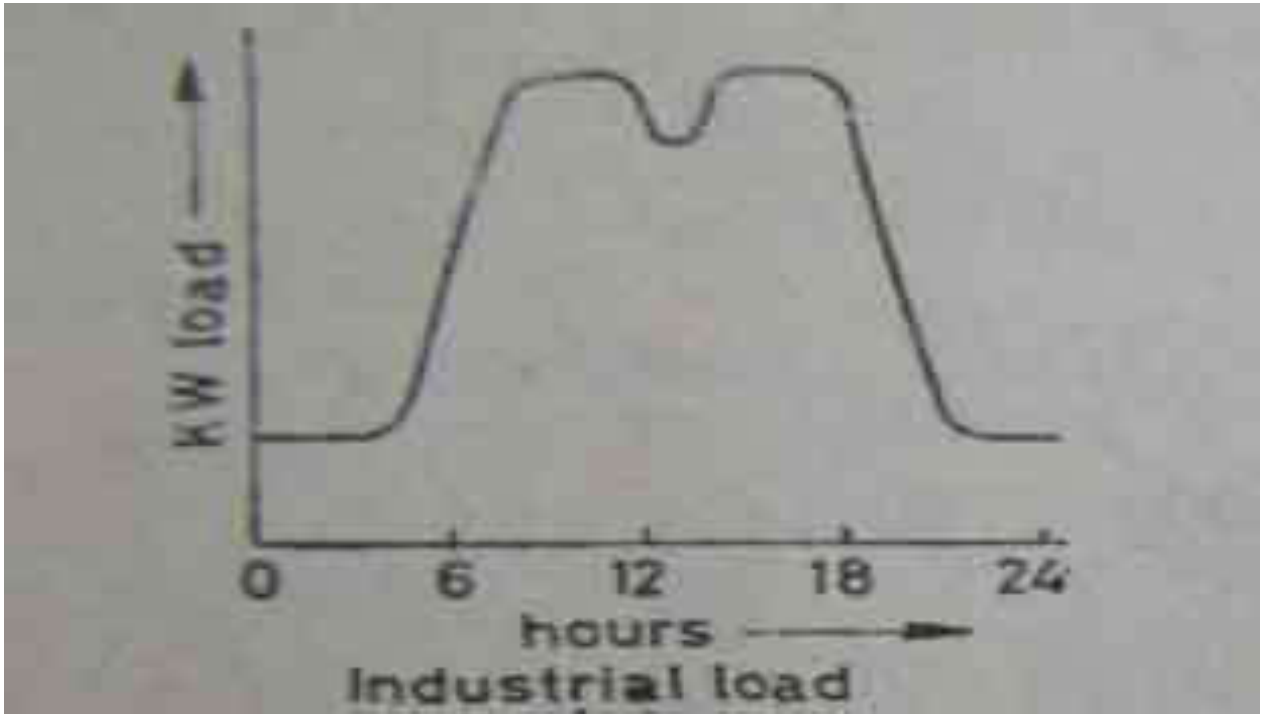


7
6
5
4
3
2
1
0
Load In MW
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Mid Night
Noon
Mid Night
Time In Hours

Residential load curve



Industrial Load curve



Municipal Load Curve Lighting

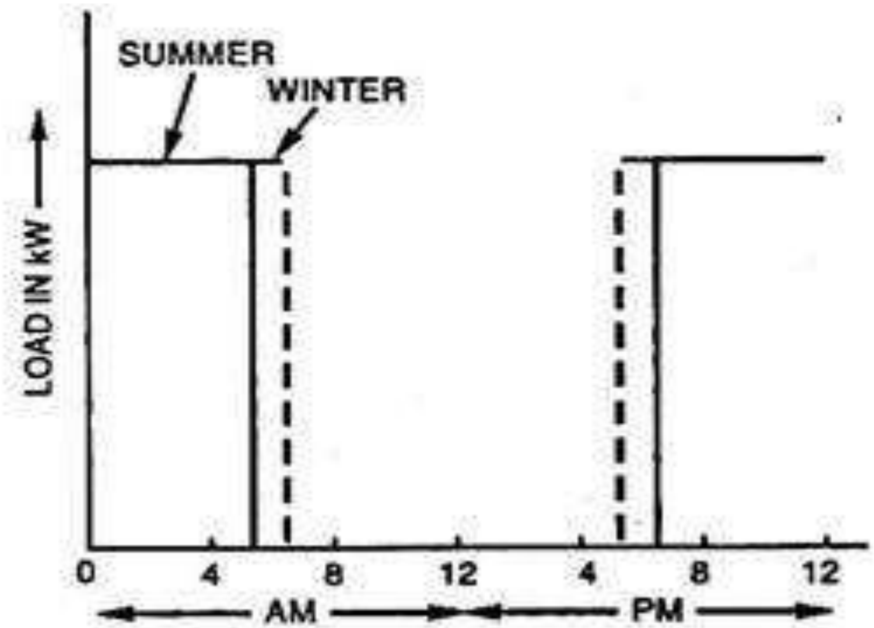


Fig. 15.5. ***Typical Chronological Load Curve For Street Lighting***

Municipal Load Curve Pumping

Irrigation Load Curve

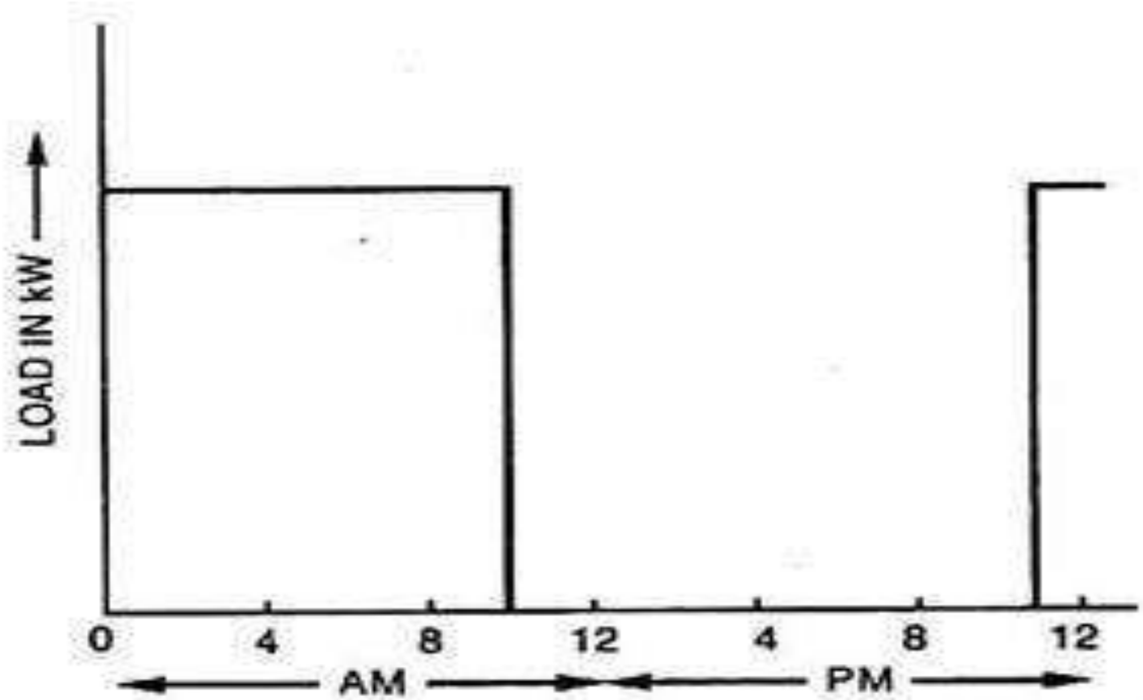
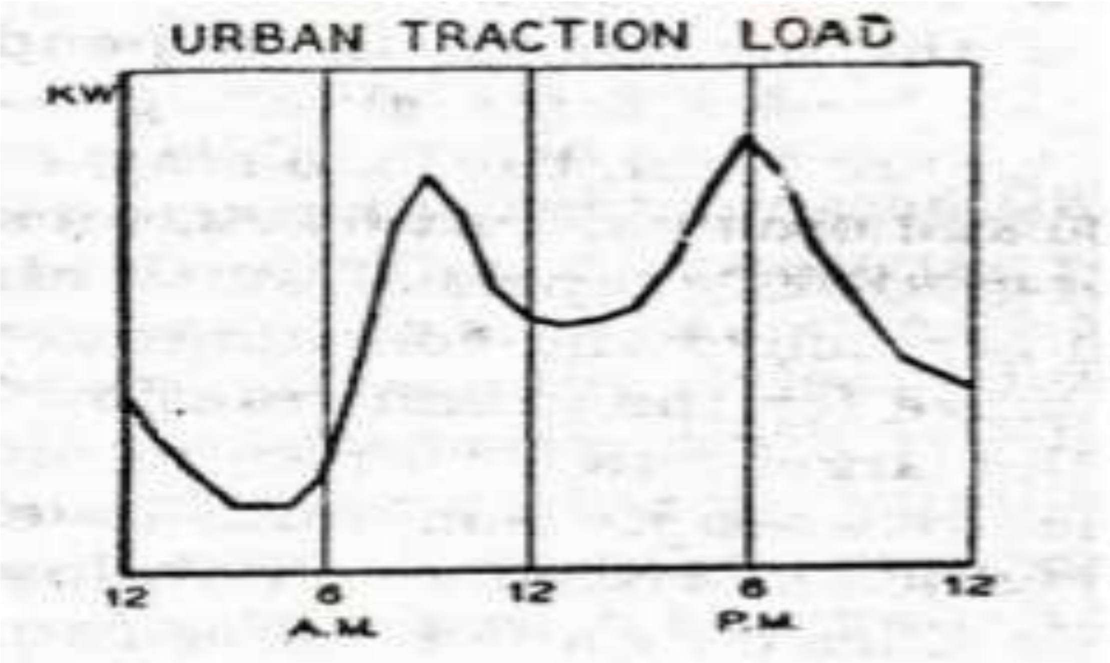
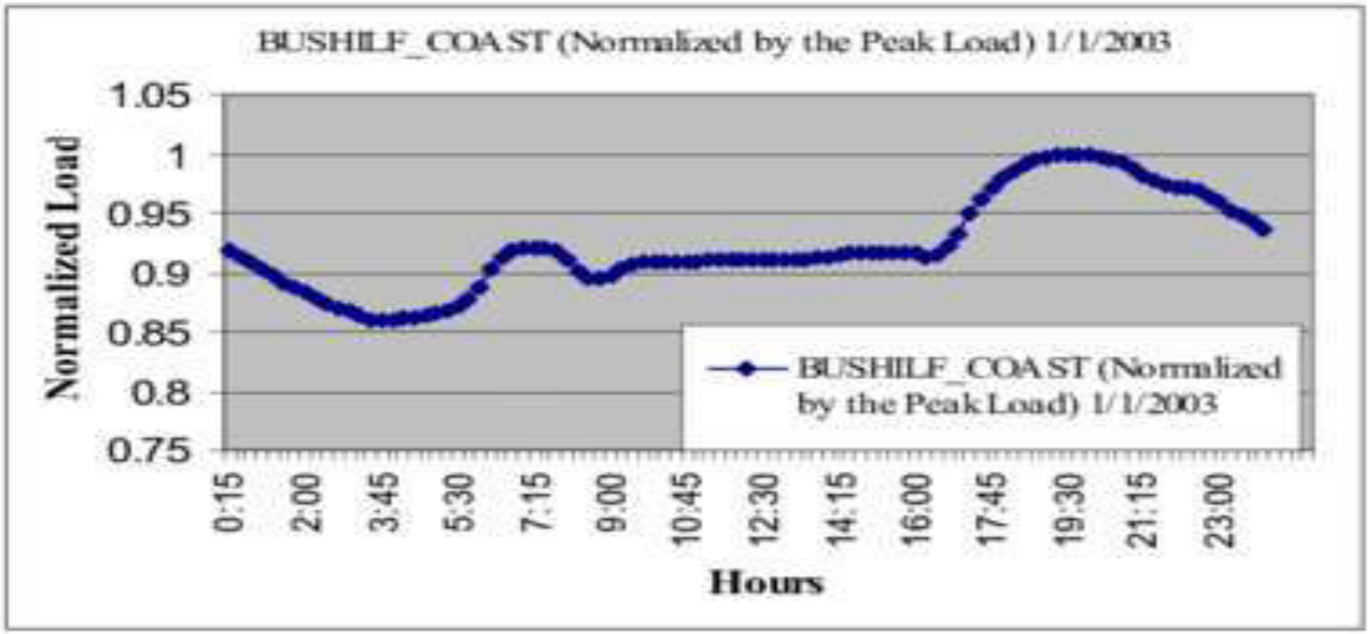


Fig. 15.3. ***Typical Chronological Load Curve For Agricultural or Irrigation***

Traction Load Curve



Commercial Load Curve

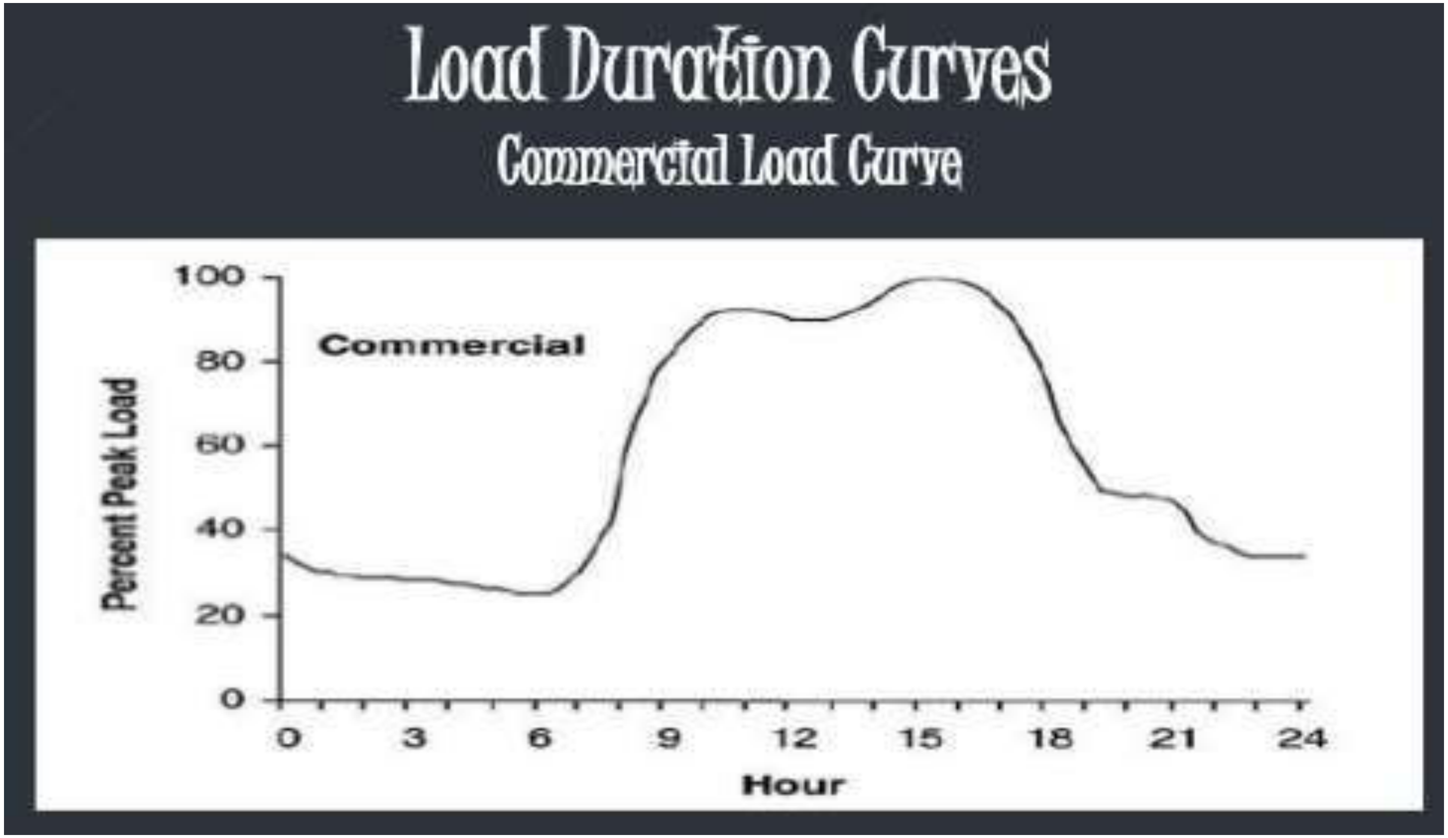


Commercial Load Curve

Commercial Load Duration Curve

A **load duration curve** (LDC) is used in **electric** power generation to illustrate the relationship between generating capacity requirements and capacity utilization.

Commercial Load Duration Curve



(P) A Company has purchased an equipment whose FC is Rs100000/- with an estimated life of 8 yrs. The estimated SV of the equipment at the end of life time is Rs 20,000/- Determine the depriciation charges and BV at the end of various years using Straight line method of depriciation

(S) $P = Rs\,1,00,000$ (FC)

$F = Rs\,20,000$ – (SV)

$n = 8$ yrs

$$\therefore D_t = \frac{(P-F)}{n} = \frac{(100000 - 20000)}{8}$$

$= Rs\,10,000$

Note: In this method depriciation value is same for all years, but Book value will change

End of year (t)	Depriciation D_t	Book value $B_t = (B_{t-1} - D_t)$
0	—	1,00,000
1	10000	$B_t = (100000 - 10000) = 90000$
2	10000	$B_t = (90000 - 10000) = 80000$
3	10000	$B_t = (80000 - 10000) = 70000$
4	10000	$B_t = (70000 - 10000) = 60000$
5	10000	= 50000
6	10000	= 40000
7	10000	= 30000
[illegible]	[illegible]	= 20000

Module VI

Environmental Impact Of Energy Conversion

General

All **energy** sources have some **impact** on our **environment**. Fossil fuels—coal, oil, and natural gas—do substantially more harm than renewable **energy** sources by most measures, including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and global warming emissions.

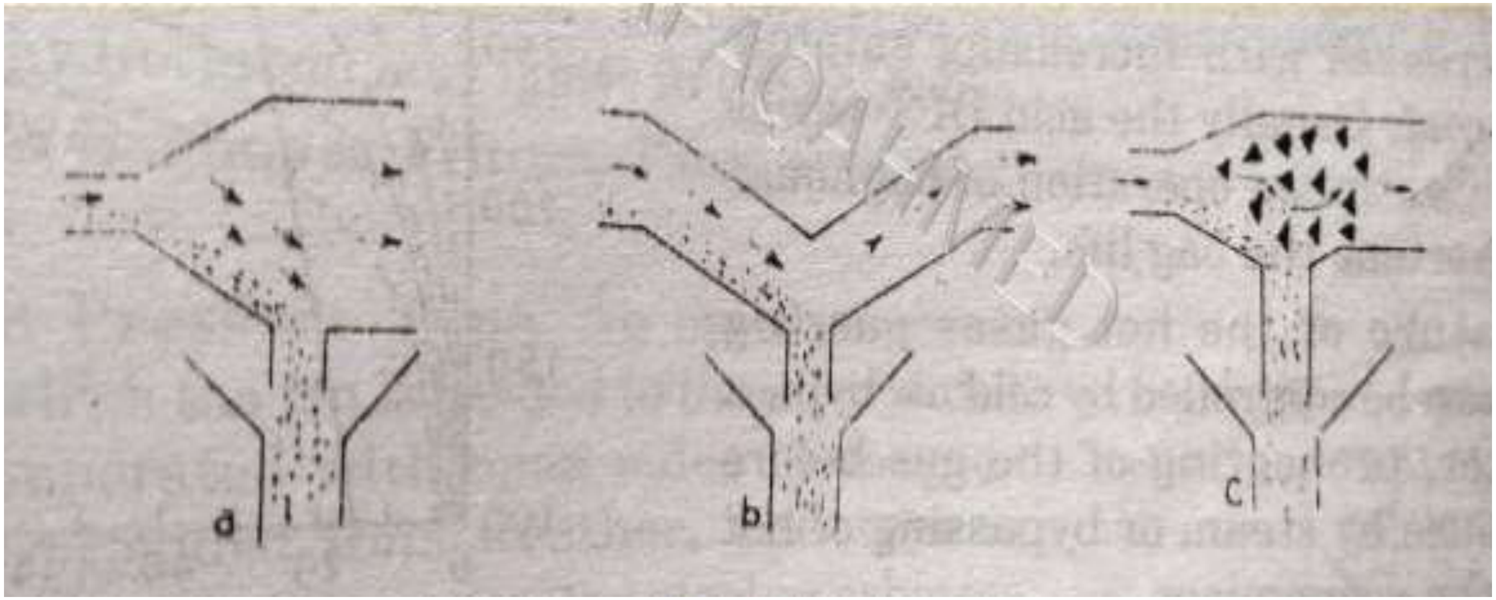
- Ozone layer depletion
- Global warming
- Greenhouse effect
- Loss of biodiversity
- Eutrophication
- Acid Rain
- Water pollution
- Land degradation
- Thermal Pollution

Control of Atmospheric pollution by Thermal Power plants

Gravitational Separator

A **dust collector/Separator** is a system used to enhance the quality of air released from industrial and commercial processes by collecting dust and other impurities from air or gas. Designed to handle high-volume dust loads.

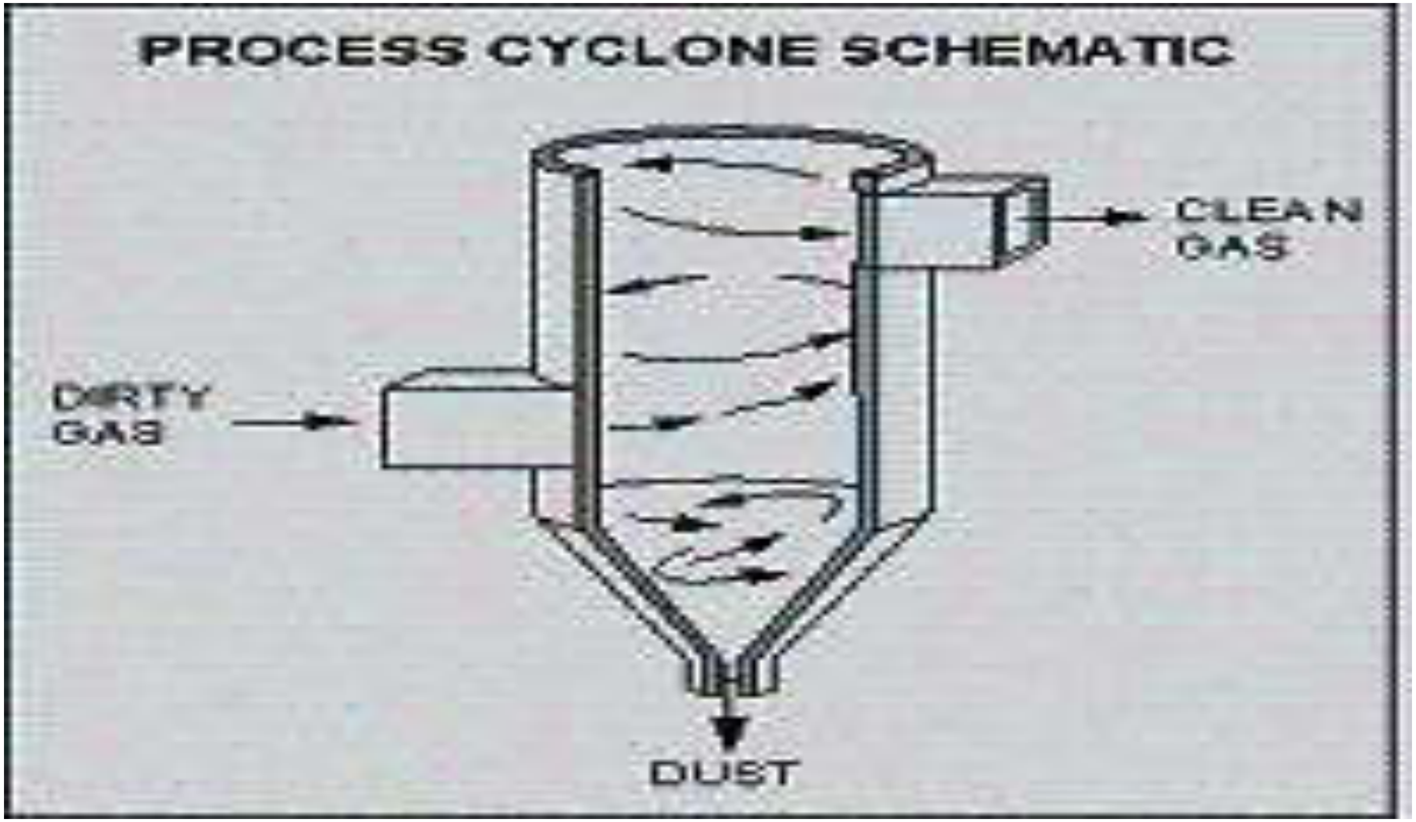
Gravitational Separator Continued..



Cyclone Separator.

Cyclone separators or simply **cyclones** are separation devices (dry scrubbers) that use the principle of inertia to remove particulate matter from flue gases. **Cyclone separators** is one of many air pollution control devices known as precleaners since they generally remove larger pieces of particulate matter

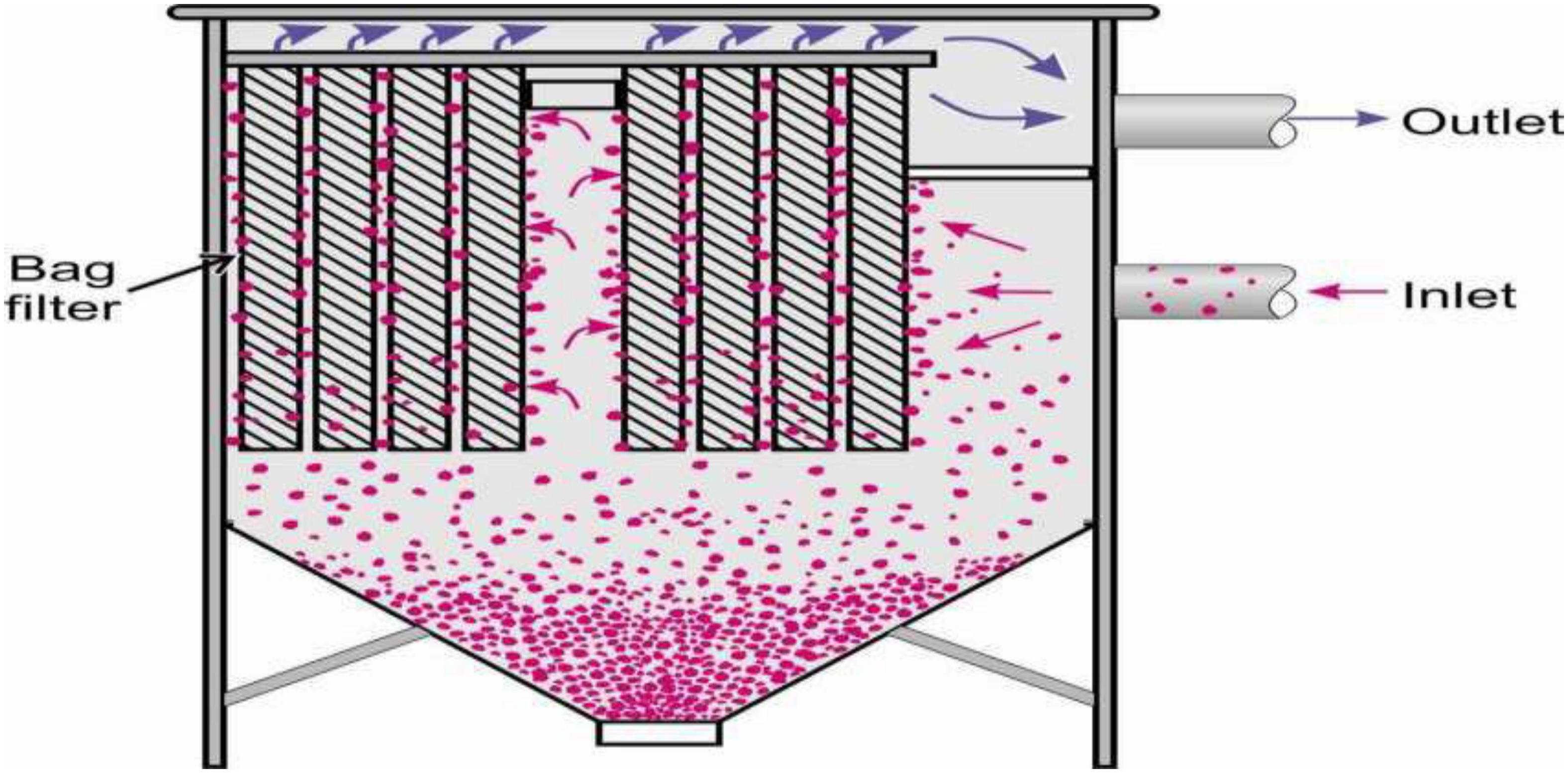
Cyclone Separator Continued..



Bag House Dust Collector

Bag houses are industrial **dust collectors** that use anywhere from 6 to 900 felt bags to filter dusty air produced by various manufacturing and processing applications.

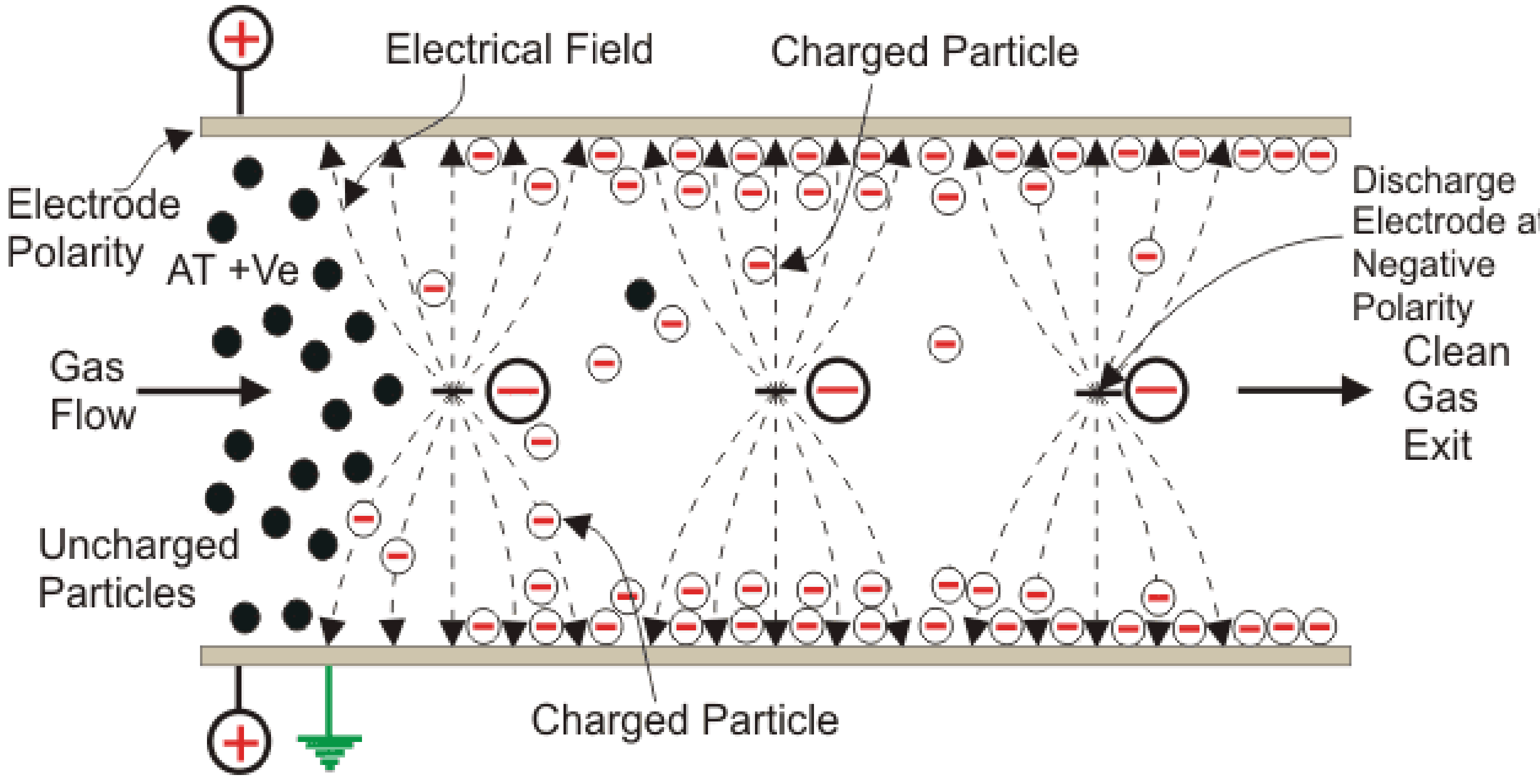
Bag House Dust Collector Continued..



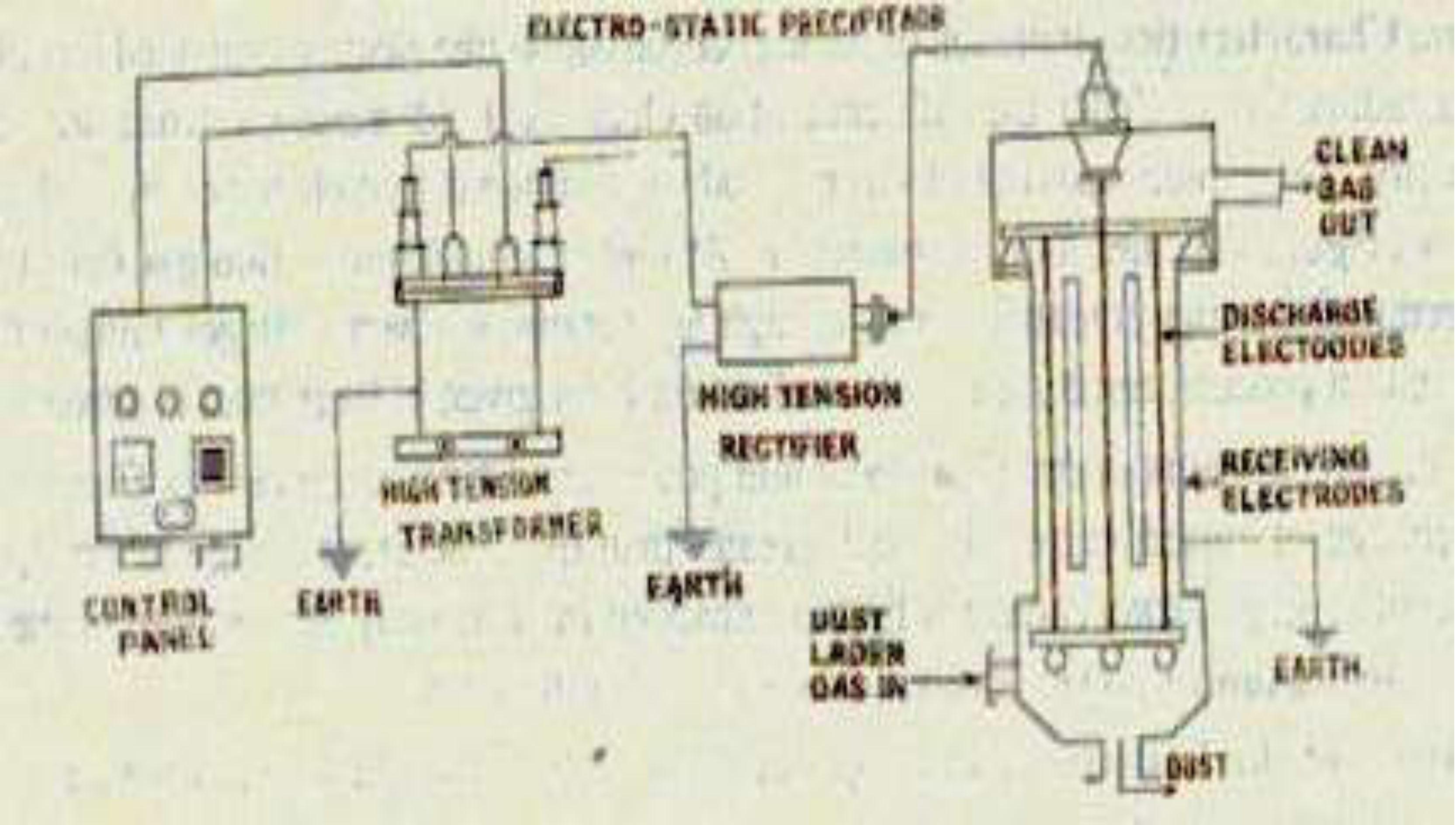
Electro Static Precipitator(ESP)

An **electrostatic precipitator** (**ESP**) is a filtration device that removes fine particles, like dust and smoke, from a flowing gas using the force of an induced **electrostatic** charge minimally impeding the flow of gases through the unit.

Layout of ESP Continued ..



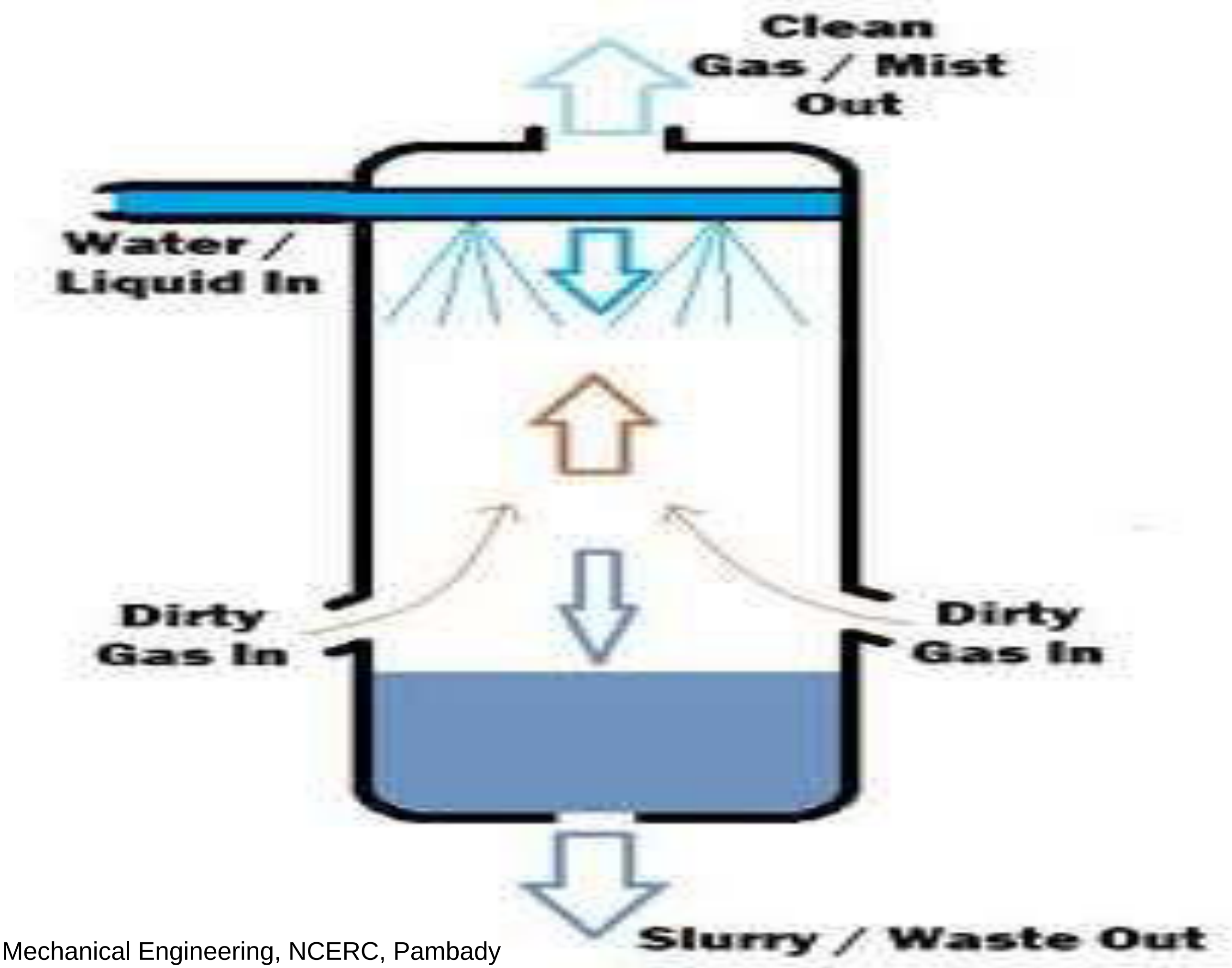
General arrange of ESP



Wet Collectors (Scrubbers)

Wet Collectors/Scrubbers are effective air pollution control devices for removing particles and/or gases from industrial exhaust streams. A Wet Scrubber operates by introducing the dirty gas stream with a scrubbing liquid – typically water. Particulate or gases are collected in the scrubbing liquid. Wet Scrubbers are generally the most appropriate air pollution control device for collecting both particulate and gas in a single system.

Wet Collectors (Scrubbers) Continued..



Diffusion of pollutants in Air

- Efficient chimneys
- Exhaust Hoods
- Fabric Filters
- ESP

Control of SO_2

1. Desulphurization of Fuel
   - Chemical treatment
   - Forth flotation
   - Magnetic separation
2. Using low sulphur fuel
3. Using tall stacks
4. Cleaning of Flue gases
   - Wet scrubbing
   - Solid absorbent
   - Catalytic Oxidation

Control of NO_x

NOx emission can be reduced

- Retard injection
- Fuel nozzle modification
- Change of compression ratio
- Water direct injection
- Water emulsification
- Exhaust gas recirculation (EGR)
- By secondary method: Selective catalytic reduction (SCR).

Water Pollution by Thermal Power Plants

Thermal pollution is the degradation of water quality by any process that changes ambient water temperature. A common cause of thermal pollution is the use of water as a coolant by power plants and industrial manufacturers.

- Degradation of water quality changes ambient water temperature.
- Which will decreases oxygen supply and affects ecosystem composition. "Thermal shock."

Control of water pollution by TPP

- Treatment plants
- Cooling towers/Ponds

Instruments used to monitor pollutions

<u>CO_2 Recorders</u>

- Thermal conductivity cell
- Chemical absorption cell
- Density balance

Automatic control for Feed water

- Single element pilot operated system
- Single element self operated system
- Two element pilot operated system
- Three element pilot operated system

Automatic Feed Water Control System

Why it is required?

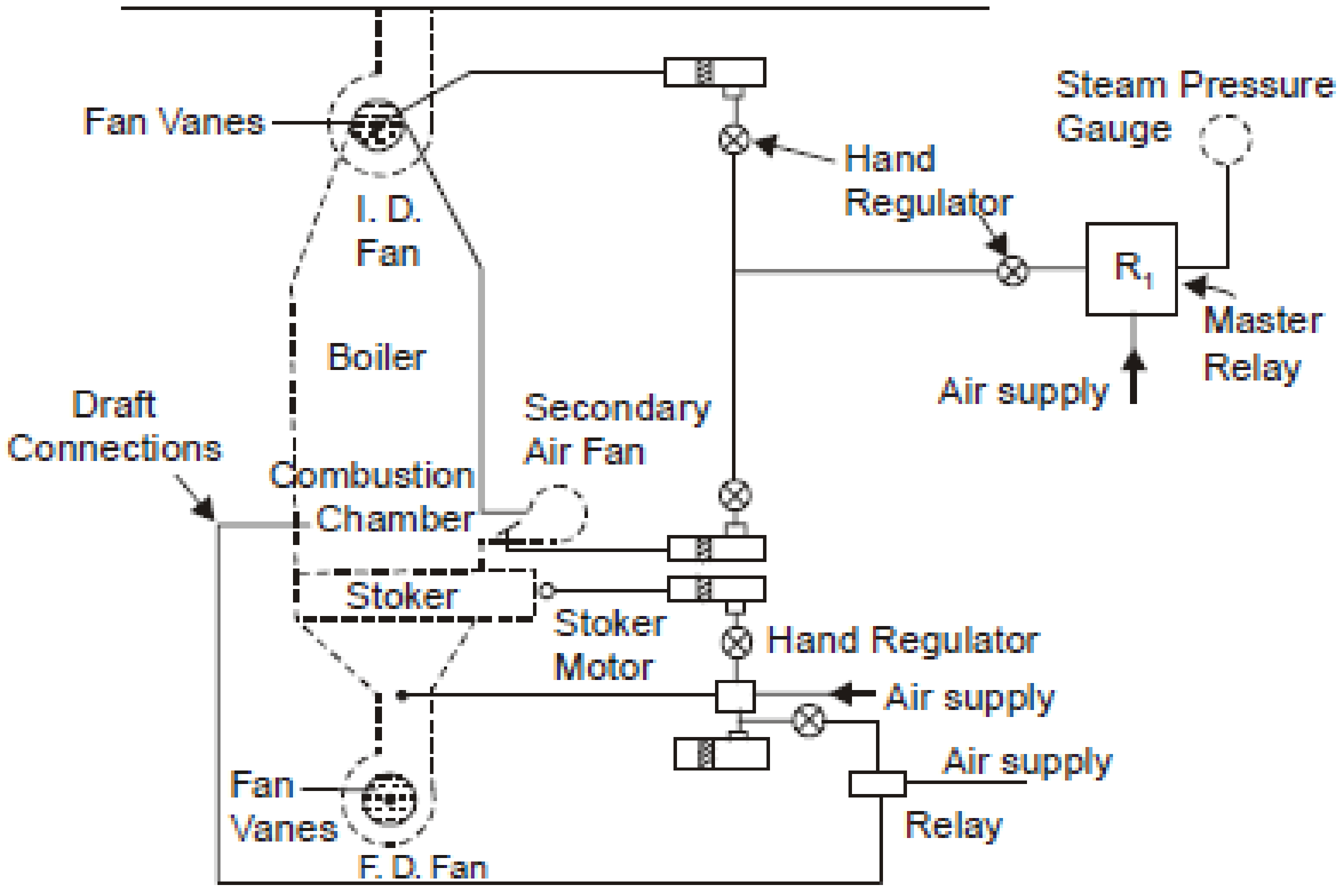
Boiler feed water control systems are often the most archaic controls in the steam plant. Poor boiler waterside control contributes to scaling, corrosion, and eventually hot spots and tube failures. The Preferred Feed water Center can control the surge tank, De-aerator (DA) tank, transfer pumps, and feed water pumps (on-off or VSD) to improve water quality and feed water system reliability.

Automatic Combustion Control

Why it is required?

The essential requirement for a combustion control system is to correctly proportion the quantities of air and fuel being burnt. This will ensure complete combustion, a minimum of excess air and acceptable exhaust gases. The control system must therefore measure the flow rates of fuel oil and air in order to correctly regulate their proportions.

Automatic Combustion Control Continued..



Causes of Thermal Pollution

1. Power, Industrial, and Manufacturing Plants
2. Industrial Effluents
3. Domestic Sewages
4. Urban Storm-water Runoff
5. Deforestation
6. Soil Erosion
7. Hydroelectric Power Generation
8. Natural Causes

Harmful Effect of Thermal Pollution

1. Decrease in DO (Dissolved Oxygen) Levels
2. Increase in Toxins
3. Loss of Biodiversity
4. Ecological Impact
5. Affects Reproductive Systems
6. Increases Metabolic Rate
7. Migration

Indian Boiler Act

Indian Boiler act History:

1863 Boiler explosion at Calcutta

1864 – Boiler act framed at Bengal Council

1923 – IBA Regulation Passed

1937 – IBA Amendment

1953 – IBA amended to Indian boiler regulation (IBR)

2017 – Amendment

2018 - Amendment

What does the IBR cover?

The IBR covers the design,fabrication,inspection, testing and certification of Boilers or any boiler part including feed piping and fittings or vessels attached thereto Boiler components

Indian Boiler Act Continued..

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Indian Boiler Act Continued..

Boilers or any boiler part including feed piping and fittings or vessels attached thereto Boiler components, meaning:

- Steam piping
- Feed piping
- Economizers
- Super heaters
- Valves, including safety valves

Indian Boiler Act Continued..

- Any mounting or fitting or any external or internal part of a boiler which is subjected to pressure exceeding one Kg/cm square gauge
- Steam receivers, separators, steam traps, accumulators and similar vessels
- Heat exchangers, converters, evaporators and similar vessels in which steam is generated
- Materials, e.g. forgings, castings, tubes, pipes, plates, welding consumables

Common issues with IBR certifications

- Design calculations not meeting requirements of IBR
- Specific IBR requirements concerning production test coupons
- Bend test requirements for materials
- Incorrect test pressures
- Failure to involve an Inspecting Authority in the case of deviations resolution
- Material sourcing with relevant IBR forms appears to be the major issue
- Incorrect/incomplete filling of relevant IBR forms
- Welder qualification and certification as per IBR 1950

Nuclear Waste Disposal And Safety

Origin of Nuclear Waste:

Radioactive waste comes from a number of sources. In countries with nuclear power plants, nuclear armament, or nuclear fuel treatment plants, the majority of waste originates from the nuclear fuel cycle and nuclear weapons reprocessing.

Nuclear Waste

Definition: Radioactive by-products resulting from fusion, fission, refinement, or processing of radioactive materials. This includes all solid and liquid radioactive wastes.

Nuclear Waste Categories:

- Medial Nuclear Waste
- Military Nuclear Waste
- Mixed Nuclear and Hazardous Waste
- Power Plant Nuclear Waste

Types of Radio active waste

These are mainly of 5 types:

1. High-level Waste:

These types are the pressurized and boiler water reactors. High-level nuclear waste, simply put, is spent fuel that is still present after it has been used inside of nuclear reactors. This radioactive waste has to cool off for several years and is considered to be very dangerous.

Types of Radio active waste Continued..

2. Intermediate-level Waste

Intermediate-level waste contains high amount of radioactivity than low-level and less than high-level. This type of waste typically requires shielding during handling and interim storage. The intermediate level waste contains 4% of all the radioactivity.

Types of Radio active waste Continued..

3. Low-level Waste

About 90% of all nuclear waste is low level. Nuclear reactors, hospitals, dental offices, and similar types of facilities often use low-level nuclear waste materials on a daily basis and it is needed in order to provide the services that are offered within these facilities. Low-level nuclear waste is not dangerous, and any of it can be disposed of inside of a landfill.

Types of Radio active waste Continued..

4. Mining and Milling

Tailings(residue) and waste rock are generates by mining and milling of uranium ore. The tailings material is covered with water and have the consistency of fine sand, when dried. It is produced by grinding the ore and the chemical concentration of uranium. After few months, the tailings material contains 75% of the radioactivity of the original ore.

The mineralized waste rock could generate acid when left on the surfaced indefinitely that could affect surrounding environment.

Types of Radio active waste Continued..

5. Transuranic Waste

Transuranic waste, or TRU waste contains more than 3700 be per gram of elements. It is much heavier than uranium. This type of waste is produced through nuclear waste reprocessing procedures in most cases. This is one of the least worried about types of radioactive waste that is out there but it is worth mentioning since it is a part of nuclear waste.

Collection and storage of nuclear materials

Storage of used fuel is normally under water for at least five years and then often in dry storage. Deep geological disposal is widely agreed to be the best solution for final disposal of the most radioactive waste produced.

Types of Nuclear waste Disposal

1. **Geological Disposal**

The process of geological disposal centers on burying nuclear waste into the ground to the point where it is out of human reach. There are a number of issues that can arise as a result of placing waste in the ground. The waste needs to be properly protected to stop any material from leaking out. Seepage from the waste could contaminate the water table if the burial location is above or below the water level. Furthermore, the waste needs to be properly fastened to the burial site and also structurally supported in the event of a major seismic event, which could result in immediate contamination

Types of Nuclear waste Disposal Continued..

2. **Reprocessing**

Reprocessing has also emerged as a viable long term method for dealing with waste. As the name implies, the process involves taking waste and separating the useful components from those that aren’t as useful.

Types of Nuclear waste Disposal Continued..

3. Transmutation

Transmutation also poses a solution for long term disposal. It specifically involves converting a chemical element into another less harmful one. Common conversions include going from Chlorine to Argon or from Potassium to Argon

Types of Nuclear waste Disposal

4. **Space Disposal**

Space disposal has emerged as an option, but not as a very viable one. Specifically, space disposal centers around putting nuclear waste on a space shuttle and launching the shuttle into space. This becomes a problem from both a practicality and economic standpoint as the amount of nuclear waste that could be shipped on a single shuttle would be extremely small compared to the total amount of waste that would need to be dealt with.

Approach to radioactive waste disposal

1. **Incineration**: Burning radioactive waste is largely done through commercially-operated incinerators developed for this purpose.
2. **Storage**: Over time, the radioactivity of nuclear material does decay, so storing this material until it is no longer radioactive is another way to deal with proper nuclear waste disposal. This process, called radioactive decay, depends on the amount of materials and the radioactivity level. Therefore, storage is typically only done with radioactive waste that has a shorter half-life, or the amount of time it takes for the material's radioactivity to be reduced by half.

Approach to radioactive waste disposal Continued..

3. **Shallow Burial**: Highly radioactive material is hard to bury, but when it comes to mill tailings, these remnants can often be buried in a specially-crafted spot nearby the mill itself.

4. **Deep Burial**: While shallow burials can be done with low-level waste, the most common way of disposing of high-level waste is in deep burial pits.

Approach to radioactive waste disposal Continued..

5. **In water**: At nuclear sites, a common way of storing material is in water. Nearly all of these sites have a special pond or have a special pool constructed, which is a place that they can store fuel that has already been used for the process of generating power.

6. **Recycling**: For some radioactive material, such as previously used fuel, certain radioactive elements can be processed or extracted for reuse.

Approach to radioactive waste disposal Continued..

7. **The Ocean**: A very small amount of liquid waste that is common when waste is reprocessed to extract usable elements is released into the ocean. This process is highly controlled, and radiation levels are deemed to be so low that they are inconsequential.

8. **Space Disposal**: The expense related to this is far too prohibitive when compared with the positive effects.

Approach to radioactive waste disposal Continued..

9. **Seabed Disposal**: Another proposal was to embed waste deep within the seabed.(Further extension Subduction process in which one tectonic plate slides beneath another and it is reabsorbed into the earth mantle)

10. **Long-term aboveground Storage Bunkers**: While some nuclear companies *do* have storage facilities above-ground, these are temporary and meant to make the waste more accessible for reuse, or to have it decay enough for another form of disposal

Approach to radioactive waste disposal Continued..

11. **Transmutation method:** can offer another solution, in addition to deep disposal, for **high-level radioactive waste**. **Transmutation** is a process in which the long-lived **radioactive** elements in **waste** are converted by fission to shorter-lived particles that produce radiation for a much shorter period and are less radiotoxic.

12. **Solar Dumping** : It is proposed that the highly concentrated radioactive waste can be placed in the earth orbit and then accelerated to that waste would drop into sun

Control of Nuclear Radiation

- Use Time Distance and Shielding to Protect Yourself.
- Putting distance and shielding between you and a radiation source is an immediately effective way of reducing your exposure. Reducing the time you are being exposed is another way. Use a Respirator or Face Mask if You are exposed to airborne sources.

Sustainable Energy

Sustainable energy is a form of energy that meet our today’s demand of energy without putting them in danger of getting expired or depleted and can be used over and over again. Sustainable energy should be widely encouraged as it do not cause any harm to the environment and is available widely free of cost. All renewable energy sources like solar, wind, geothermal, hydropower and ocean energy are sustainable as they are stable and available in plenty.

Development Pathways

- The goal of **sustainable development** is to meet the needs of today, without compromising the needs of tomorrow. This means we cannot continue using current levels of resources as this will not leave enough for future generations. Stabilizing and reducing carbon emissions is key to living within environmental limits.
- The sustainable development it is required to conserve plant , land, water , and other natural resources.
- Environment and development both are important to man life.

Sustainable Goals

GOAL 1: No Poverty

GOAL 2: Zero Hunger

GOAL 3: Good Health and Well-being

GOAL 4: Quality Education

GOAL 5: Gender Equality

GOAL 6: Clean Water and Sanitation

GOAL 7: Affordable and Clean Energy

GOAL 8: Decent Work and Economic Growth

GOAL 9: Industry, Innovation and Infrastructure

Sustainable Goals Continued..

GOAL 10: Reduced Inequality

GOAL 11: Sustainable Cities and Communities

GOAL 12: Responsible Consumption and Production

GOAL 13: Climate Action

GOAL 14: Life Below Water

GOAL 15: Life on Land

GOAL 16: Peace and Justice Strong Institutions

GOAL 17: Partnerships to achieve the Goal