GREEN ENERGY SYSTEMS (R15A0322)

COURSE FILE

III B. Tech II Semester
(2018-2019)

Prepared By

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MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

Affiliated to JNTU, Hyderabad, Approved by AICTE - Accredited by NBA & NAAC – 'A' Grade - ISO 9001:2015 Certified)
Maisammaguda, Dhulapally (Post Via. Kompally), Secunderabad – 500100, Telangana State, India.

MRCET VISION

- To become a model institution in the fields of Engineering, Technology and Management.
- To have a perfect synchronization of the ideologies of MRCET with challenging demands of

PROGRAM OUTCOMES

(PO's)

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 team work**: 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 multi disciplinary 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.

DEPARTMENT OF AERONAUTICAL ENGINEERING

VISION

Department of Aeronautical Engineering aims to be indispensable source in Aeronautical Engineering which has a zeal to provide the value driven platform for the students to acquire knowledge and empower themselves to shoulder higher responsibility in building a strong nation.

MISSION

The primary mission of the department is to promote engineering education and research. To strive consistently to provide quality education, keeping in pace with time and technology. Department passions to integrate the intellectual, spiritual, ethical and social development of the students for shaping them into dynamic engineers.

QUALITY POLICY STATEMENT

Impart up-to-date knowledge to the students in Aeronautical area to make them quality engineers. Make the students experience the applications on quality equipment and tools. Provide systems, resources and training opportunities to achieve continuous improvement. Maintain global standards in education, training and services.

PROGRAM EDUCATIONAL OBJECTIVES – Aeronautical Engineering

1. **PEO1 (PROFESSIONALISM & CITIZENSHIP):** To create and sustain a community of learning in which students acquire knowledge and learn to apply it professionally with due consideration for ethical, ecological and economic issues.
2. **PEO2 (TECHNICAL ACCOMPLISHMENTS):** To provide knowledge based services to satisfy the needs of society and the industry by providing hands on experience in various technologies in core field.
3. **PEO3 (INVENTION, INNOVATION AND CREATIVITY):** To make the students to design, experiment, analyze, and interpret in the core field with the help of other multi disciplinary concepts wherever applicable.
4. **PEO4 (PROFESSIONAL DEVELOPMENT):** To educate the students to disseminate research findings with good soft skills and become a successful entrepreneur.
5. **PEO5 (HUMAN RESOURCE DEVELOPMENT):** To graduate the students in building national capabilities in technology, education and research

PROGRAM SPECIFIC OUTCOMES – Aeronautical Engineering

1. To mould students to become a professional with all necessary skills, personality and sound knowledge in basic and advance technological areas.
2. To promote understanding of concepts and develop ability in design manufacture and maintenance of aircraft, aerospace vehicles and associated equipment and develop application capability of the concepts sciences to engineering design and processes.
3. Understanding the current scenario in the field of aeronautics and acquire ability to apply knowledge of engineering, science and mathematics to design and conduct experiments in the field of Aeronautical Engineering.
4. To develop leadership skills in our students necessary to shape the social, intellectual, business and technical worlds.

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

III Year B. Tech, ANE-II Sem

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(R15A0322) GREEN ENERGY SYSTEMS

Objectives: To study important non-conventional energy sources and the technologies for harnessing these. Compare different non-conventional energy choose the most appropriate based on local conditions.

UNIT-1

Introduction, Energy sources and availability, new Energy techniques, Renewable energy sources, solar energy, solar constant, radiation geometry, solar energy collectors, concentrated and flat plate, Energy balance and collector efficiency, solar energy storage, application to space heating, distillation, cooking and green house effect.

UNIT-2

Wind Energy, basic principle, site selection, aerodynamic analysis of blades, Bio-energy, Biomass conversion technology, photosynthesis, Biogas plant, Thermal gasification.

UNIT-3

Geothermal Energy; Sources, hydrothermal sources, hot dry rock resources, geothermal fossil system, prime movers for geothermal energy from ocean; Ocean thermal electric conversion, energy from tides, small scale hydroelectric development.

UNIT-4

Hydrogen energy sources; production, storage, utilization, magneto hydrodynamic power, thermal ionic generation, nuclear fusion energy, energy storage. Energy conservation.

UNIT-5

Fuel cell principle of working, construction and applications.

Outcomes: Design renewable/hybrid energy systems that meet specific energy demands, are economically feasible and have a minimal impact on the environment.

Text Books

1. G.D Rai, Non-Conventional Energy Sources, Khanna Publishers, Delhi.
2. S Rao, B B Parualker, Energy Technolgy: Non Conventional Renewable and Conventional, Khanna Publishers, Delhi.
3. H.P Garg & Jai Prakash Solar Energy: Fundamentals and Applications Tata MC Graw hill, N Delhi.

Reference Books

1. S P Sukhatne, Solar Energy: Principles of Thermal Collection and Stoerage, Tata Mc Graw Hill, N Delhi.
2. Sutton, Direct Energy Convection Mc Graw Hill Inc., 1996.
3. Duffie and Beckman, Solar Energy Thermal Process, John Wiley, 1974.

UNIT-I

Principles of solar radiation

MAN AND ENERGY:

- ENERGY is the ability to do work.
- ENERGY is the primary and most universal measure of all kind of work by human beings and nature.
- Energy: It is the capability to produce motion, force, work, change in shape, change in form etc.

Energy exists in several forms such as:

- Chemical energy
- Nuclear energy
- Mechanical energy
- Electrical energy
- Internal energy
- Bio-energy in vegetables and animal bodies
- Thermal energy etc.
- Man has needed and used energy at an increasing rate for his sustenance and well- being ever since he came on the earth a few million years ago.
- Primitive man required energy primarily in the form of food. He derived this by eating plants or animals which he hunted. Subsequently he discovered fire and his energy needs increased as he started to make use of wood and other biomass to supply the energy needs for cooking as well as for keeping himself warm.
- With the passage of time man started to cultivate land for agriculture. He added a new dimension to the use of energy by domesticating and training animals to work for him. With further demand for energy, man began to harness the wind for sailing ships and for driving windmills, and the force of falling water to turn water wheels.
- Till this time, it would not be wrong to say that the sun was supplying all the energy needs of man either directly or indirectly and that man was using only renewable sources of energy.

CLASSIFICATION OF ENERGY SOURCES:

1. BASED ON USABILITY

a) PRIMARY SOURCES
   - These sources are obtained from environment.
   - Example: fossil fuels, solar energy, hydro energy and tidal energy.

b) SECONDARY SOURCES
   - These resources do not occur in nature but are derived from primary energy resources.

c) SUPPLY MENTRY SOURCES
   - It is define as those whose net energy yield is zero and those requiring highest investment in terms of energy insulation (thermal) is an example of this source.

2. BASED ON TRADITIONAL

a) CONVECTION

- The sources of energy which have been in use for a long time, e.g., coal, petroleum, natural gas and water power.

b) NON CONVECTION

- The resources which are yet in the process of development over the past few years. It includes solar, wind, tidal, biogas, and biomass, geothermal.

3. BASED ON LONG TERM AVAILABILITY

a) RENEWABLE

- These sources are being continuously produced in nature and are inexhaustible.
- Wood, wind energy, biomass, biogas, solar energy etc.

b) NON RENEWABLE

- These are finite and exhaustible.
- Coal, petroleum etc.

4. BASED ON COMMERCIAL APPLICATION

a) COMMERCIAL

- The commercial energy has great economic value. This energy pollutes the environment badly. These types of energy are limited in nature. High capital investment is required in the purification. It is used in urban as well as rural areas. Coal, petroleum, natural gas and nuclear energy.

b) NON COMMERCIAL

- The non-commercial energy is cheaper. This is pure and keeps the environment clean. Abundant in nature. It can be used in raw form. It is dominantly used in rural areas. Cow dung, charcoal, firewood and agricultural waste.

WORLD'S AND INDIA'S PRODUCTION AND RESERVES OF ENERGY

- Today, every country draws its energy needs from a variety of sources.
- We can broadly categorize these sources as

a) Commercial/Conventional

b) Non-commercial/Non-conventional

- The commercial source include the fossil fuels, nuclear, Hydro-electric power, while the non commercial source include wood ,animal waste and agricultural wastes.

GLOBAL ENERGY CONSUMPTION

- The global primary energy consumption at present was equivalent to 9741 million tons of oil equivalent (Mtoe)

Coal	32.5	
Oil	38.3	
Gas	19	**92%**
Uranium	0.13	
Hydro	2	
Wood	6.6	
Dung	1.2	**8%**
Waste	0.3	

CONVECTIONAL/NON RENEWABLE ENERGY SOURCES

Convectional sources are as follow: FOSSIL FUEL: Coal Oil Gas
Uranium/ Nuclear Hydro-electric

COAL

- It has been estimated that there are over 847 billion tones of proven coal reserve worldwide. This means that there is enough coal to last us around 118 years at current rate of production (2011). In contrast, proven oil and gas reserves are equivalent to around 46 and 59 years at current production levels respectively.
- Coal reserves are available in almost every country worldwide, with recoverable reserves in around 70 countries. The biggest reserves are in the USA, Russia, China, and India.
- Coal provides 30.3% of global primary energy needs and generates 42% of the world's electricity. In 2011 coal was the fastest growing form of energy outside renewable. Its share in global primary energy consumption increased to 30.3% - the highest since 1969.
- Total world coal production reached a record level of7,678 Mt in year 2011, increasing by 6.6% over 2010. The average annual growth rate of coal since 1999 was 4.4%.

India’s scenario

- The coal reserves in India up to depth of 1200 meters have been estimated by the geological survey of India is 285.86 billion tones as on 1st April, 2011,
- Coal deposits are chiefly located in Jharkhand, Odessa, Chhattisgarh, west Bengal, Madhya Pradesh, Andhra Pradesh, and Maharashtra.
- The coal production all over India during the year 2011 was 588.5 million tones = 5.6% of world’s production.
- The production of coal by country and year is shown in Table 1.1:

Table 1.1

Country	Production Year		% share	Reserve life (years)
	2010	2011		
China	3235	3520	49.5	35
USA	983.7	992.8	14.1	239
India	573.8	588.5	5.6	103
European Union	535.7	576.1	4.2	97
Australia	424	415.5	5.8	184

OIL

- World's proven oil reserves in 2012 are estimated to be about 1324 billion barrels; it is equivalent to 210.5 x 109 m3. The most of the world's oil reserves (56%) are in the Middle East.
- Oil began to be used in significant quantities around 1900 and that there was an almost steady increase in its production all through and even during the world wars. The production increased at the average rate of over 7% per year from 1945 to 1973 and reached a value of 19.96 billion barrels in 1973. Thereafter with the beginning of the oil crisis, the annual production fluctuated up and down for 12 years from 1973 to 1985 before starting to increase more or less steadily from 1985 onwards.

India's scenario

- In 1951, the consumption of petroleum products was only 3.89 Mt, most of which were imported; while in 2011 it was increase to 141.785 Mt.
- Crude oil production during 2010-11 at 37.71 Mt. The refining capacity in country was 187.686 Mt per annum as on 1st April 2011.
- India has total reserves (proved and indicated) of 757 Mt of crude oil 1 as on 1st April 2011.

NATURAL GAS

- Natural gas is a mixture of various compounds of hydrocarbons and small quantities of non-hydrocarbons.
- The world's proven natural gas reserves are estimated to be 196,163 billion m3 in the year 2011. They were 192,549 billion m3 in the year 2010. Associated gas will last for approximately the same time as crude oil. However, the presence of non- associated gas should help. Thus, the peak in the production of natural gas may occur around 2025, about 10 years after the peak in oil production.
- The world's marketed production of natural gas is about 2,636,611 million m3 in the year 2011. It is seen that the production has been increasing more or less continuously at the rate of about 5% per year.
- India has total reserves (proved and indicated) of 1241 billion m3 of natural gas as on 1st April 2011.Gross production of natural gas in the country at 52.22 billion m3 during 2010-11

HYDRO-ELECTRIC POWER

- Hydro-electric power (water power) is developed by allowing water to fall under the force of gravity. Hydroelectricity accounted for 16% of global electricity consumption and 3,644 terawatt hours of electricity production in 2011.
- Hydroelectric power is produced in 150 countries with the Asia-Pacific region generated 32% of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt- hours of production in 2010, representing around 17% of domestic electricity use.
- Brazil, Canada, New Zealand, Norway, Paraguay, Australia, Switzerland, and Venezuela have a majority of the internal electric energy production from hydroelectric power. Paraguay produces 100% of its electricity from hydroelectric dams, and exports 90% of its production to Brazil and to Argentina. Norway produces 98-99% of its electricity from hydroelectric sources.
- Out of the total power generation installed capacity in India of 1, 76,990 MW (June, 2011), hydro power contributes about 21.5%, i.e. 38,106 MW.
- The public sector has a predominant share of 97% in this sector.
- National Hydroelectric Power Corporation (NHPC), Northeast Electric Power company (NEEPCO), Satluj Jal Vidyut Nigam ltd.(SJVNL), Tehri Hydro Development Corporation, NTPC- Hydro are a few public sector companies engaged in development of Hydro electric power in India.

NUCLEAR POWER

- Nuclear power is developed by fission reactions of nuclear fuel in nuclear reactor.
- Common nuclear fuel used is uranium. Nuclear power plants provided 12.3% of the world's electricity production in 2011. In total, 13 countries relied on nuclear energy to supply at least one-quarter of their total electricity.
- As of August 2012, 30 countries worldwide are operating 435 nuclear reactors for electricity generation and 66 new nuclear plats are under construction in 14 countries.
- The world's resources of uranium are estimated to be 8.8 Mt.
- As of 2011, India had 4.8 GW of installed electricity generation capacity using nuclear fuels. Nuclear power plants generated 32455 million units or 3.75% of total electricity produced in India.
- India’s nuclear power plant development began in 1964. India signed an agreement with general electric of the United States for the construction and commissioning of two boiling water reactors at Tarapur. In 1967, this effort was placed under India's Department of atomic energy. In, 1971, India set up its first pressurized heavy water reactors with Canadian collaboration in Rajasthan. In 1987, India created Nuclear Power Corporation of India Limited (NPCIL) to commercialize nuclear power.
- India’s Kakrapar-I reactor is the world's first reactor which uses thorium rather than Depleted uranium to achieve power flattening across the reactor core. India, which has about 25% of the world’s thorium reserves; is developing a 300 MW prototype of a thorium-based Advanced Heavy Water Reactor (AHWR). The prototype is expected to be fully operational by 2013, after which five more reactors will be constructed. India currently envisages meeting 30% of its electricity demand through thorium based reactors by 2050.

- India’s resources of uranium are not extensive. It is estimated that reserves available are about 61,000 t. It is easy to show that the reserves would only be adequate for providing
- The requirements of an installed capacity of 10,000 MW for about 30 years.

Advantages of convectional/non renewable energy sources

- The advantage of non renewable energy is it's easy and cheap to use.
- There is no better way to store transfer and use energy than gasoline for powering motor vehicles.
- It's quick to pump fossil fuel into a car. It's stable in the tank and a gas tank hold quite a bit, and a gasoline powered car is cheap to manufacture.
- Coal is a ready-made fuel. It is relatively cheap to mine and to convert into energy. Coal supplies will last longer than oil or gas Oil is a ready-made fuel. Relatively cheap to mine and to convert into energy. It is a relatively cheap form of energy.
- Natural Gas is a ready-made fuel. It's a slightly cleaner fuel than coal or oil, emitting less carbon dioxide.
- Nuclear has a small amount of radioactive material produces a lot of energy. And raw materials are relatively cheap and can last quite a long time. It doesn't give off atmospheric pollutants.

Disadvantages of convectional/non renewable energy sources

- Non-renewable energy comes from fossil fuels (coal, oil, natural gas, uranium): they are non- renewable and fast depleting.
- They leave behind harmful by-products upon combustion, thereby causing a lot of pollution; mining of such fuels leads to irreversible damage to the adjoining environment.
- Fossil fuels pollute the environment. They will eventually run out. Prices for fossil fuels are rising, especially if the real cost of their carbon is included. Burning fossil fuels produces carbon dioxide, a major cause of global warming.

NON CONVENTIONAL/ RENEWABLE ENERGY SOURCE PRODUCTION & RESERVE

- These sources include wind energy, solar energy, biomass and biofuel, small hydro resources, geothermal energy etc.
- The mankind’s have started the use of these sources recently, hence they are known as non-conventional energy sources. The share of these sources in world’s electricity generation is around 3% in 2011.
- The use of wind power is increasing at an annual rate of 20% with a worldwide installed capacity of 238,000 MW at the end of 2011, and is widely used in Europe, Asia, and the United States. Since 2004, photovoltaic’s passed. Wind as the fastest growing energy source, and since 2007 has more than doubled every two years.
- At the end of 2011 the photovoltaic (PV) capacity worldwide was 67,000 MW, and PV power stations are popular in Germany and Italy.
- Solar thermal power stations operate in the USA and Spain, and the largest of these is the 354 MW SEGS power plant in the Mojave Desert.

- The world's largest geothermal power installation is the Geysers in California; with aerated capacity of 750 MW Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugarcane, and ethanol now provide 18% of the country's automotive fuel. Ethanol fuel is also widely available in the USA.
- Top ten wind power generating countries are given in table 1.2

Table 1.2

COUNTRY	TOTAL CAPACITY IN 2011(MW)	COUNTRY	TOTAL CAPACITY IN 2011(MW)
China	62,733	France	6,800
USA	46,919	Italy	6,747
Germany	29,060	U.K.	6,540
Spain	21,674	Canada	5,265
India	16,084	Portugal	4,083

India's non-conventional sources

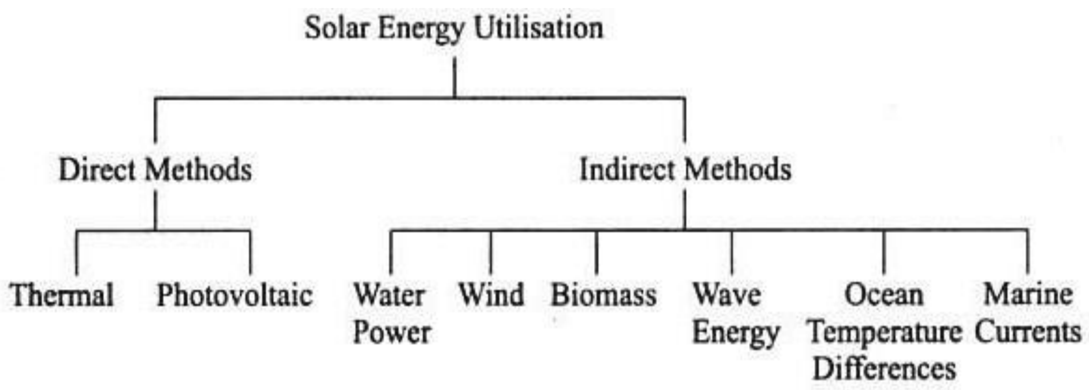
1. **Grid based:** As of June 2011, the Government of India was successful in deploying a total of 2051.05 MW capacity of grid based renewable energy 14550.68 MW of which was from wind power, 3105.63 MW from small hydro power, 1742.53 MW from bagasse cogeneration, 1045.10 MW from biomass power, 39.66 MW from solar power (SPV), and the rest from waste to power.

2. **Off-grid:** As of June 2011, the total deployment total deployment of off-grid based renewable energy capacity was 601.23 MW Of these, biomass (non-bagasse) cogeneration consisted of 316.76 MW, biomass gasifier was 133.63 MW; waste to energy was 73.72 MW. SPV systems (less than 1 kW) capacity was 69 MW, and the rest from micro-hydro and wind power. As was the case for the world, in India also, wind energy is the main contributor. India has the fifth largest installed wind power capacity in the world. In 2011, wind power accounted for 6% of India's total installed power capacity, and 1.6% of the country's power output. Suzlon is the leading Indian company, in wind power, with an installed generation capacity of 6.2 GW in India.

NON-CONVENTIONAL SOURCES/RENEWABLE ENERGY SOURCES

- A plenty of energy is needed to sustain industrial growth and agricultural production. The existing sources of energy such as coal, oil, uranium etc. may not be adequate to meet the ever increasing energy demands. These conventional sources of energy are also depleting and may be exhausted at the end of the century or beginning of the next century.
- Consequently sincere and untiring efforts shall have to be made by the scientists and engineers in exploring the possibilities of harnessing energy from several non- conventional energy sources.
- The various non-conventional energy sources are as follows:

1. Solar energy
2. Wind energy
3. Energy from biomass and biogas
4. Ocean thermal energy conversion
5. Tidal energy
6. Geothermal energy
7. Hydrogen energy
8. Fuel cells
9. Magneto-hydro-dynamic generator
10. Thermionic converter
11. Thermo-electric power.



1. Direct application of solar energy

1. Solar Space heating and cooling of residential buildings
2. Solar water heating
3. Solar drying of agricultural and animal products
4. Solar distillation
5. Salt production by evaporation of seawater or inland brines
6. Solar cookers
7. Solar pumping
8. Food refrigeration
9. Solar green houses
10. Solar furnaces
11. Solar electric Power generation
12. Solar photovoltaic cells

2. Indirect application of solar energy

1. Wind energy

– A small portion of solar radiation reaches on earth surface causes wind due to:

a) Heating up of earth surface due to absorption of solar radiation and cooling at night.
b) Rotation of earth and its motion around sun.

Fig1.1 Horizontal Axis Wind Turbine

2. Tidal energy

- Tides are generated due to gravitational pull between the earth and the moon and sun.
- The difference between high tide & low tide could be utilized to operate hydraulic turbine.

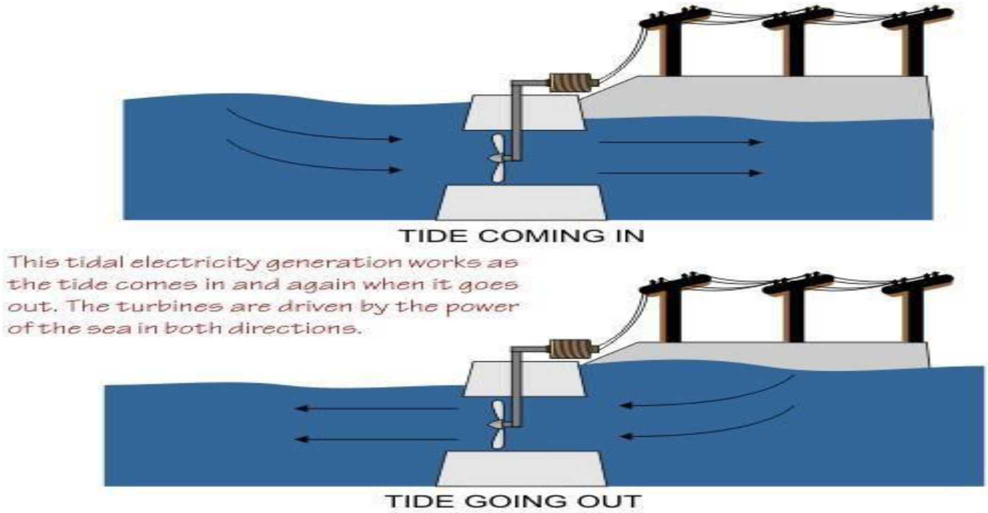


Fig1.2

3. Wave energy

- The wave energy is developed due to wind interacting with the surface of the ocean .wind get 1 to 5% of sun energy and part of this is transfer to wave this can be used for power generating.

Fig1.3

4. Geo thermal energy

- Geo thermal energy itself on earth's surface in the form of geyster, hot spring, furnar hole & boing Mud
- By drilling hole 3 km deep in the field the steam and water comes out from surface at temperature Up to 500°c
- It can be used for power generating.

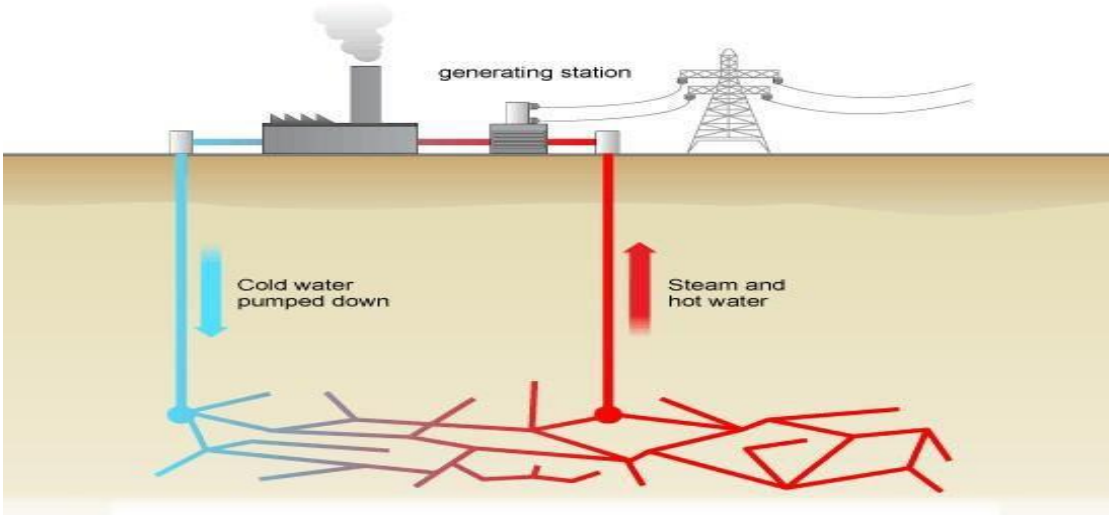


Fig1.4

5. Ocean thermal energy

- Ocean serves a big store house of solar energy
- At water surface 23°c-source, while temperature at depth of 100m is 5°c-sink
- Temperature differential can be used to run heat engine & power can be produce using working fluids NH3, R-12, propane gas .

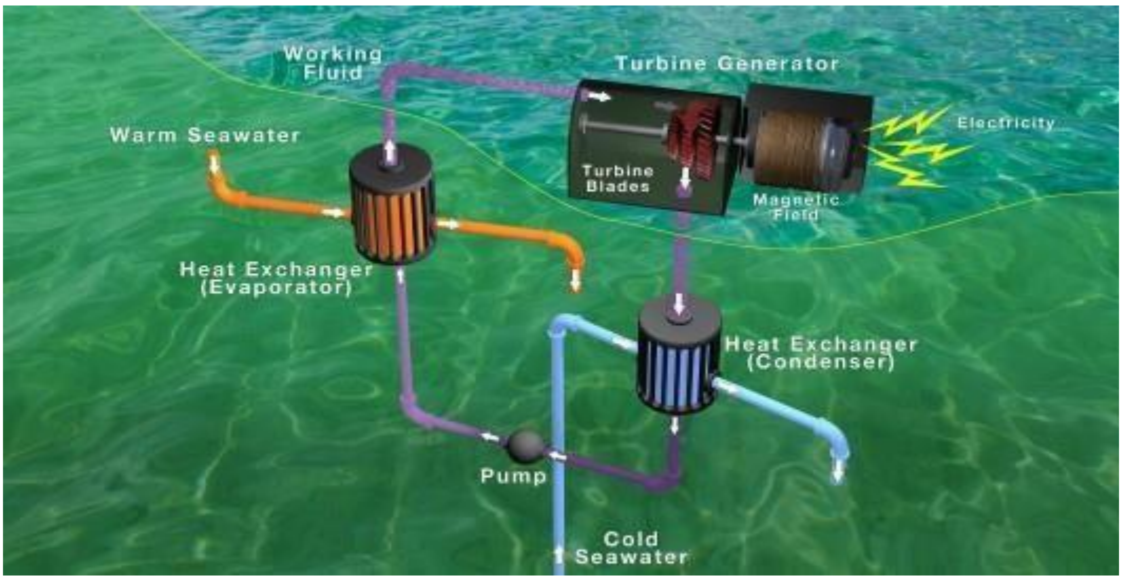


Fig1.5

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6. Biomass & biogas

- Bio mass is an organic matter produced by plant both grown on land and in water and their derivatives and animal manure .
- Biomass is in indirect application because it grows by photo synthesis.
- Bio-gas is a gaseous fuel which is obtained by fermenting the biomass and aerobically in absence of oxygen.
- It contains Methane (55 to 65%), CO2 (30 to 40%)
- Rest impurities N2, H2S, H2 etc.
- Used for power generation, cooking etc

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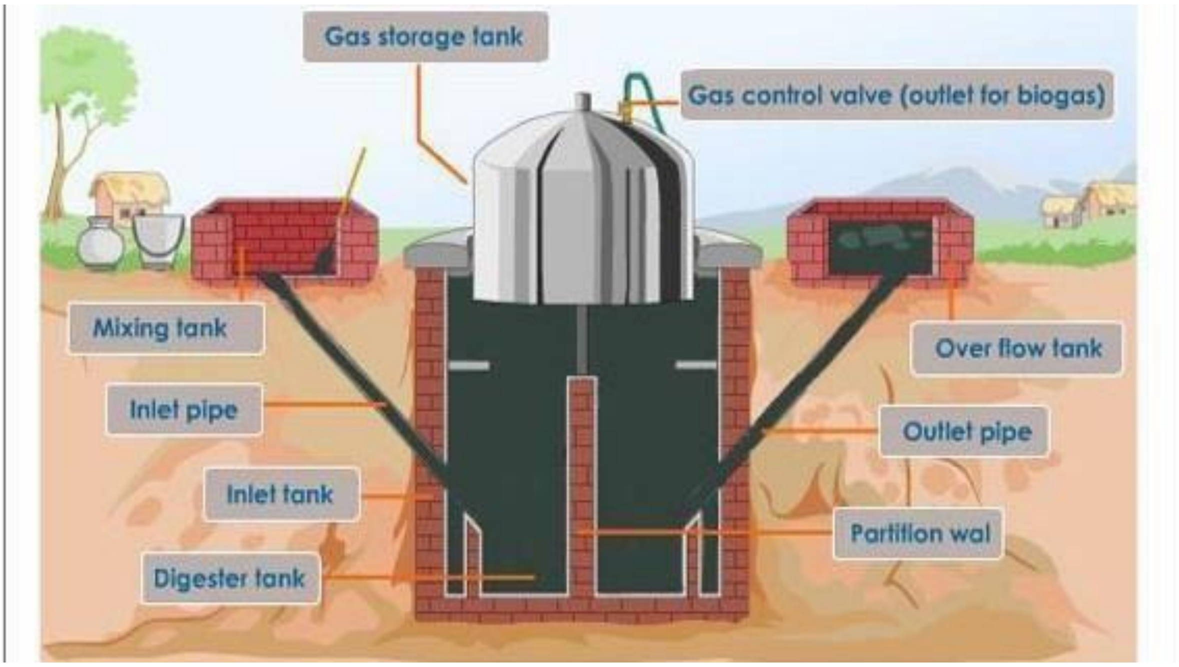


Fig1.6

Advantages of non-conventional sources/renewable energy sources

- The main advantage is the fact that they are renewable.
- We will never run out of sources of renewable energy (at least in our lifetimes, as long as humans will exist) solar energy - the sun will always be there, and in abundance.
- The amount of solar energy intercepted by the Earth every minute is greater than the amount of energy the world uses in fossil fuels each year.
- wind energy - the wind will always exist - The energy in the winds that blow across the United States each year could produce more than 16 billion GJ of electricity - more than one and one- half times the electricity consumed in the United States in 2000.
- Tidal energy - the moon which provides the forces that causes the tides will always be there hydroelectric energy - unless there is a drastic change in rain patterns, it will always be there On the other hand, non-renewable resources such as fossil fuels are finite - our resources of them will run out eventually.

- A second advantage, renewable resources are seen as being 'green', or environmentally friendly. This is because they do not emit carbon dioxide (the biggest contributor to global warming) into the atmosphere. Non-renewable resources such as petroleum release CO_2 into the environment when they are combusted for energy.
- Other renewables such as biofuels are carbon neutral - producing them consumes about as much CO_2 as using them produces.

Disadvantages of non-conventional sources/renewable energy sources

- Renewable energy is energy derived from sources that will not run out. Some of the present disadvantages are:
- Solar panels are expensive. Governments are not all willing to buy home generated electricity. Not all climates are suitable for solar panels.
- Wind -- turbines are expensive. Wind doesn't blow all the time, so they have to be part of a larger plan.
- Waves -- different technologies are being tried around the world. Scientists are still waiting for the killer product.
- Tides -- barrages (dams) across river mouths are expensive to build and disrupt shipping. Smaller turbines are cheaper and easier to install. rivers -- Dams are expensive to build and disrupt the environment. They have also caused earthquakes. Smaller turbines are cheaper and easier to install.
- Geothermal -- Difficult to drill two or three kilometers down into the earth.
- Biofuel -- Often uses crop lands and crops (like corn) to produce the bio-alcohol. This means that more land has to be cleared to grow crops, or there is not enough food, or that food becomes more expensive.

Electrical power generation

- It has been widely recognized that the fossil fuels and other conventional resources, presently used in generation of electrical energy, may not be either sufficient or suitable to keep pace with the ever increasing world demand for electrical energy. The prospects for meeting this demand and avoiding a crisis in supply would be improved if new and alternative energy sources could be developed.
- The present total installed capacity of electrical power generation in India is 1,10,000 MW, produced from various resources as given in Table 1.3:

Table 1.3

RESOURCE	**%**
THERMAL	68.8
HYDRO	24
NUCLEAR	2.7
NON CONVENTIONAL	4.5

Need for alternate sources

- Due to increasing use of fossil fuels and environmental concern and rapid depletion of natural resources have led to development of alternative source of energy which are renewable and environment friendly. In this connection, the following points may be considered.
- Due to rapid industrialization and population growth the demand of energy is increasing very rapidly. Hence the conventional source of energy will not be sufficient to meet the growing demand.
- Conventional sources except hydropower are non-renewable and are bound to finish up one day.
- Conventional sources also cause pollution; thereby their use degrades the environment.
- Large hydro resources affect wildlife, cause deforestation and pose various social problems.
- Fossil fuels can also be used extensively as feed stock materials for the manufacture of organic chemicals.
- Now, it has become important to explore and develop non-conventional energy resources to reduce too much dependence on conventional resources due to above reasons.

Solar Radiation

Solar Radiation outside the Earth's Surface:

Sun is a large sphere of very hot gases, the heat being generated by various kinds of fusion reactions. Its diameter is 1.39X106km, while that of the earth is 1.27X104 km. It subtends an angle of 32minutes at the earth's surface. This is because it is also at large distance. Thus the beam radiation received from the sun on the earth is almost parallel. The brightness of the sun varies from its center to its edge. However for engineering calculations. It is customary to assume that the brightness all over the solar disc uniform.

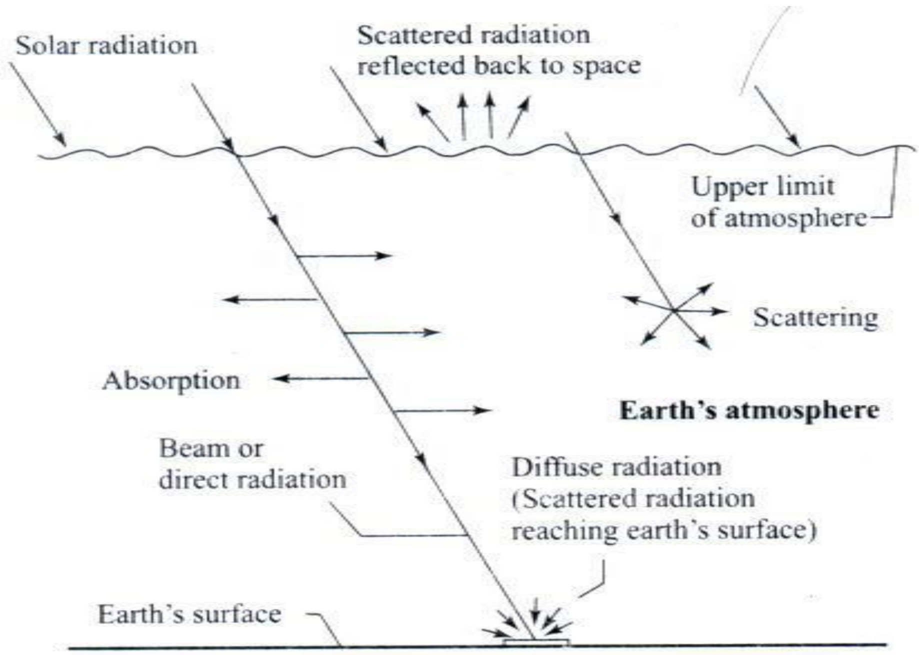
Solar Constant (Isc):

It is the rate at which energy is received from the sun on a unit area perpendicular to the ray's of the sun, at the mean distance of the earth from the sun. Based on the measurements made up to 1970 a standard value of 1353 W/m2 was adopted in 1971. However based on subsequent measurements, a revised value of 1367 W/m2 has been recommended. The earth revolves around the sun in an elliptical orbit having a very small eccentricity and the sun at the foci. Consequently, the distance between earth and sun varies a little through the year. Because of this variation, the extra terrestrial flux also varies. The value on any day can be calculated from the equation.

$$I'_{sc} = I'_{sc} \left\{ I + 0.033 \cos \frac{360n}{365} \right\}$$

Solar Radiation Received at the Earth's surface:

Solar radiation received at the earth's surface is in the attenuated form because it is subjected to the mechanisms of absorption and scattering as it passes through the earth's atmosphere (Figure below). Absorption occurs primarily because of the presence of ozone and water vapour in the atmosphere and lesser extent due to other gases (like CO2, NO2, CO,O2 and CH4) and particulate matter. It results in an increase in the internal energy of the atmosphere. On the other hand, scattering occurs due to all gaseous molecules as well as particulate matter in the atmosphere. The scattered radiation is redistributed in all directions, some going back to the space and some reaching the earth's surface.



Solar radiation received at the earth's surface without change of direction i.e, in line with the sun is called *direct radiation* or *beam radiation*. The radiation received at the earth's surface from all parts of sky's hemisphere (after being subjected to scattering in the atmosphere) is called *diffuse radiation*. The sum of beam radiation and diffuse radiation is called as *total* or *global radiation*.

Instruments used for measuring solar radiation

Pyranometer:

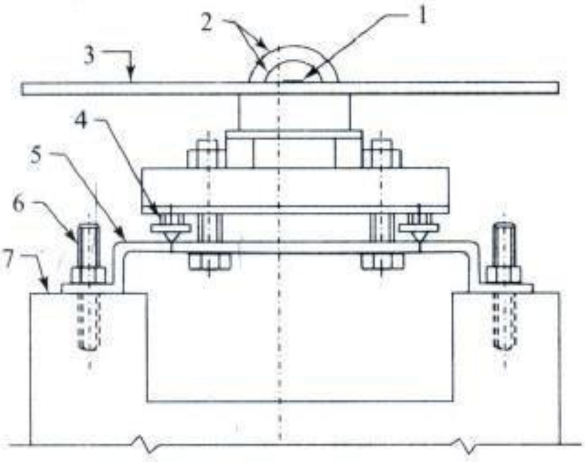
A Pyranometer is an instrument which measure's either global or diffuse radiation falling on a horizontal surface over a hemispherical field of view. A sketch of one type of Pyranometer as installed for measuring global radiation is shown in the following figure. Pyranometer consists of a black surface which heats up when exposed to solar radiation. It's temperature increases until the rate of heat gain by solar radiation equals the rate of heat loss by convection, conduction and radiation. The hot junctions of thermopile are attached to the black surface, while the cold junctions are located under a guard plate so that they do not receive the radiation directly. As a result an emf is generated. This emf which is usually in the range of 0 t0 10mv can be read, recorded or integrated over a period of time and is a measure of global radiation. The Pyranometer can also be used for measurement of diffuse radiation. This is done by mounting it at the center of a semi circular shading ring. The shading ring is fixed in such a way that it's plane is parallel to the plane of path of sun's daily movement across the sky and it shades the thermopile element and two glass domes of Pyranometer at all the times from direct sun shine. Consequently the Pyranometer measures only the diffuse radiation received from the sky.

1.Black surface, 2. Glass domes ,

3. Guard plate 4. Leveling screws,

5.mounting plate, 6. Grouted bolts,

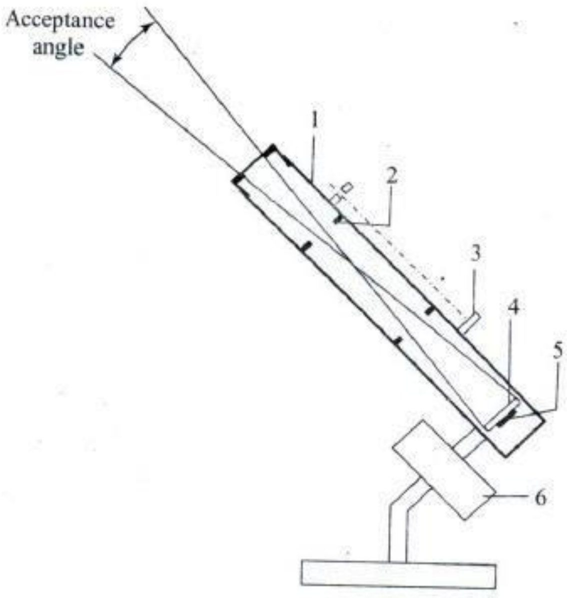
7.platform.



Pyrheliometer:

This is an instrument which measures beam radiation falling on a surface normal to the sun's rays. In contrast to a Pyranometer, the black absorber plate (with hot junctions of a thermopile attached to it) is located at the base of a collimating tube. The tube is aligned with the direction of the sun's rays with the help of a two-axis tracking mechanism and alignment indicator. Thus the black plate receives only beam radiation and a small amount of diffuse radiation falling within the acceptance angle of the instrument.

The Following figure shows a Pyrheliometer.



1.tube blackened on inside surface,

2.baffle, 3.Alignment indicator,

4. Black absorber plate

5.thermopile junctions

6.two-axis tracking mechanism

Solar Radiation Geometry

Definitions:

(a) Solar altitude angle (α):

Altitude Angle is the angle between the Sun's rays and projection of th*e Sun's rays* on the horizontal plane

(b) Zenith angle (θz):

It is Complementary angle of Sun's Altitude angle It is a vertical angle between Sun's rays and line perpendicular to the horizontal plane through the point i.e. angle between the beam and the vertical Θz=m/2-α

(c) Solar Azimuth Angle (ys):

It is the solar angle in degrees along the horizon east or west of north or It is the horizontal angle measured from north to the horizontal projection of sun's rays.

(d) Declination (6):

It is the angle between a line extending from the centre of the Sun and center of the earth and projection of this on earth's equatorial plane. Declination is the direct consequence of earth's tilt and It would vary between 23.5o on June 22 to – 23.5o on December 22. On equinoxes of March21 & Sept22 declination is zero.

– The declination is given by the formula

$$\delta = 23.45\ Sin\left\{\frac{360}{365}(284+n)\right\}$$

Where **n** is the day of the year

(e) Meridian:

Meridian is the imaginary line passing through a point or place on earth and north and south poles of the earth'.

(f) Hour angle (ω):

Hour angle is the angle through which the earth must turn to bring meridian of the point directly in line with the sun's rays. Hour angle is equal to 15o per hour.

(g) Slope (β):

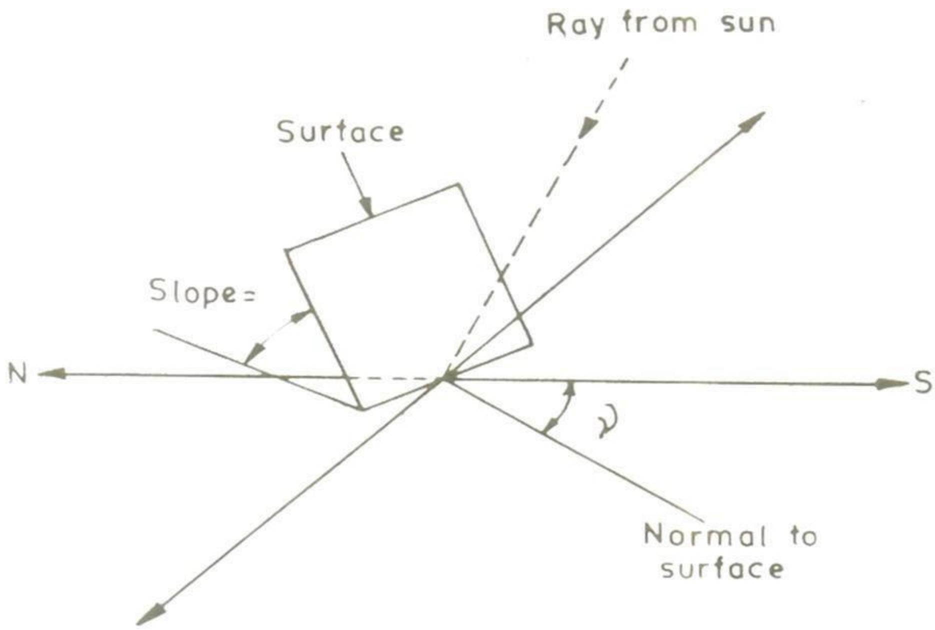
Angle between the collector surface with the horizontal plane is called slope(β).

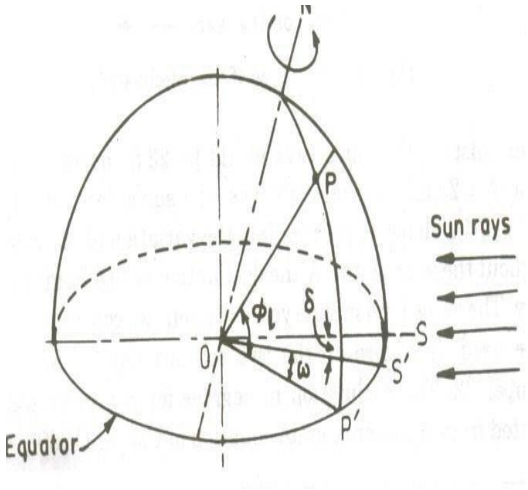
(h) Surface azimuth angle (y):

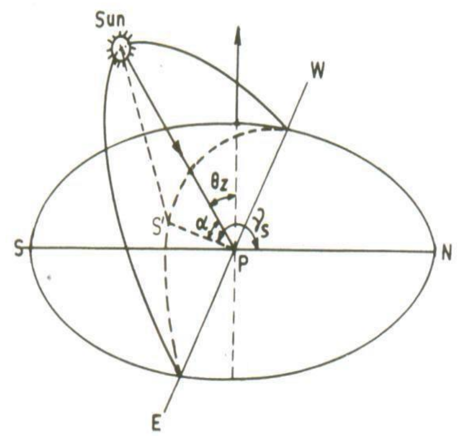
Angle between the normal to the collector and south direction is called surface azimuth angle(y)

(i) Solar Incident angle (θ):

It is the angle between an incident beam radiation falling on the collector and normal to the plane surface


Ray from sun
Surface
Slope=
N
S
Normal to
surface


P
Sun rays
S
O
S'
P'
Equator


Sun
W
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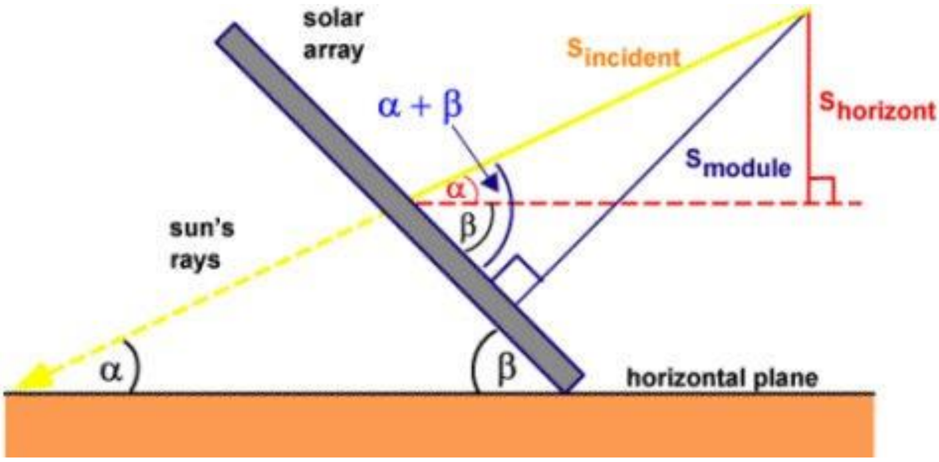

solar
array
sincident
α + β
shorizont
smodule
sun's
rays
α
β
horizontal plane

Relation between θ and other angles is as follows

Cosθ=Sin ϕl(sin6 cosβ+Cos6 cosy cos ω sin β)+ Cosϕl (Cos6 cosω cos β-sin6 cosy sin β)+ Cos6 siny sinωsin β **Eqn (1)**

ϕl=Latitude(north positive) 6=declination(north positive)

ω=solar hour angle(Positive between midnight and solar noon)

- Case1 Vertical Surface:

  β=90° Eqn (1) becomes

  Cosθ=Sin ϕ cos6 cosy cos ω- Cos ϕsin6 cosy+ Cos6 siny Sinω -----------------------------**Eqn (2)**
- Case2 Horizontal surfaces

  β=0° Eqn(1) becomes

  Cosθ=Sin ϕ sin6+cos6 cos ϕ cosω=sinα=cos θz-- **Eqn (3)**
- Case3

  Surface facing south y =0

  cos θT=Sin ϕ (sin6cosβ+ Cos6 cosω sinβ)

  =Cos ϕ (cos6 cosω cosβ-sin6 sinβ)

  =Sin6 Sin (ϕ-β)+Cos6 cosω Cos(ϕ-β)-- **Eqn (4)**
- Case4

  Vertical surfaces facing south (β=90°, y=0)

  cos θz=Sin ϕ cos6 cos ω- Cos ϕ Sin6-- **Eqn (5)**

Day Length:

At the time of sunset or sunrise the zenith angle θz=90°, we obtain sunrise hour angle as

$$Cos\ \omega s = -\frac{Sin\phi Sin\delta}{cos\phi\ Cos\delta} = -tan\phi\ tan\delta$$

$$\omega s = Cos^{-1}\{-\tan\phi\ \ tan\delta\}$$

Since 15^0 of the hour angle are equivalent to 1 hour

The day length(hrs) is given by

$$td = \frac{2\omega}{15} = \frac{2}{15} cos^{-1} - \{tan\phi\ tan\delta\}$$

Local Solar Time (Local Apparent Time (LAT) :

Local Solar Time can be calculated from standard time by applying two corrections. The first correction arises due to the difference in longitude of the location and meridian on which standard time is based. The correction has a magnitude of 4minutes for every degree difference in longitude. Second correction called the equation of time correction is due to the fact that earth's orbit and the rate of rotation are subject to small perturbations. This is based on the experimental observations.

Thus, Local Solar Time=Standard time± 4(Standard time Longitude-Longitude of the location)+(Equation of time correction)

Solar collectors:

Solar collectors are the devices used to collect solar radiation. Generally there are two types of solar collectors. They are 1) Non-conventional type or Flat plate collector and 2) Concentrating or Focusing collector. In a non-concentrating type the area of the absorber is equals the area of the collector and since the radiation is not focused, the maximum temp achieved in this type is about 100° C. on the other hand in a concentrating type the area of the absorber is very small (50-100 times) as compared to the collector area. This results in less loss of heat and also since the radiation is focused to a point or a line the maximum temp achieved is about 350°C.

Principle of solar energy conversion to heat:

The principle on which the solar energy is converted into heat is the greenhouse effect. The name is derived from the first application of green houses in which it is possible to grow vegetation in cold climate through the better utilization of the available sunlight. The solar radiation incident on the earth's surface at a particular wavelength increases the surface temp of the earth. As a result of difference in temp between the earth's surface and the surroundings, the absorbed radiation is reradiated back to the atmosphere with its wavelength increased. The Co2 gas in the atmosphere is transparent to the incoming shorter wavelength solar radiation, while it is opaque to the long wavelength reradiated radiation. As a result of this the long wavelength radiation gets reflected repeatedly between the earth's atmosphere and the earth's surface resulting in the increase in temp of the earth's surface. This is known as the Green House Effect. This is the principle by which solar energy is converted to thermal energy using collector. In a flat plate collector the absorber plate which is a black metal plate absorbs the radiation incident through the glass covers. The temp of the absorber plate increases and it begins to emit radiation of longer wavelength (IR). This long wavelength radiation is blocked from the glass covers which act like the Co2 layer in the atmosphere. This repeated reflection of radiation between the covers and the absorber plate results in the rise of the temp of the absorber plate.

Flat plate collector (FPC):

The schematic diagram of a FPC is as shown in fig. it consists of a casing either made up of wood or plastic having an area of about 2m*1m*15cm. in the casing insulator is provided at the bottom to check conductive heat transfer. Mineral wool, glass wool, fiber glass, asbestos thermo cal etc. are used as insulator. Above the insulator the absorber plate is fixed. The absorber plate is made of good conducting material like aluminum or copper. It is coated black to increase its absorption property. Usually the black coating is done by chemical treatment. Selective coatings which allow for maximum absorption of radiation and minimum amount of emission are applied on to the absorber plate. The underside of the plate consists of absorber tubes which run along the length of the plate. These plates are also made of the same material as that of the absorber plate. Sometimes the plate itself is bent into the form of tubes. Through these tubes the heat absorbing medium (water) is circulated. This medium will absorb the heat from the plates and the tubes and its temp increases. This medium will absorb the heat from the plates and the tubes and its temp increases. This way solar energy is collected as heat energy. Above the absorber plate glass covers are provided. These glasses covers help to bring out the greenhouse effect, thus increasing the η of the collector. More than one cover is used to prevent the loss of radiation by refraction.

Energy balance equation and collector efficiency: The performance of solar collector is described by an energy balance equation that indicates the distribution of incident solar radiation into the useful energy gain and various losses.

The energy balance equation is given as **$Qu=Ac\ [HR\ (\tau, \alpha) - UL\ (tp-ta)]$**

Where Qu is the useful energy gained by the collector in watts, Ac is the collector area in m2, HR is the solar energy received on the upper surface of the inclined collector, τ is the fraction of incoming radiation that is transmitted through the cover system and is known as transmissivity, α is the fraction of solar energy reaching the surface that is absorbed and is known as absorptivity. (τ,α) is the effective transmittance and absorptance product of cover system for beam and diffuse radiation. UL is the overall heat transfer coefficient. It is the rate of heat transfer to the surroundings per sq.meter of exposed collector surface per deg C Difference between average collector surface temp and the surrounding air temp in w/m2 C. tp is the absorber plate temp in °C, ta is the atmospheric temp in °C.

Thus the total incident radiation on the collector is **$QT= AcHR[(\tau,\alpha)]$**

The total losses from the collector is **$AcUL[(tp-ta)]$**

In order to increase the η of the collector Qu has to be increased. This is done by decreasing the losses as it is not possible to vary the incident radiation. The losses that occur are

1) **Conduction loss:** This loss is prevented by introducing an insulating material between the absorber plate and the casing where there is contact between the two and also by using a low conducting material like wood or plastic for the casing. Thus the conduction loss is reduced.
2) **Convection loss:** It takes place both from the top and the bottom of the absorber plate. The bottom loss is reduced by providing insulation between the absorber tubes and the base of the casing. The top side loss is prevented by providing glass covers and maintaining the distance between the covers by about 1.25 to 2.5 cm. Also convection loss is prevented by evacuating the top and the bottom side of the absorber plate.
3) **Radiation losses:** It is prevented by applying a selective coating on to the top side of the absorber plate. This coating allows 90% of the radiation to be incident on to the absorber plate while transmissivity of the plate is reduced to only 10%. The usual material used for the coating is —black chrome. The radiation loss also prevented by treating the underside of the glass covers by coating which are opaque to the reradiated infrared radiations but are transparent to the incident visible radiation. The materials used for this coating are tin oxide or indium oxide.

4) Reflection and refraction losses: These losses are prevented by providing more than one glass covers so that the reflected and refracted radiation is incident back on the absorber plate.
Thus the collector efficiency is given as,

$$\eta = \frac{\int Qu\ dt}{\int HR\ dt} = \frac{\text{the total useful heat gain in the collector}}{\text{the total incident radiation on the collector}}$$

Parameters affecting the performance of the FPC:

- Selective coating
- No. of covers
- Spacing between the covers
- Tilt of the collector
- Incident radiation
- Inlet fluid temperature
- Dust collection on the cover plate

Selective coating:
The η of the collector can be maximized by coating the absorber plate by materials which will absorb maximum amount of radiation but emit minimum amount of radiation. Such a coating is known as selective coating. By applying the selective coating on the absorber plate, input to the collector is maximized while the loss is minimized by this the η of the collector will improve. The selective coating Should have maximum absorptivity for a wavelength of less than 4µm, because the incident radiation will be having a wavelength less than 4µm. Similarly the coating should have minimum transmissivity for h greater than 4µm, because the radiation emitted from the absorber plate will be having a h of greater than 4µm. Should have maximum absorptivity for a wavelength of less than 4µm, because the incident radiation will be having a wavelength less than 4µm.

Parameter	Non selective absorber $\alpha = \varepsilon = 0.95$	Selective Absorber α=0.95, ε = 0.12	Selective Absorber α=0.85, ε = 0.11
T_{pm} (K)	356.1	359.3	357
U_L (W/m^{2}K)	3.87	2.56	2.51
Q_U (W)	593.6	682.9	616.1
T_{fo} (K)	341.7	342.95	342
η (%)	43.3	49.8	44.9

Similarly the coating should have minimum transmissivity for h greater than 4µm, because the radiation emitted from the absorber plate will be having a h of greater than 4µm.
The effect of selective coating on the performance of the collector is studied with the help of following data. From the above data it is seen that the η of the collector having a nonselective absorber is minimum because of the maximum loss. As the loss increases, the useful heat gains decreases resulting in decreased η. A collector having a selective absorber coating will have less loss and more useful heat gain because of its improved absorptivity and reduced emissivity. As

result of this the useful heat gain will increase resulting in the increased η of the collector. The commercially used selective coating are copper oxide on copper (α=0.89, s=0.17) nickel black on galvanized iron (α=0.868, s=0.088).

Desirable properties of selective coatings: The selective coatings should withstand the continuous exposed to high temperature without losing the absorbing and emitting characteristics. These should be less expensive. These coatings should not get corroded or eroded by the atmosphere.

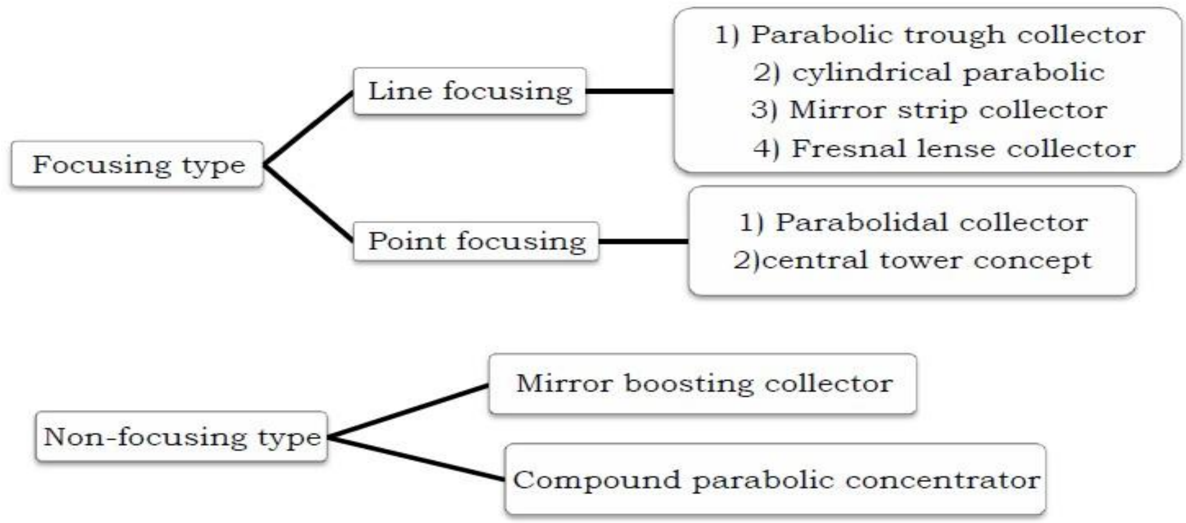
Concentrating collectors:

These are the solar collectors where the radiation is focused either to a point (focal point of the collector) or along a line (focal axis of the collector). Since the radiation is focused, the η of concentrating collector is always greater than that of non-focusing or FPC.

This is because of the following reasons,

1) In case of focusing collector the area of the absorber is many times smaller than that of the area of the collector. Where as in a non-concentrating type the area of the absorber equals area of the collector. Hence here the loss of absorbed radiation is more compared to the concentrating type.

Classification of concentrating collectors:



2) In a concentrating collector since the radiation is focused, its intensity is always greater than that in the non-focusing type. Because of these reasons the concentrating collectors are always used for high temp applications like power generation and industrial process heating.

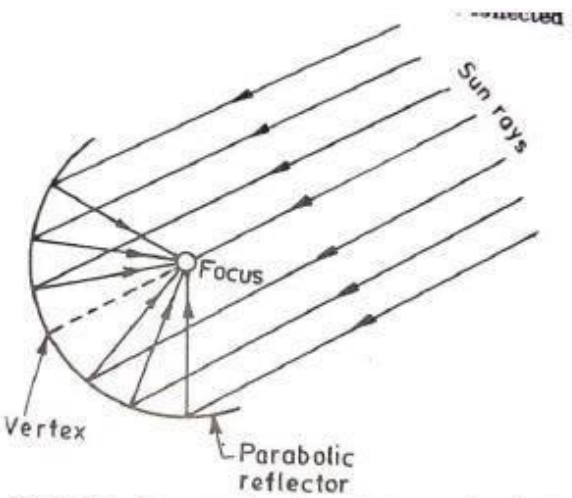
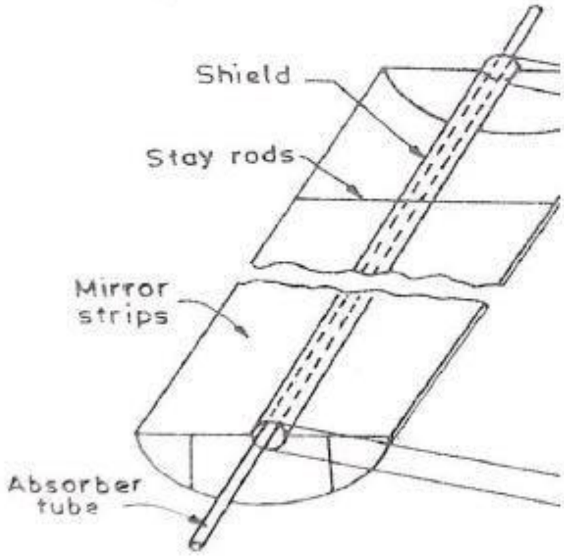


Fig. 3.7.1. Cross-section of parabolic-trough collecto:



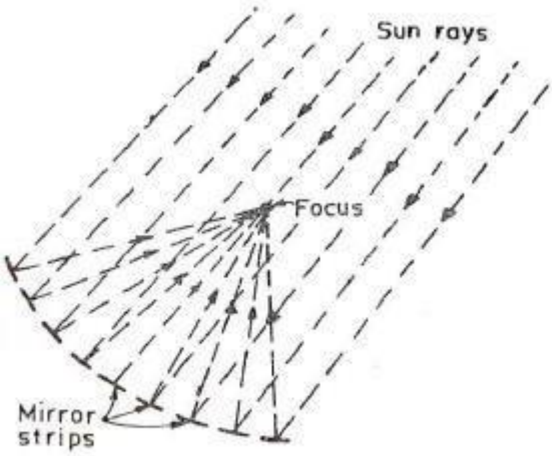
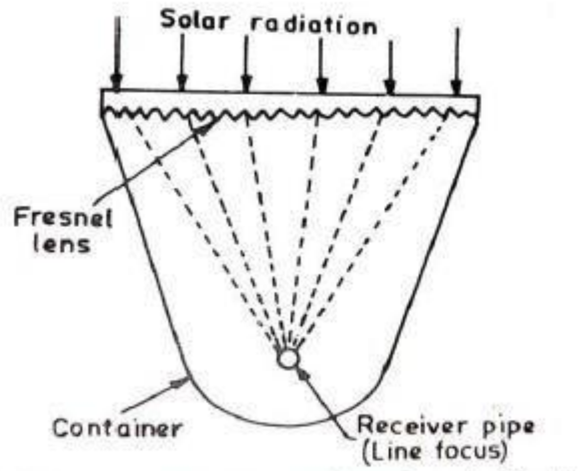


Fig. 3.7.3. Mirror-strip solar collector.



3.7.4 Cross-section of Fresnel lens through collector.

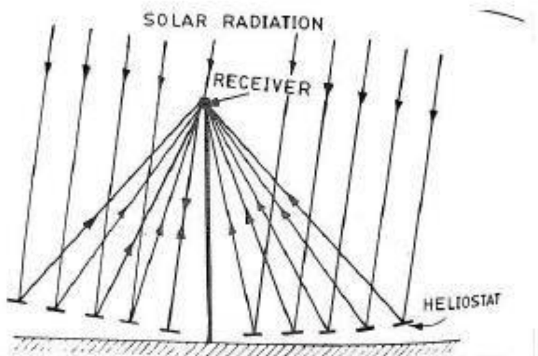


Fig. 5.5.4. Schematic arrangement of central receiver heliostat array.

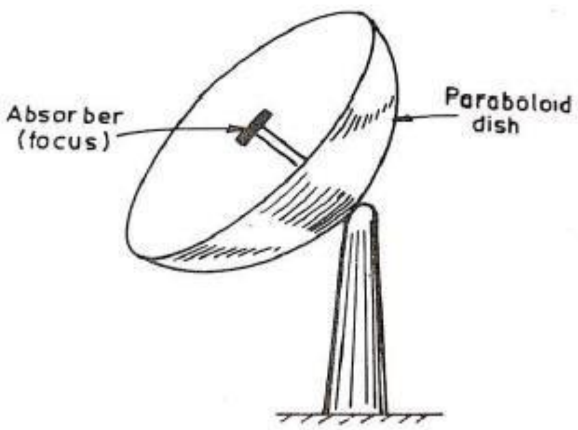


Fig. 3.7.7. Point focus solar collector (Paraboloid).

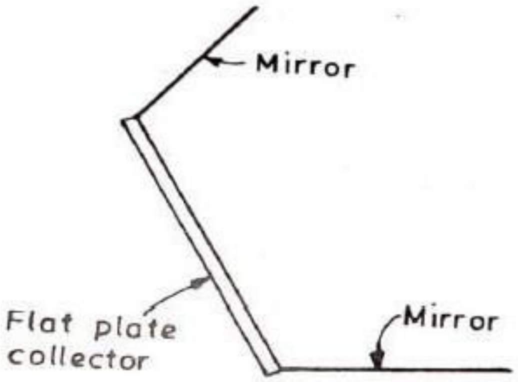


Fig. 3.7.9. Flat-plate collector augmented with mirrors.

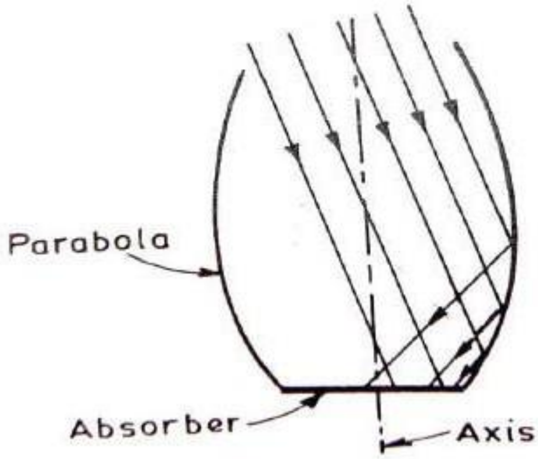


Fig. 3.7.10. Compound parabolic concentrator.

Compound Parabolic Concentrator (CPC):

Compound Parabolic Concentrator consists of two parabolic mirror segments, attached to a flat receiver. The segments are oriented such that the focus of one is located at the bottom end point of the other in contact with the receiver. It has a large acceptance angle and needs to be adjusted intermittently. Rays in the central region of the aperture reach the absorber directly whereas, those near the edges undergo one or more reflections before reaching the absorber. The concentration ratio achieved from this collector is in the range of 3-7.

Cylindrical Parabolic Concentrator:

It consists of a cylindrical parabolic through reflector and a metal tube receiver at its focal line as shown in figure above. The receiver tube is blackened at the outside surface to increase absorption. It is rotated about one axis to track the sun. The heat transfer fluid flows through the receiver tube, carrying the thermal energy to the next stage of the system. This type of collector may be oriented in any one of the three directions: East-West, North-South or polar. The polar configuration intercepts more solar radiation per unit area as compared to other modes and thus gives best performance. The concentration ratio in the range of 5-30 may be achieved from these collectors.

Fixed Mirror Solar Concentrator:

Due to practical difficulty in manufacturing a large mirror in a single piece in cylindrical parabolic shape, long narrow mirror strips are used in this concentrator. The concentrator consists of fixed mirror strips arranged on a circular reference cylinder with a tracking receiver tube as shown in Figure above. The receiver tube is made to rotate about the center of curvature of reflector module to track the sun. The image width at the absorber is ideally the same as the projected width of a mirror element; the concentration ratio is approximately the same as the number of mirror strips.

Linear Fresnel Lens Collector:

In this collector a Fresnel lens, which consists of fine, linear grooves on the surface of refracting material (generally optical quality plastic) on one side and flat on the other side, is used. The angle of each groove is designed to make the optical behavior similar to a spherical lens. The beam radiation, which is incident normally, converges on focal line, where a receiver tube is provided to absorb the radiation. A concentration ratio of 10-30 may be realized which yields temperatures between 150-3000C.

Paraboloidal Dish Collector:

When a parabola is rotated about its optical axis a paraboloidal surface is produced. Above figure shows the details of this type of collector. Beam radiation is focused at a point in the paraboloid. This requires two axis tracking. It can have concentration ratio ranging from 10 to few thousands and can yield temperature up to 3000oC. Paraboloidal dish collectors of 6-7m in diameter are commercially manufactured.

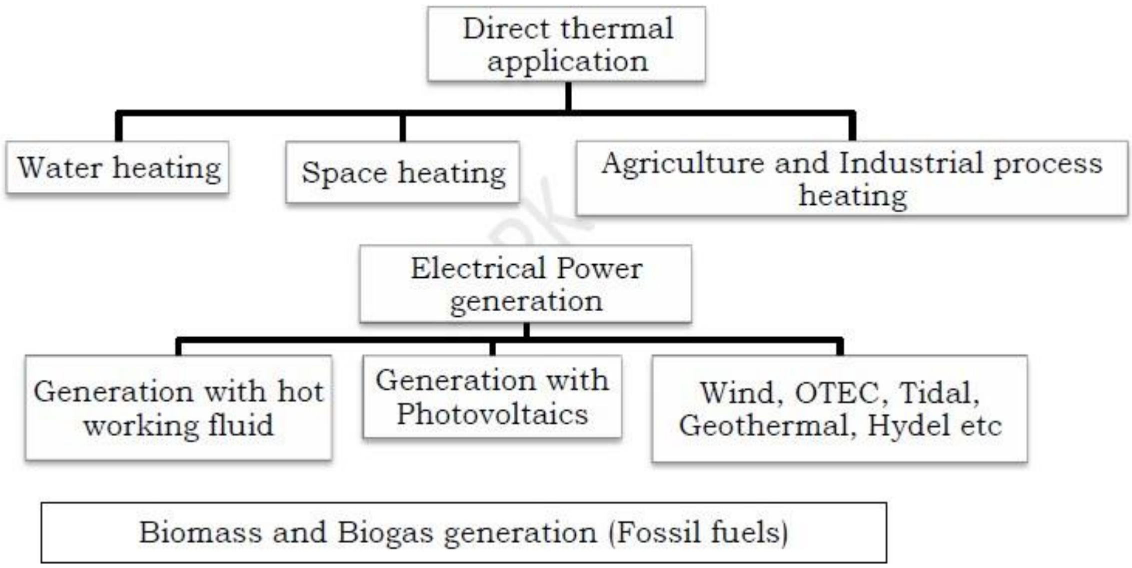
Hemispherical Bowl Mirror Concentrator:

It consists of hemispherical fixed mirror, a tracking absorber and supporting structure, as shown in Figure. All rays entering the hemisphere after reflection cross the paraxial line at some point between the focus and the mirror surface. Therefore, a linear absorber pivoted about the center of curvature of the hemisphere intercepts all reflected rays. The absorber is to be moved so that its axis is always aligned with solar rays passing through the center of the sphere. This requires two-axis tracking. The absorber is either driven around a polar axis at a constant angular speed of 15 degrees/hour or adjusted periodically during the day. This type of concentrator gives lesser concentration, owing to spherical aberration, than that obtained in paraboloidal concentrator.

Central Tower Receiver:

In central tower receiver collector, the receiver is located at the top of a tower. Beam radiation is reflected on it from a large number of independently controlled; almost flat mirrors, known as heliostats, spread over a large area on the ground, surrounding the tower. Thousands of such heliostats track the sun to direct the beam radiation on the receiver from all sides. The heliostats, together act like a dilute paraboloid of very big size. Concentration ratio of as high value as 3,000 can be obtained. The absorbed energy can be extracted from the receiver and delivered at a temperature and pressure suitable for driving turbines for power generation. The schematic view of central tower receiver is shown in figure above.

Applications of solar Energy:



Thermal applications:

1) Water heating
2) Space heating or cooling
3) Process heating
4) Refrigeration
5) Distillation
6) Furnace heating
7) Electric power generation
8) Cooking
9) Pumping

WATER HEATING SOLAR SYSTEM

NATURAL CIRCULATION SOLAR WATER HEATER (PRESSURIZED):

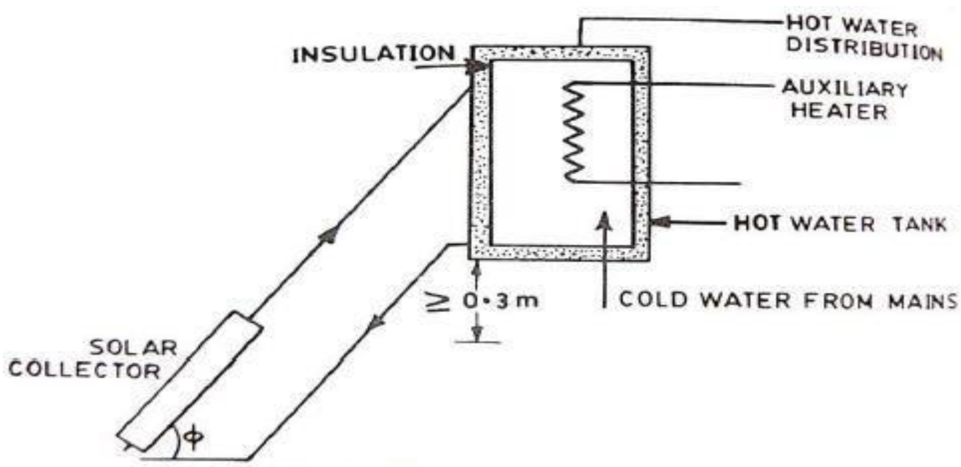


Fig. 5.2.1. Schematic of a neutral circulation solar water heater (pressurized).

A natural circulation system is shown in Fig. 5.2.1. It consists of a titled collector with transparent cover glasses, a separate highly insulated water storage tank, and well insulated pipes connecting the two. The bottom of the tank is at least 1ft the top of the collector, and no auxiliary energy is required to circulate water through it. The density difference between the hot and cold water thus provides the driving force for the circulation of water through the collector and the storage tank. Hot water is drawn off from the top of the tank as required and is replaced by cold water from the service system. As long as the sun shines the water will quietly circulate, getting warmer. After sunset, a thermosiphon system can reverse its flow direction and loss heat to the environment during the night. The thermosiphon system is one of the least expensive solar hot-water systems and should be used whenever possible.

Thermosiphon solar water heaters are passive systems and do not require a mechanical pump to circulate the water. Such heaters can be used extensively in rural areas, where electricity is expensive and there is little danger of freezing.

NATURAL CIRCULATION SOLAR WATER HEATER (NON-PRESSURIZED

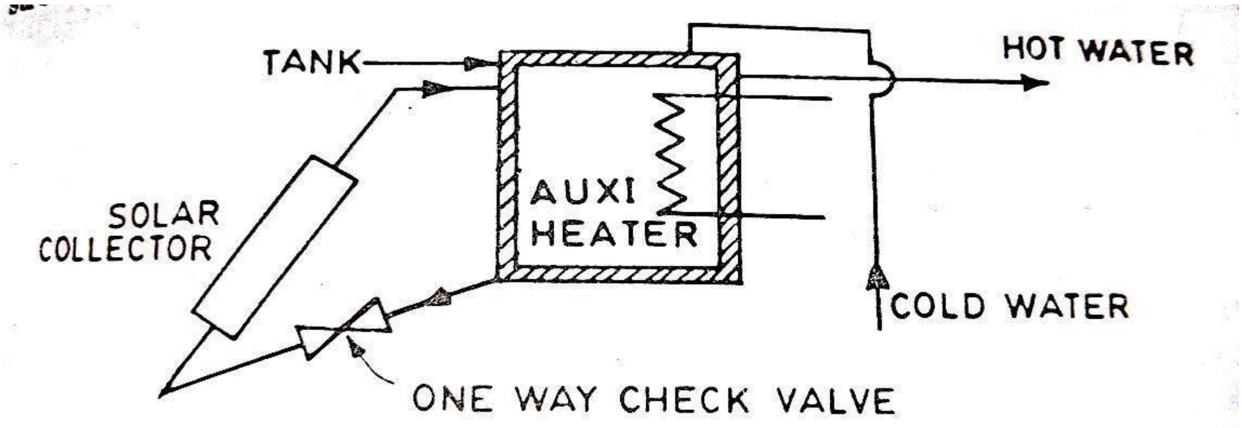


Fig. 5.2.2. Non-pressurized solar water heater.

The pressurized system is able to supply hot water at locations of the storage tank. This creates considerable stress on the water channels in the collector which must be designed accordingly. The non-pressurized systems supply hot water by gravity flow only to users lower than tank. If pressurized hot water is required (for showers, or appliances) the difference in height will have to be large enough to meet the requirements. If the height of difference cannot be accommodated, the only solution is to install a separate pump and pressure tank. The stresses within non-pressurized system are lower which allows cheaper and easier construction. In this type also mechanical pump is not required as shown in Fig.5.2.2, however, a one-way check valve may be desirable to prevent reverse circulation and thus loss of heat at night. A typical system for domestic water heating is shown in Fig.5.2.3.

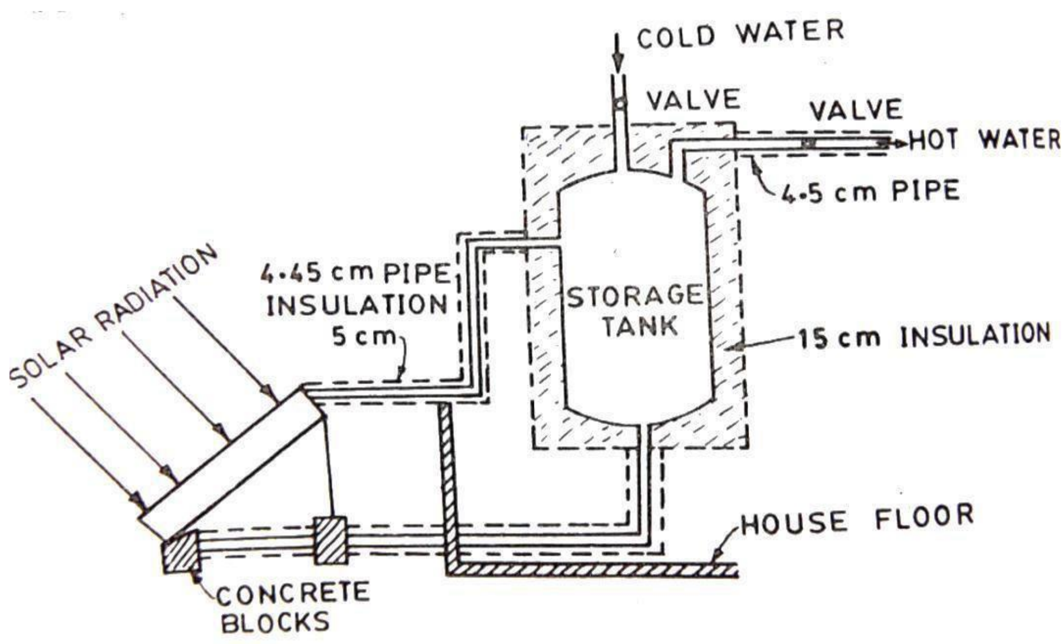


Fig. 5.2.3. A typical solar water heater.

FORCED CIRCULATION SOLAR WATER HEATER (WITHOUT ANTIFREEZE)

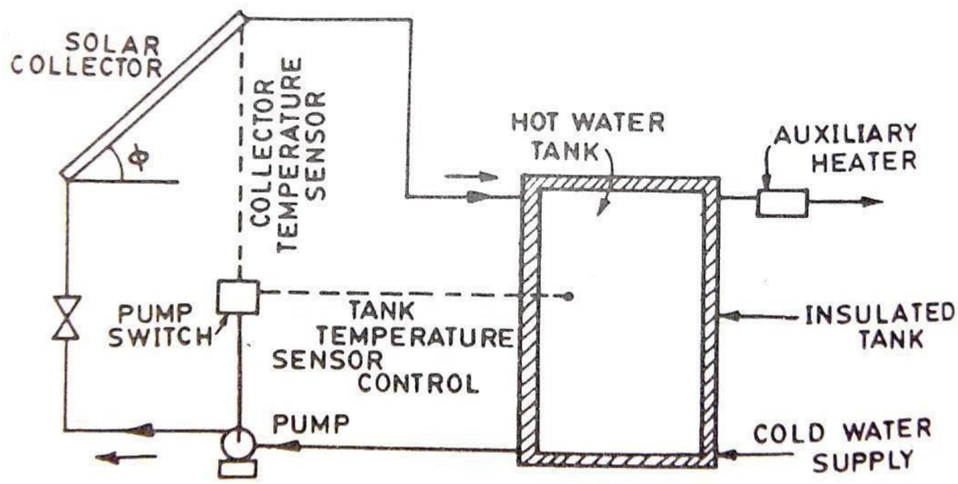


Fig. 5.2.4. Schematic of a forced circulation solar water heater.

Fig.5.2.4 shows schematically an example of forced circulation system. By including an electric pump in the return circuit between the bottom of the storage tank and the lower header of the collector, the tank can be placed at a more convenient level (e.g. in the house basement). This is now an active system. A control unit permits the pump to operate only when the temperature of the water at the bottom of the tank is below that of the water in the upper header. A check valve is needed to prevent reverse circulation and resultant night time thermal losses from the collector. In this example, auxiliary heater is shown as provided to the water leaving the tank and going to the load. When there is a danger of freezing, the water may be drained from the collector; alternately, a slow reverse flow of the warmer water may be permitted through the collector on cold nights. The freezing danger can be overcome, although at some increase in cost, by using an antifreeze solution as the heat-transport medium, as described earlier. The heat is then transferred to water in the storage tank by way of a heat exchanger coil.

FORCED CIRCULATION SOLAR WATER HEATER (WITH ANTIFREEZE)

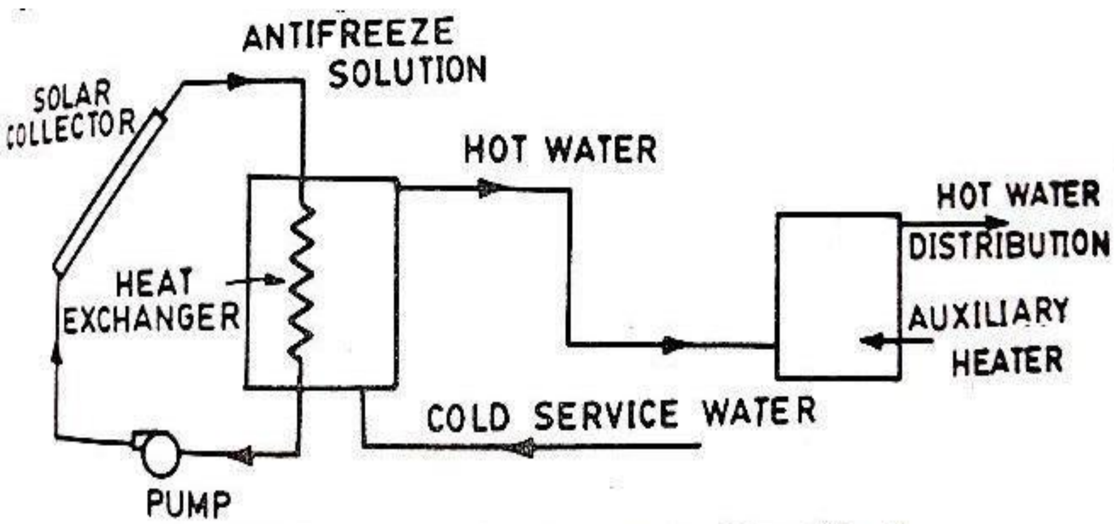


Fig. 5.2.5. Solar water heating system with antifreeze.

SPACE-HEATING:

SOLAR HEATING OF BUILDING:

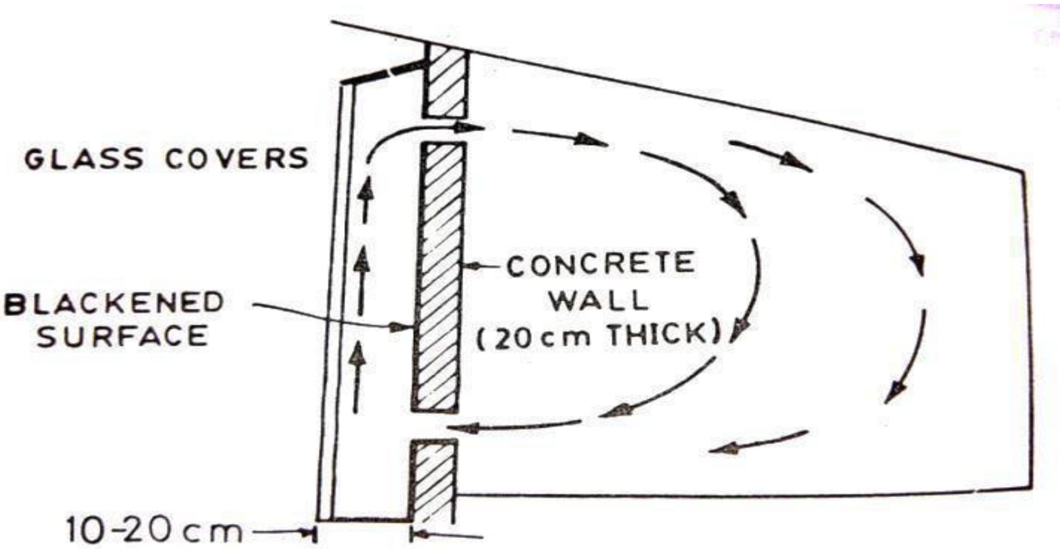


Fig. 5.3.1. A passive solar heating system.

A sunspace is any enclosed space, such as a green house or sun porch, with a glass wall on the south side. A sunspace may be attached (or built on) to a thick south wall of the building to be heated by the sun. Vents near the top and bottom of the wall, as in Fig. 5.3.1, permit circulation through the main building of the heated in the sunspace. Heat storage is provided by the thick wall, a concrete or masonry floor, water containers, and other materials in the sunspace. Thus, an attached sunspace system combines features of direct gain and storage wall concepts

ROOF STORAGE OF SOLAR HEAT:

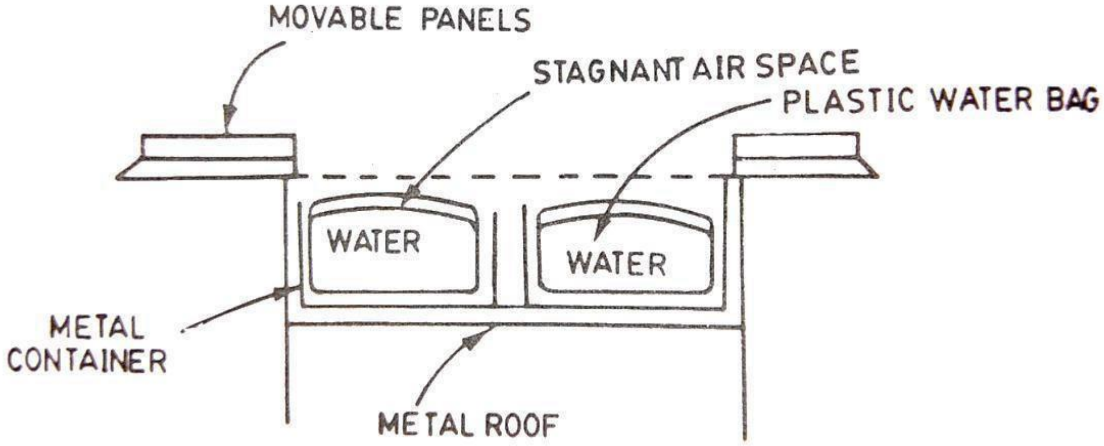


Fig. 5.3.2. Roof storage of Solar heat.

A passive solar system, trade named sky therm, was designed for house having a flat roof located in a mild climate. The heat is absorbed and stored in water about 0.25 m deep contained in plastic bags held in blackened steel boxes on the house roof. In a later design, a layer of clear plastic sealed to the top of the bag provides a stagnant airspace to reduce heat losses to the atmosphere. Heat is transferred from the heated water to the rooms below by conduction through a metal ceiling. Air circulation may be aided by means of electric fans, but this is not essential. To prevent loss of heat during the night, thermal insulator panels are moved, either manually or by a time controlled electric motor, to cover the water bags. In the day time, the panels, which are in sections, are removed and stacked one above the other.

CONVECTIVE LOOP PASSIVE SOLAR HEATING:

In most passive solar space heating systems, the heated air is circulated by convection, but the term convective loop is applied to systems that resemble the thermo siphon hot-water scheme described earlier. Such a convective loop heating system is outlined in Fig.5.3.3. It includes a convectional flat plate collector at a level below that of the main structure. A bed of rock, which may be located beneath a sunspace, provides thermal storage. In normal operation, air passing upward through the collector is heated and enters the building through floor vents. The cool, denser air leaving the building returns to the bottom of the collector and is reheated. If more solar heat is available than is required for space heating, the floor vents may be partly closed. The heated air then flows through and deposits heat in the storage bed. Heat stored in this way may be used later, as needed, by transfer to the cooler air leaving the building.

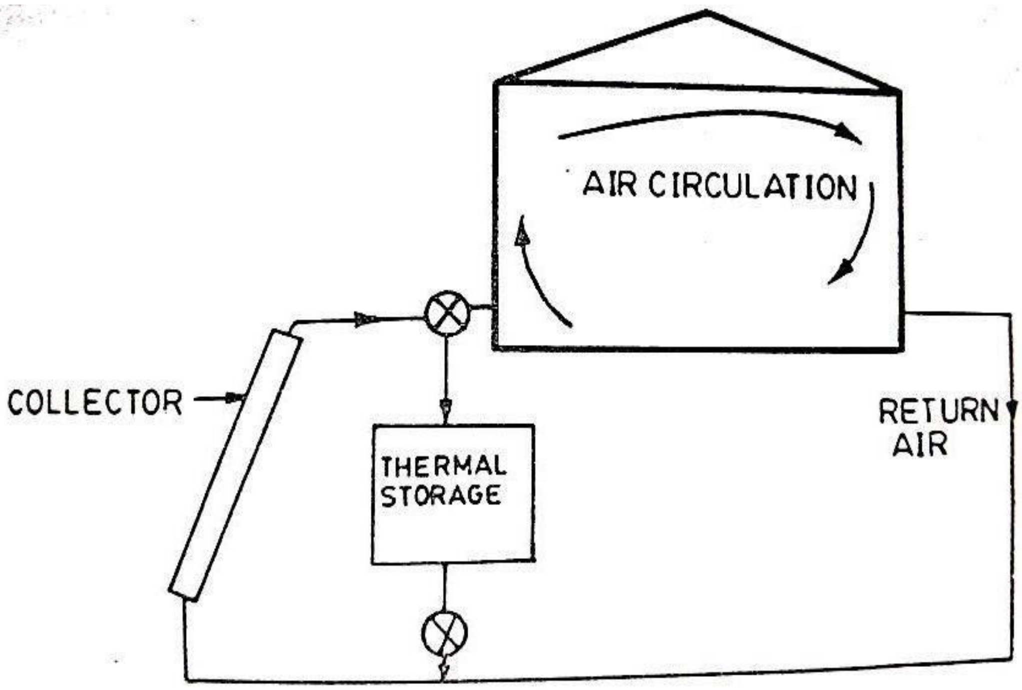


Fig. 5.3.3. Convective loop passive Solar heating.

BASIC HOT WATER ACTIVE SYSTEM:

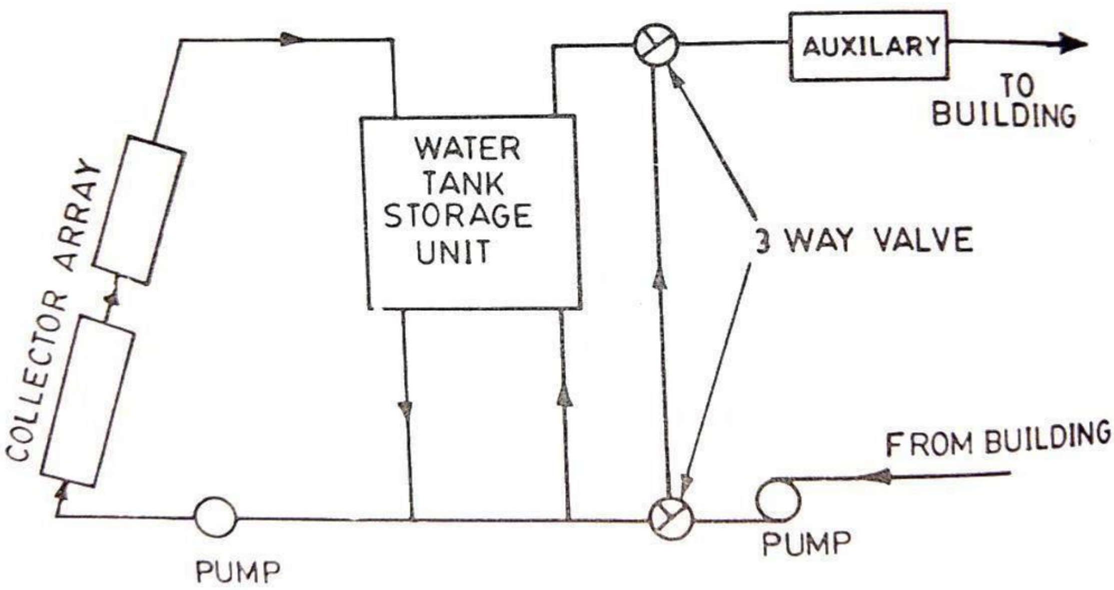


Fig. 5.3.4. Schematic of a basic hot water active system.

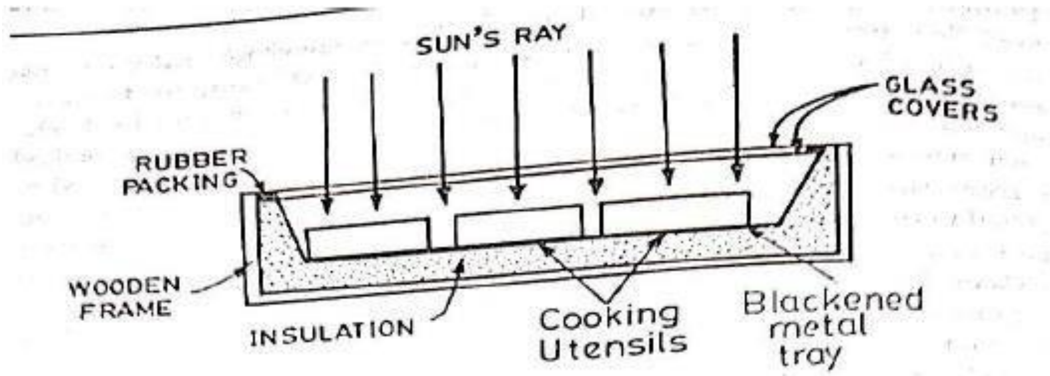
An outline of an active heating system with a sloping flat plate collected located on the roof of the building is given in Fig.5.3.4. This is a basic hot water heating system, with water tank storage and auxiliary energy source. Heat is transferred to the water in the storage tank, commonly located in the basement of the building. The solar heated water from the tank passes through an auxiliary heater, which comes on automatically when the water temperature falls below a prescribed level. For space heating, the water maybe pumped through radiators or it may be used to heat air in a water to air heat exchanger. During normal operation, the three way valves are set to permit solar heated water to flow from the storage tank and auxiliary heater to the distribution system and back to the tank. If after several cloudy days, the heat in storage is depleted, the valves will adjust automatically to bypass the storage tank. In this way, auxiliary heating of the large volume of water in the tank is prevented. If the temperature in the heater at the top of the collector should fall below that at the bottom of the tank, the pump would be switched off automatically. If in this system, the heat transport medium is an antifreeze solution, then there is a closed circuit of it, with the heat exchanger coil in the storage tank. This type of solar space heating system with hot water system is shown in Fig.5.3.5.

SOLAR COOKING:

Thermal energy requirements for cooking purpose forms a major share of the total energy consumed, especially in rural areas. Variety of fuels like coal, kerosene, cooking gas, firewood, dung cakes and agricultural wastes are being used to meet the requirement. Fossil fuel is a fast depleting resource and need to be conserved, firewood for cooking causes deforestation and cow dung, agricultural waste etc. may be better used as a good fertilizer. Harnessing solar energy for cooking purpose is an attractive and relevant option. A variety of solar cookers have been developed, which can be clubbed in four types of basic designs:

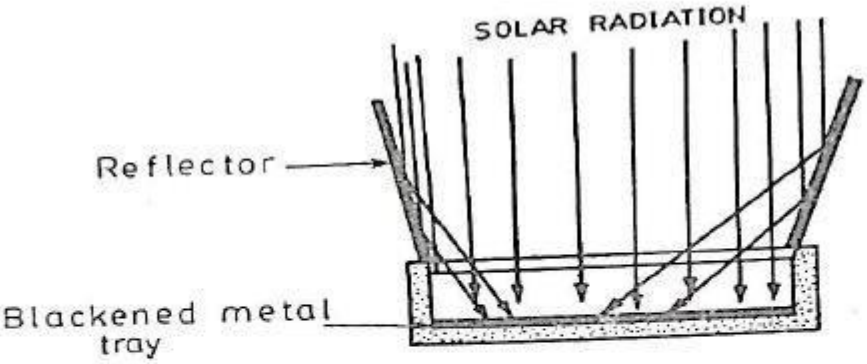
(i) box type solar cooker,

(ii) dish type solar cooker (iii) community solar cooker, and (iv) advance solar cooker.

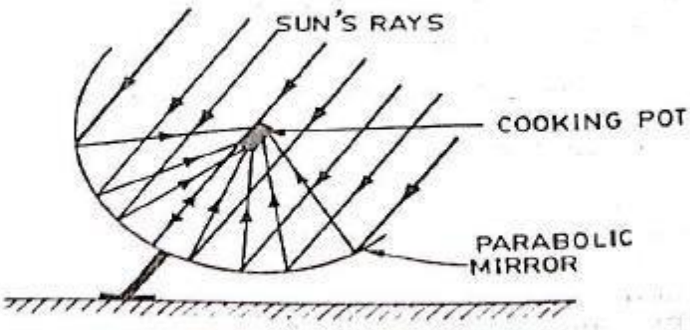


(a) Principle of box type cooker.

(a) Principle of box type cooker.



(b) Reflector type solar cooker.



(c) Principle of concentrating type cooker.
Fig. 5.11.1. Principle of operation of Solar cookers.

BOX TYPE SOLAR COOKER: (160°C) & Reflector type (240°C):

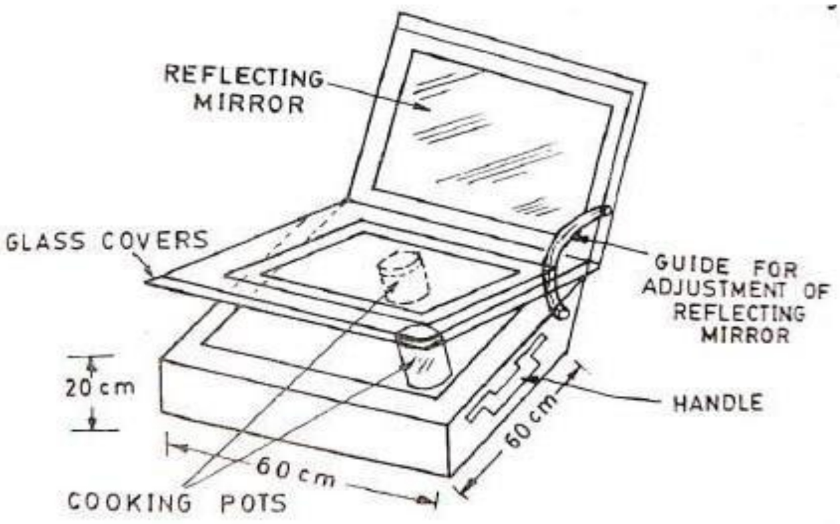
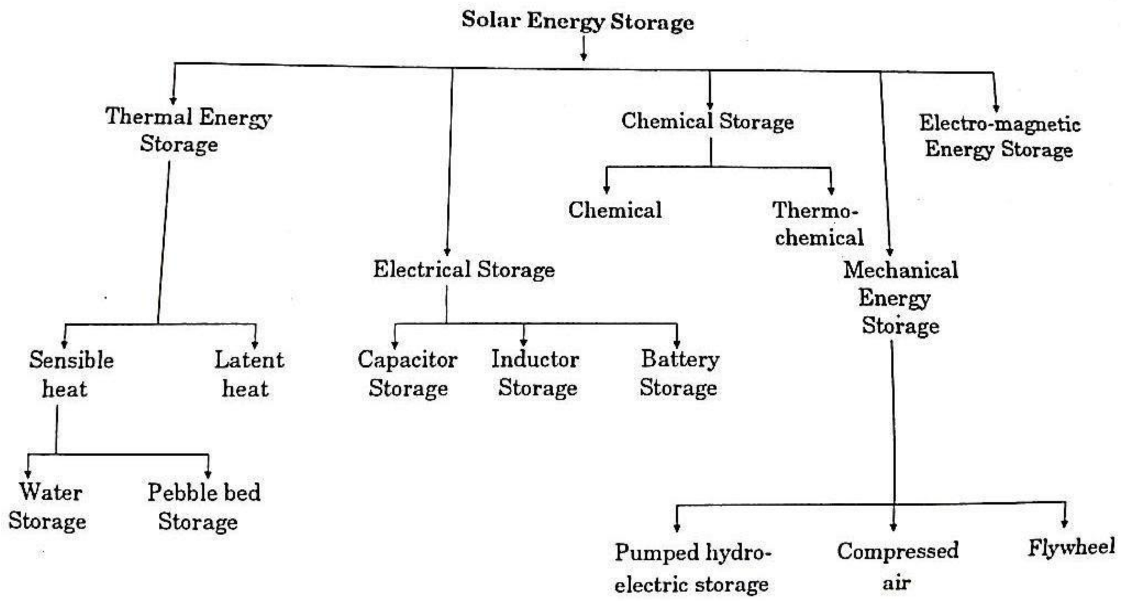


Fig. 5.11.2. Details of a box type cooker.

The construction of a most common, box type solar cooker is schematically shown in figure above. The external dimensions of a typical family size box type cooker are 60x60x20 cm. This cooker is simple in construction and operation. An insulated box of blackened aluminum contains the utensils with food material. The box receives direct radiation and also reflected radiation from a reflector mirror fixed on inner side of the box cover hinged to one side of the box. The angle of reflector can be adjusted as required. A glass cover consisting of two layers of clear window glass sheets serves as the box door. The glass cover traps heat due to the greenhouse effect. Maximum air temperature obtained inside the box is around 140-1600C. This is enough for cooking the boiling type food slowly in about 2-3 hours.

SOLAR ENERGY STORAGE SYSTEMS;

The thermal energy of sun can be stored in a well-insulated fluids or solids. It is either stored as **i)** sensible heat – by virtue of the heat capacity of the storage medium, or as **ii)** Latent heat – by virtue of the latent heat of change of phase of the medium or both. In the first type of storage the temp of the medium changes during charging or discharging of the storage whereas in the second type the temp of the medium remains more or less constant since it undergoes a phase transformation. An overview of the major techniques of storage of solar energy is as shown in the fig. A wide range of technical options are available for storing low temp thermal energy as shown. Some of the desired characteristics of the thermal energy as shown below. Some of the different storage techniques and their main features are compared in the next table. Desired properties of phase change heat storage materials are also listed in subsequent table.



There are four main factors affecting the cost affecting the cost of solar thermal energy storage systems. They are,

1) Thermal heat storage materials,
2) Insulating material,
3) Space occupied by the storage device,
4) Heat exchange for charging and discharging the storage.

The following chart shows the different storage systems used as per the required capacity. Depending on the available energy one can select the particular storage system thus optimizing the cost and the efficiency of the storage system.

UNIT-II

Wind Energy

INTRODUCTION

- Wind is essentially air in motion, which carries with it kinetic energy.
- The amount of energy contained in the wind at any given instant is proportional to the wind speed at that instant.
- Wind results primarily by unequal heating of the earth's surface by the sun.
- About 2% of the total solar flux that reaches the earth's surface is transformed into wind energy.
- Solar energy meets clouds, uneven surfaces, and mountains while reaching the earth.
- This unequal heating causes temperature, density, and pressure differences on the earth's surface that are responsible for local wind formation.
- During daytime, the air over the land mass heats up faster than the air over the oceans. Hot air expands and rises while cool air from oceans rushes to fill the space, creating local winds.
- At night the process is reversed as the air cool more rapidly over land than water over off-shore land, causing breeze.
- On a global scale, the primary force for global winds is developed due to differential heating of the earth at equatorial and Polar Regions.

POWER IN WIND

- Wind possesses energy by virtue of its motion. Any device capable of slowing down the mass of moving air like a sail or propeller can extract part of the energy of the energy and convert it into useful work.
- Three factor determine the output from a wind energy converter:
- The wind speed
- The cross-section of wind swept by rotor
- The overall conversion efficiency of the rotor, transmission system and generator or pump.
- Wind mill/turbine converts the kinetic energy of the wind into mechanical energy.
- The total power of the wind stream is equal to the time rate of kinetic energy.

$$K.E=1/2mV^2$$

- The amount of air passing in unit time through an area A with velocity V

$$m=A.V\ m^3/s$$

∴ Mass flow rate of air m =p A • V Where, p is the density of air.

$$K.E=1/2(\rho AV)V^2$$

BASIC COMPONENTS OF A WIND ENERGY CONVERSION SYSTEM (WECS)

The main components of a wind energy conversion system (WECS) in the form of block diagram. A wind energy conversion system converts wind energy into some form of electrical energy. In particular, medium and large scale WECS are designed to operate in parallel with a utility AC grid. This is known as a grid-connected system. A small system, isolated from the id, feeding only to a local load is known as autonomous or isolated power system.

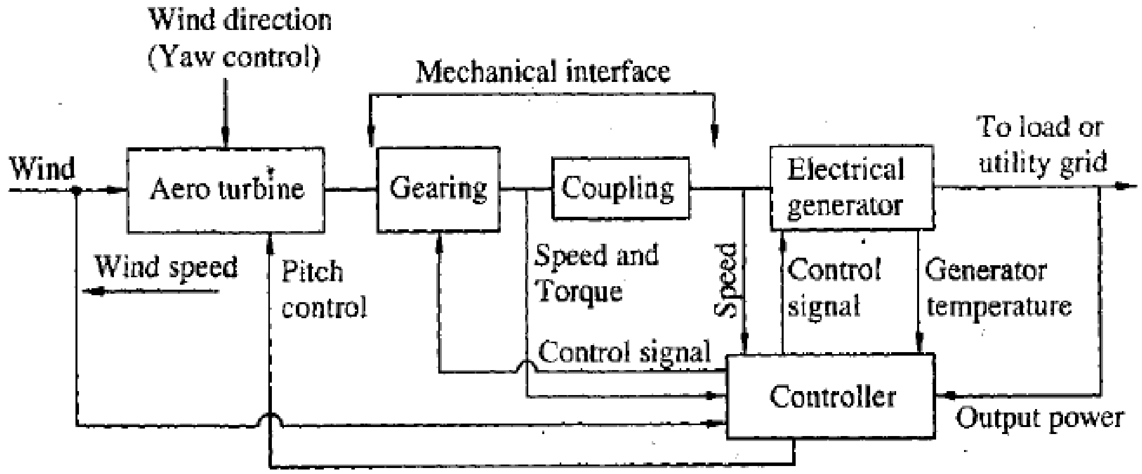


Fig: Wind Energy Conversion System (WECS)

Types of Wind Energy:

1. **According to orientation of the axis of rotor**

- Horizontal axis: When the axis of rotation is parallel to the air stream (i.e. horizontal), the turbine is said to be a Horizontal Axis Wind Turbine (HAWT).
- Vertical axis: When the axis of rotation is perpendicular to the air stream (i.e. vertical), the turbine is said to be a Vertical Axis Wind Turbine (VAWT)

2. **According to useful electrical power output**

- Small output: up to 2 kW
- Medium output: 2 to 100 kW output
- Large output: More than 100 kW output

3. **According to type of rotor**

- Propeller type: It is horizontal axis high speed rotor.
- Multiple blade type: It is horizontal axis low speed rotor.
- Savonius type: It is vertical axis rotor.
- Darrieus type: It is vertical axis rotor.

Horizontal Axis Wind Turbine (HAWT)

– Horizontal axis machines have emerged as the most successful type of turbines. These are being used for commercial energy generation in many parts of theworld.
– They have low cut-in wind speed, easy furling and, in general, show high power coefficient.
– However, their design is more complex and expensive as the generator and gear box are to be placed at the top of the tower. Also, a tail or yaw drive is to be installed to orient them in the wind direction.

Main components:

1. Turbine blades
2. Hub
3. Nacelle
4. Power transmission system
5. Generator
6. Yaw control
7. Brakes
8. Tower

1. Turbine blades

– Wind turbine blades need to be light weight and possess adequate strength and hence require to be fabricated with aircraft industry techniques.
– The blades are made of glass fibre reinforced plastic (F.R.P.). They have an aerofoil type of cross section to create lift as the air flows over them.
– The blades are slightly twisted from the outer tip to the root to reduce the tendency to stall.
– In addition to centrifugal force and fatigue due to continuous vibration, there are many extraneous forces arising from wind turbulence, gust, gravitational forces and directional changes in the wind. All these factors have to be considered at the designing stage.
– The diameter of a typical, MW range, modern rotor may be of the order of 100m.

SITE SELECTION CONSIDERATIONS

1. Average annual wind speed

– The power available in wind increases rapidly with wind speed. Therefore, the main consideration for locating a wind-power generation plant is the availability of adequate and uniform average wind velocity throughout the year.

- The total wind power from free wind stream increases as the cube of the wind speed. Therefore, wind velocities available should be in the range of 5 m/s to 25 m/s throughout the year.

2. Area

- As the building, forests offers the resistance to the air movement, the wind farms are located away from cities and forests. Flat open area should be selected, as the wind velocities are high in flat open area.

3. Altitude of the site

- Altitude of the proposed site should be considered. Higher altitude ground experience strong winds than lower altitude ground. Thus, altitude affects the electric power output of wind energy conversion system.
- Wind velocities must be measured by anemometer at several heights from the ground The velocity of wind increases with height given by the relation:

$$V \propto H^{1/7}$$

- This relation is applicable for the heights between 50 m to 250 m.

4. Wind structure

- At the proposed site, wind should blow, smooth and steady all the time, i.e. the wind velocity curve should be flat. Wind specially near the ground is turbulent and gusty, and changes rapidly in direction and in velocity.

5. Local ecology

- If small trees, grass or vegetations are present, all of which destructure the wind, then the height of the tower will increase, which increases the cost of thesystem.

6. Nature of land and its cost

- The site selected should have high load bearing capacity. It would reduce the cost of foundation. The cost of the land should be low to reduce the initial cost.

7. Transport facilities

- There should be transport facilities for transportation of heavy machinery, structures, materials, blades, etc to chosen site for installation.

8. Nearness of site to load centre

- The site should be located near the load to which the power is supplied. The location of site near load centre reduces the cost of transmission lines and the losses occurring in it.

9. Away from localities

The selected site should be away from localities so that the sound pollution caused by wind turbine does not affect.

Advantages

1. It is renewable and not depleted with the use like fossil fuels.

2. Wind energy generation is eco-friendly and does not pollute the atmosphere, unlike in the case of generation from coal, oil, etc.
3. The cost of installation of wind power plant is competitive compared to conventional power plant/Since, there is no fuel cost and low maintenance cost, the cost of energy produced in long run is almost free.
4. Wind energy system does not require fuel and its transportation.

5. In large portion of the world, wind blows for 320 days in a year and this gives them an advantage over sunlight in direct conversion programmer.

Disadvantages

1. Wind energy is available in dilute and fluctuating in nature.
2. It is necessary to store wind energy in some other forms during periods of high winds for use later on during calm.
3. Favorable winds are available only in few geographical locations.
4. There is fluctuation in electric power depending on fluctuating wind speed.

5. The capital cost is high. At present it is about Rs. 3.5 crores/MW.
6. It causes negative impacts like noise, bird hits, land erosion, impact on wild life, etc.

WIND ENERGY DEVELOPMENT IN INDIA

- The wind power programmer in India was initiated towards the end of the Sixth Plan, in 1983- 84.
- In India, the wind energy programmer is managed and implemented by the Ministry of New and Renewable Energy sources, Government of India. The wind power potential in India is 49,130 MW as per the official estimates in the Indian Wind Atlas (2010) by the Centre for Wind energy Technology.
- The potential is calculated with respect to 2% land availability at windy locations and pertains to a 50 meter hub height level of the wind turbines.
- A total capacity of 17365.03 MW has been established up to March 31, 2012 in the country. India is now the fifth largest wind power producer in the world, after USA, Germany, Spain and China.
- The break-up of projects implemented in prominent wind potential states is as given in Table

Sr No.	State	Potential (MW)	Installed capacity (MW)
1	Andhra Pradesh	5394	245.50
2	Gujarat	10609	2,966.30
3	Karnataka	8591	1,933.50
4	Kerala	790	35.1
5	Madhya Pradesh	920	376.40
6	Maharashtra	5439	2,733.30
7	Rajasthan	5005	2,070.70
8	Tamil Nadu	5374	6,987.60
9	Others	7008	3.2
	Total	**49130**	**17351.50**

Bio Energy

INTRODUCTION

In the past few years, there have been significant improvements in renewable energy technologies along with declines in cost. The growing concern for the environment and sustainable development, have led to worldwide interest in renewable energies and bio-energy in particular. Biomass can be converted into modern energy forms such as liquid and gaseous fuels, electricity, and process heat to provide energy services needed by rural and urban populations and also by industry. This paper explains the different ways of extracting energy from biomass and a comparison is made among them. This paper also explains about the potentiality of biomass energy in India, analyses current situation compares bio- energy and other options for promoting development, brings out the advantages over the other renewable putting forth the drawbacks to be overcome to make it still more successful. This paper analyses current situation compares bio-energy and other options for promoting development, explore the potential for bio-energy.

In past 10 years or so, considerable practical experience has accumulated in India as well as in other developing and industrialized countries, on biomass energy production and conversion. India is pioneer among developing countries, with significant indigenous efforts in promoting renewable energy technologies. The importance of bioenergy as a modern fuel has been recognized. India has about 70,000 villages yet to be connected to the electricity grid. The supply of grid power to rural areas is characterized by

(a) Low loads
(b) Power shortages
(c) Low reliability
(d) Low and fluctuating voltages
(e) High transmission and distribution costs and power losses

Decentralized power generation based on renewable is an attractive option to meet the energy needs. The availability of biomass such as wood, cow-dung, leaf litter in rural areas is more. Hence a choice of biomass energy especially in rural areas is more reasonable but at the same time the technology is being developed to meet the large- scale requirements using biomass. Biomass energy has played a key role in the time of Second World War when there was a fuel deficiency. Many vehicles, tractors and trucks used wood gasifies, which generate producer’s gas, running an internal combustion Engine. One of the major advantages of biomass energy is that it can be used in different forms. For e.g., Gas generated from the biomass can be directly used for cooking or it can be used for running an internal combustion Engine for developing stationary shaft power or otherwise coupled to generator for generating electric power. The subsequent sections explain about the different ways of extracting energy from biomass, explaining about technological and economic aspects followed by a case study. The issue of land availability for biomass (wood) production is also discussed.

Different Ways of extracting energy from biomass

The different methods of biomass extraction can be broadly be classified as:

1) Anaerobic Digestion
2) Gasification
3) Liquefaction

Solid fuel combustion

The simplest and most common way of extracting energy from biomass is by direct combustion of solid matter. Majority of the developing countries especially in rural areas obtain the majority of their energy needs from the burning of wood, animal dung and other biomass. But burning can be inefficient. An open fireplace may let large amounts of heat escape, while a significant proportion of the fuel may not even get burnt.

Gasification

– Gasification is a process that exposes a solid fuel to high temperatures and limited oxygen, to produce a gaseous fuel. This is a mix of gases such as carbon monoxide, carbon dioxide, nitrogen, hydrogen and methane.
– Gasification has several advantages over burning solid fuel. One is convenience - one of the resultant gases, methane, can be treated in a similar way as natural gas, and used for the same purposes.
– Another advantage of gasification is that it produces a fuel that has had many impurities removed and will therefore cause fewer pollution problems when burnt. And, under suitable circumstances, it can produce synthesis gas, a mixture of carbon monoxide and hydrogen. This can be used to make almost any hydrocarbon (e.g., methane and methanol), which can then be substituted for fossil fuels. But hydrogen itself is a potential fuel of the future.

Paralysis

– Paralysis is an old technology with a new lease of life. In its simplest form it involves heating the biomass to drive off the volatile matter, leaving behind the black residue we know as charcoal. This has double the energy density of the original material. This means that charcoal, which is half the weight of the original biomass, contains the same amount of energy - making the fuel more transportable. The charcoal also burns at a much higher temperature than the original biomass, making it more useful for manufacturing processes. More sophisticated Paralysis techniques have been developed recently to collect the volatiles that are otherwise lost to the system. The collected volatiles produce a gas rich in hydrogen (a potential fuel) and carbon monoxide. These compounds, if desired, can be synthesized into methane, methanol and other hydrocarbons. 'Flash' Paralysis can be used to producebio-crude a combustible fuel.

Digestion

– Biomass digestion works by the action of anaerobic bacteria. These microorganisms usually live at the bottom of swamps or in other places where there is no air, consuming dead organic matter to produce, among other things, methane and hydrogen.
– We can put these bacteria to work for us. By feeding organic matter such as animal dung or human sewage into tanks - called digesters - and adding bacteria, we can collect the emitted gas to use as an energy source. This can be a very efficient means of extracting usable energy from such biomass - up to two-thirds of the fuel energy of the animal dung is recovered.
– Another, related, technique is to collect gas from landfill sites. A large proportion of household biomass waste, such as kitchen scraps, lawn clippings and pruning, ends up at the local tip. Over a period of several decades, anaerobic bacteria are at work at the bottom of such tips, steadily decomposing the organic matter and emitting methane. The gas can be extracted and used by 'capping' a landfill site with an impervious layer of clay and then inserting perforated pipes that collect the gas and bring it to the surface.

Fermentation

- Like many of the other processes described here, fermentation isn't a new idea. For centuries, people have used yeasts and other microorganisms to ferment the sugar of various plants into ethanol. Producing fuel from biomass by fermentation is just an extension of this old process, although a wider range of plant material can now be used, from sugar cane to wood fiber. For instance, the waste from a wheat mill in New South Wales has been used to produce ethanol through fermentation. This is then mixed with diesel to produce 'dishelm', a product used by some trucks and buses in Sydney and Canberra.
- An elaborated discussion on Digestion and Gasification, which are the major ways employed in India, are explained in subsequent sections.

Anaerobic Digestion

- Anaerobic Digestion is a biochemical degradation process that converts complex organic material, such as animal manure, into methane and other byproducts.

What is Anaerobic Digester?

Anaerobic digester (commonly referred to as an AD) is a device that promotes the decomposition of manure or “digestion” of the organics in manure to simple organics and gaseous biogas products. Biogas is formed by the activity of anaerobic bacteria. Microbial growth and biogas production are very slow at ambient temperatures. These bacteria occur naturally in organic environments where oxygen is limited. *Biogas is comprised of about 60% methane, 40% carbon dioxide, and 0.2 to 0.4% of hydrogen sulfide.* Manure is regularly put into the digester after which the microbes break down the manure into biogas and a digested solid. The digested manure is then deposited into a storage structure. The biogas can be used in an engine generator or burned in a hot water heater. AD systems are simple biological systems and must be kept at an operating temperature of 100 degrees F in order to function properly. The first methane digester plant was built at a leper colony in Bombay, India. Biogas is very corrosive to equipment and requires frequent oil changes in an engine generator set to prevent mechanical failure. The heating value of biogas is about 60% of natural gas and about 1/4 of propane. Because of the low energy content and its corrosive nature of biogas, storage of biogas is notpractical.

There are two major types of biogas designs promoted in India

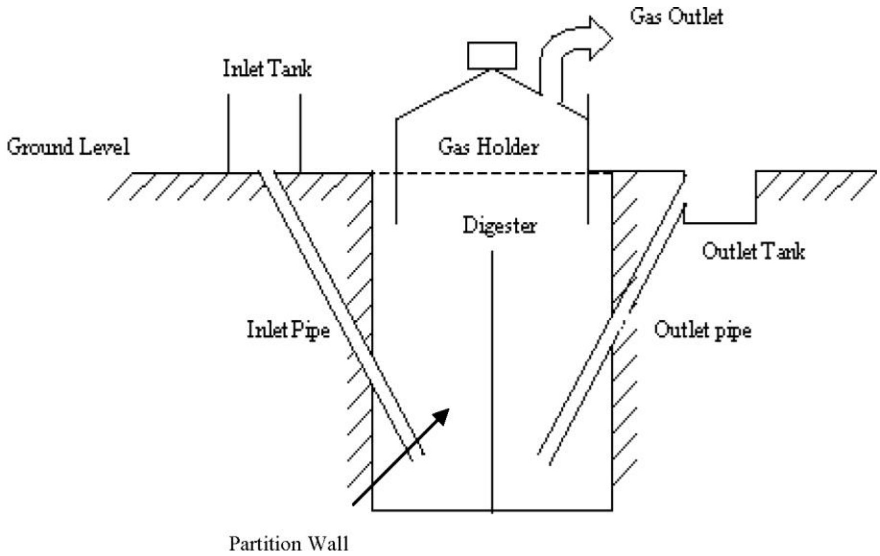
1) Floating Drum

2) Fixed Dome

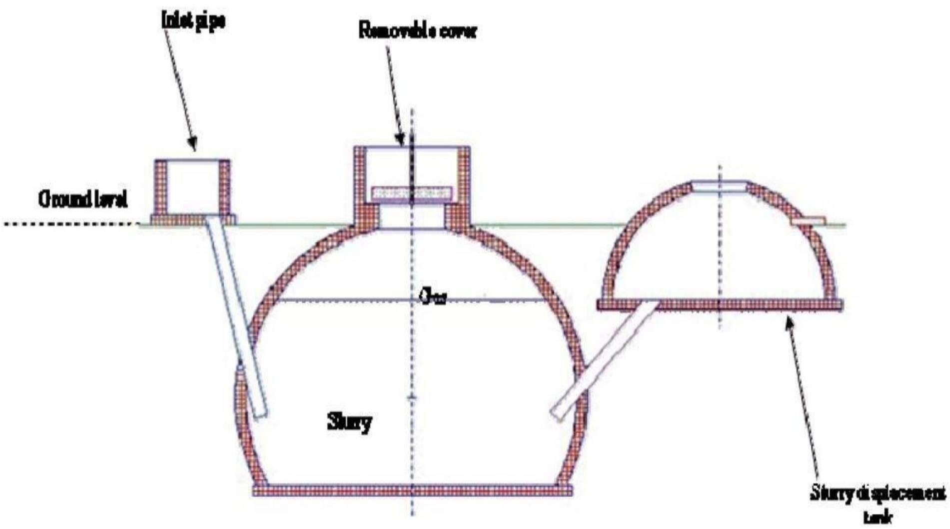
The floating drum is an old design with a mild-steel, Ferro-cement or fiberglass drum, which floats along a central guide frame and acts as a storage reservoir for the biogas produced. The fixed dome design is of Chinese origin and has dome structure made of cement and bricks. It is a low-cost alternative to the floating drum, but requires high masonry skills and is prone to cracks and gas leakages. Family biogas plants come in different size depending on the availability of dung and the quantity of biogas required for cooking. The average size of the family is 5-6 persons, and thus biogas plant of capacity 2-4 m^3 is adequate. The biomass requirement is estimated to be 1200 liters for afamily.

Comparison between two designs:

Fixed dome	**Floating Drum**
Digester and gas holder, masonry or concrete structure	Digester, masonry, Gas holder, mild steel or fiberglass
Requires high masonry skills	Low masonry or fabricating skills
Low reliability due to high construction failure	High reliability, gas holder prefabricated
Variable gas pressure	Constant gas pressure
Digester could be inside the ground	Requires space above ground for three tanks; inlet, digester, outlet
Low Cost (2 m^3 = Rs.5000)	Low Cost (2 m^3 = Rs.8000)



Floating Gasholder drum design (a conventional Indian design



Spherical shaped fixed - dome plant

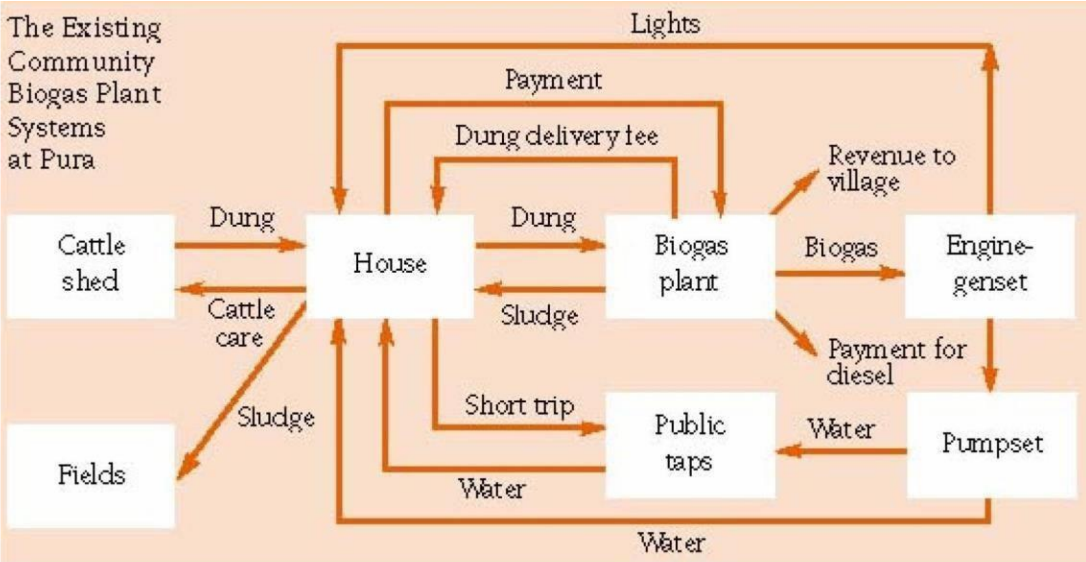
Uses of Biogas

Biogas can be directly used for cooking by supplying the gas though pipes to households from the plant. Biogas has been effectively used as a fuel in industrial high compression spark ignition engines. To generate electricity an induction generator can be used and is the simplest to interface to the electrical grid. Induction generators derive their voltage, phase, and frequency from the utility and cannot be used for stand-by power. If a power outage occurs generator will cease to operate. Synchronous generator can also be used to connect to the grid. However, they require expensive and sophisticated equipment to match the phase, frequency and voltage of the utility grid. Biogas can also be used as fuel in a hot water heater if hydrogen sulfide is removed from the gas supply.

Case Study of Community Biogas programmers in India

Biogas Electricity in Pure Village

In India, Biogas option is considered largely as a cooking fuel. The need for considering decentralized electricity options and the potential of biogas is analyzed. A field- demonstration programmer was implemented in pure village in South India to use cattle dung in a community biogas plant to generated electricity for services such as pumping drinking water and home lighting.



Community Biogas Plant in Pura Village

Technology

The Indian floating-drum design shown in fig.1 with modified dimensions for cost reductions was used. The Pure biogas plants have a capacity to digest up to 1.2 t cattle dung/day and produce 42.5-m3 biogas/day. Sand bed filters were installed to remove excess water and convert the sludge to dung-like consistency for subsequent use as a fertilizer. The filtrate, which contains the required anaerobic microorganisms, is mixed with the input dung. A 5 kW diesel engine is connected to a 5kVA, 440 V three-phase generator of electricity generation.

Lighting

Out of 87 households in the village 39 already had grid electricity, there are 103 fluorescent tube lights of 20 W capacity connected biogas generated electricity. Forty-seven houses opted for one tube light and 25 houses have two tube lights. Lighting is provided in the evening for 2.5 hours/day. Even homes connected to the grid had lighting connections from the biogas system.

Water supply

A submersible pump is connected to a tube well and water is pumped to storage tanks for 1 hour and 40 minutes/day. The majority of the households have opted for private taps at their doorsteps.

Biomass Gasifies:

Biomass, or more particularly wood, can be converted to a high-energy combustible gas for use in internal combustion engines for mechanical or electrical applications. This process is known as gasification and the technology has been known for decades, but its application to power generation is of recent origin. A biomass gasified consists of a reactor where, under controlled temperature and air supply, solid biomass is combusted to obtain a combustible gas called *Producers gas* (consisting of H_2 and CH_4). This gas passes through a cooling and cleaning system before it is fed into a compression ignition engine for generation of mechanical or electricity (by coupling to a generator). An assessment of its potential concluded that India presents a unique opportunity for large-scale commercial exploitation of biomass gasification technology to meet a variety of energy needs, particularly in the agricultural and rural sectors. The large potential of biomass gasification for water pumping and power generation for rural electrification was recognized.

Feed Stocks for producer-gas systems:

A range of crop residues and woody biomass from trees could be used as feed stocks for producer-gas systems. Currently, wood-based systems are available, and designs using other low-density biomass are under development and should soon be available in India. Crop residues with fuel potential are limited, since nearly all cereal and most pulse residues are used as fodder or manure and thus are not available as fuel. It is important to note that currently crop residues are used and have an opportunity cost. Rice husks are used in the cement industry, in rice mills and in the manufacture of bricks. Coconut leaves are used as thatch and the husk as fiber and sugarcane biogases is used in sugar mills. In Punjab, for rice-husk-based power generation systems, the price of residues such as rice husk could increase once new uses and demands are developed. Crop residues may continue to be used as fuel in domestic sector assuming that cooking-energy requirements are going to be met from bio-energy options. Constant supply of crop residues as feedstock cannot be assured over a long period on continuous basis and the transportation of low-density residues is not feasible. Woody biomass would be the dominant source of feedstock for gasification. The availability of woody biomass and production potentials are discussed in the following section.

Biomass availability issues:

Before assessing the country's bio-energy production potential, it is important to:

i. Estimate the land availability for biomass production.
ii. Identify and evaluate the biomass production options—yield/ha and financial viability,
iii. Estimate sustainable biomass production potential for energy,
iv. Estimate the energy potential of biomass production,
v. Assess the investment required and barriers to producing biomass sustainably for energy.

Different options for wood supply:

1. Conservation potential of wood used in cooking.
2. Producing wood on community, government, or degraded forest land.
3. Producing wood on degraded private or farm land.
4. Sustainable harvest from existing forest.
5. Logging waste.

Consideration of options 2 and 3 involves a range of related issues, such as land availability, land quality, competitive uses of land, and sustainability of wood production. Some proportion of wood currently burnt, as cooking fuel would become available for the producer-gas electricity option. Tree plantations, farm trees, homestead gardens, and degraded lands are the various sources of fuel wood used for cooking. Among these sources, only wood from tree plantations could be considered as easily available as feedstock for power generation. Woody biomass would be the dominant source of feedstock for gasification. The availability of woody biomass and production potentials are discussed in the following section.

Estimates of degraded land availability in India (Mha):

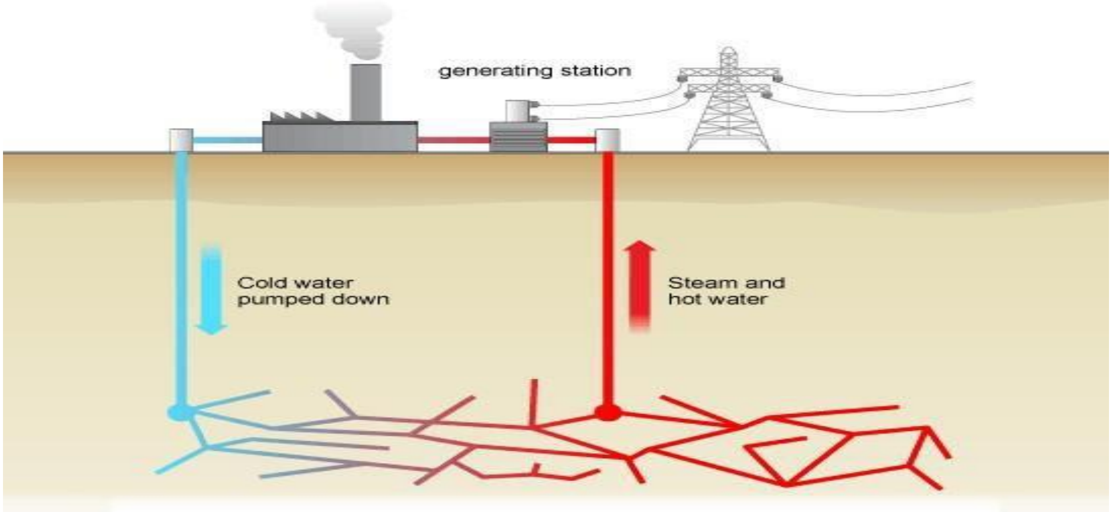
SPWD; degraded (waste) land quoted in PC	Degraded forest, Degraded non-forest, Total degraded land	Total degraded land 130 Mha
Chambers; land available for tree planting	Cultivated lands, Strips and boundaries, Uncultivated degraded land, Degraded forest land, Land for tree planting	Total Land for tree planting 84 Mha
Kapoor; land available plantation	Agricultural land, Pasture land, Fallow, Urban	Total land for tree 106 Mha
Ministry of Agriculture	Forest land with < 10% tree crown cover, Grazing land, Tree groves, Culturable waste, Old fallow,	Total degraded land 66 Mha

UNIT-III

Geothermal energy:

Geo thermal energy

- Geo thermal energy itself on earth's surface in the form of geyster, hot spring, furnar hole & boing Mud
- By drilling hole 3 km deep in the field the steam and water comes out from surface at temperature Up to 500°c
- It can be used for power generating.



Geothermal power plant:

Geothermal electricity is electricity generated from geothermal energy. Technologies in use include dry steam power plants, flash steam power plants and binary cycle power plants. Geothermal electricity generation is currently used in 24 countries while geothermal heating is in use in 70 countries.

Estimates of the electricity generating potential of geothermal energy vary from 35 to 2000 GW. Current worldwide installed capacity is 10,715 megawatts (MW), with the largest capacity in the United States (3,086 MW), Philippines, and Indonesia.

Geothermal Power (Hot Dry Rocks)

Geothermal heat of over 200 °C can be delivered from up to 5000 m deep holes to operate organic Rankine cycles or Kalina cycle power machines. Unit sizes are about 1 MW today and limited to about 100 MW maximum in the future. Geothermal energy is often used for the co-generation of heat and power. Geothermal power plants are used all over the world where surface near geothermal hot water or steam sources are available, like in USA, Italy and the Philippines. In the MED-CSP study region those conventional geothermal potentials are significant in Island, Italy, Turkey, Yemen and Iran. Those potentials are small in comparison to the HDR potentials and are not quantified separately in the study. The Hot Dry Rock technology aims to make geothermal potentials available everywhere, drilling deep holes into the ground to inject cold water and receive hot water from cooling down the hot rocks in the depth /IGA 2004/. However, this is a very new though promising approach and technical feasibility must still be proven. Geothermal power plants provide power on demand using the ideal storage of the earth's hot interior as reservoir. They can provide peak load, intermediate load or base load electricity. Therefore, the capacity factor of geothermal plants is defined by the load and their operation mode. Assuming a plant availability of 90 %, their capacity credit would have that same value.

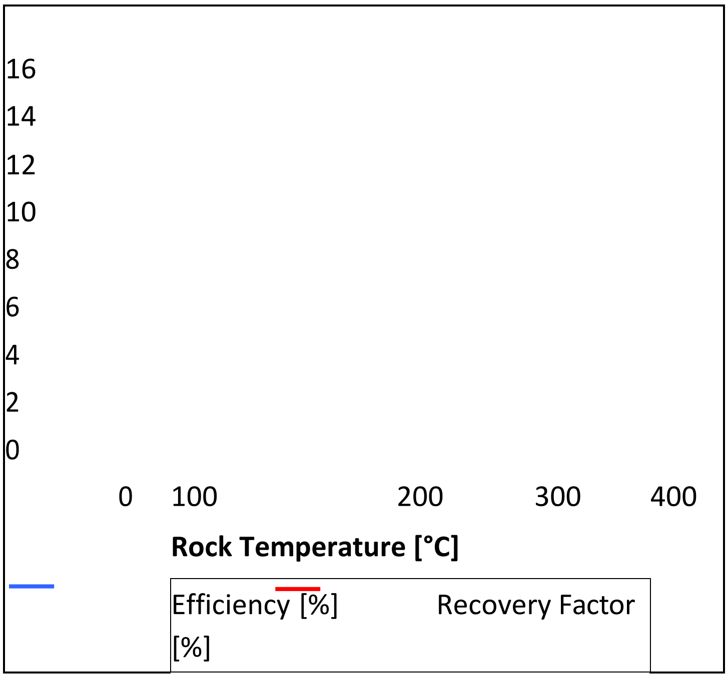
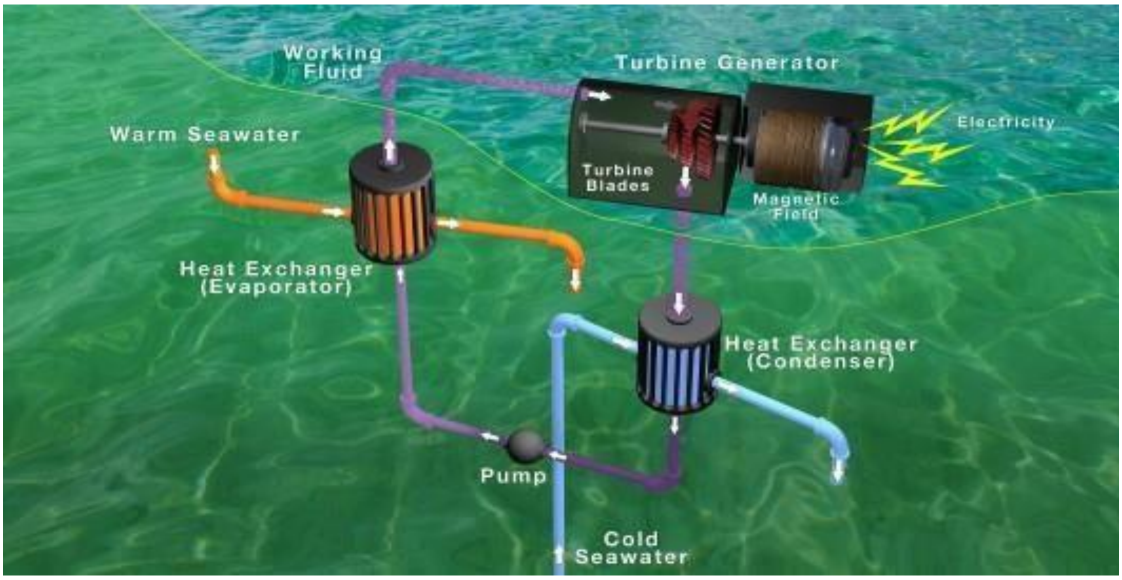


Figure 2-6: Efficiency (□) and recovery factor (R) of geothermal power schemes as function of temperature adapted from /TAB 2003/.

The available heat in place E_{th} is calculated as a function of the volume of rocks that will be affected by the cooling process /TAB 2003/. From that the extrac. Table 2-geothermal electricity per year E_{geo} can be calculated as a function of the power cycle efficiency, the recovery factor and the total time of extraction. The recovery factor takes into account that only a small part of the affected rock volume is cooled down, and that the lower cycle temperature is higher than the surface temperature.

Ocean thermal energy conversion (OTEC):

- Ocean serves a big store house of solar energy
- At water surface 23°c-source ,while temperature at depth of 100m is 5°c-sink
- Temperature differential can be used to run heat engine & power can be produce using working fluids NH_3, R-12, propane gas .



Ocean thermal energy conversion (OTEC) uses the difference between cooler deep and warmer shallow or surface ocean waters to run a heat engine and produce useful work, usually in the form of electricity.

A heat engine gives greater efficiency and power when run with a large temperature difference. In the oceans the temperature difference between surface and deep water is greatest in the tropics, although still a modest 20ºC to 25ºC. It is therefore in the tropics that OTEC offers the greatest possibilities. OTEC has the potential to offer global amounts of energy that are 10 to 100 times greater than other ocean energy options such as wave power. OTEC plants can operate continuously providing a base load supply for an electrical power generation system. The main technical challenge of OTEC is to generate significant amounts of power efficiently from small temperature differences. It is still considered an emerging technology. Early OTEC systems were of 1 to 3% thermal efficiency, well below the theoretical maximum for this temperature difference of between 6 and 7%.[2] Current designs are expected to be closer to the maximum. The first operational system was built in Cuba in 1930 and generated 22 kW. Modern designs allow performance approaching the theoretical maximum Carnot efficiency and the largest built in 1999 by the USA generated 250 kW.

The most commonly used heat cycle for OTEC is the Rankine cycle using a low- pressure turbine. Systems may be either closed-cycle or open-cycle. Closed-cycle engines use working fluids that are typically thought of as refrigerants such as ammonia or R-134a. Open-cycle engines use vapour from the seawater itself as the working fluid.

OTEC can also supply quantities of cold water as a by-product. This can be used for air conditioning and refrigeration and the fertile deep ocean water can feed biological technologies. Another by-product is fresh water distilled from the sea. Cold seawater is an integral part of each of the three types of OTEC systems: closed- cycle, open-cycle, and hybrid. To operate, the cold seawater must be brought to the surface. The primary approaches are active pumping and desalination. Desalinating seawater near the sea floor lowers its density,

which causes it to rise to the surface.
The alternative to costly pipes to bring condensing cold water to the surface is to pump vaporized low boiling point fluid into the depths to be condensed, thus reducing pumping volumes and reducing technical and environmental problems and lowering costs.

Diagram of a closed cycle OTEC plant

Closed-cycle systems use fluid with a low boiling point, such as ammonia, to power a turbine to generate electricity. Warm surface seawater is pumped through a heat exchanger to vaporize the fluid. The expanding vapor turns the turbo-generator. Cold water, pumped through a second heat exchanger, condenses the vapor into a liquid, which is then recycled through the system.

In 1979, the Natural Energy Laboratory and several private-sector partners developed the "mini OTEC" experiment, which achieved the first successful at-sea production of net electrical power from closed-cycle OTEC.[12] The mini OTEC vessel was moored 1.5 miles (2 km) off the Hawaiian coast and produced enough net electricity to illuminate the ship's light bulbs and run its computers and television.

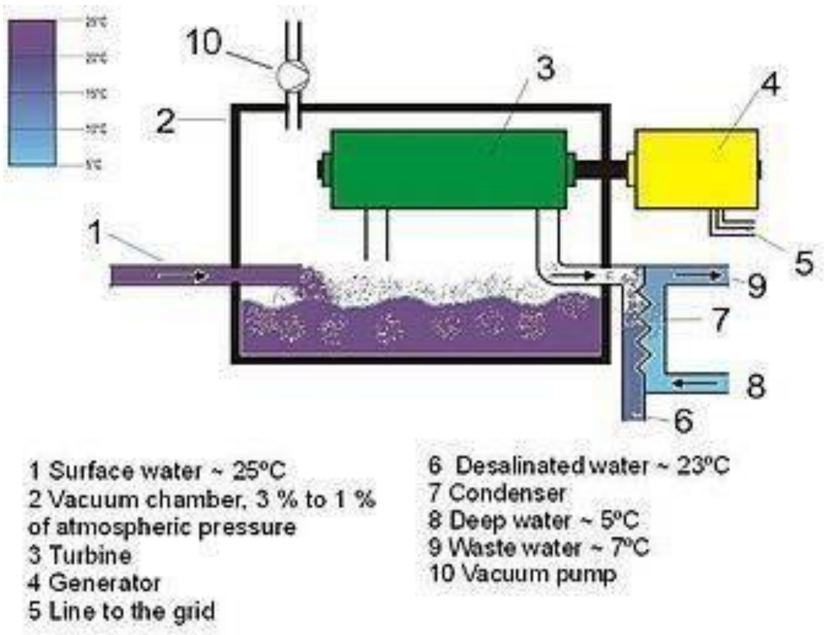


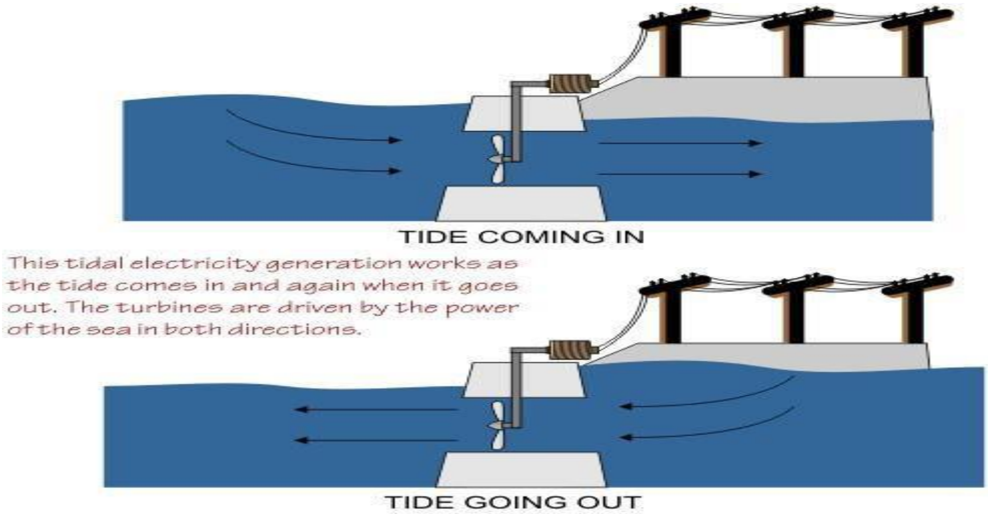
Diagram of an open cycle OTEC plant

Open-cycle OTEC uses warm surface water directly to make electricity. Placing warm seawater in a low-pressure container causes it to boil. The expanding steam drives a low-pressure turbine attached to an electrical generator. The steam, which has left its salt and other contaminants in the low-pressure container, is pure fresh water. It is condensed into a liquid by exposure to cold temperatures from deep-ocean water. This method produces desalinized fresh water, suitable for drinking water or irrigation.
In 1984, the *Solar Energy Research Institute* (now the National Renewable Energy Laboratory)

developed a vertical-spout evaporator to convert warm seawater into low- pressure steam for open-cycle plants. Conversion efficiencies were as high as 97% for seawater-to-steam conversion (overall efficiency using a vertical-spout evaporator would still only be a few per cent). In May 1993, an open-cycle OTEC plant at Keahole Point, Hawaii, produced 50,000 watts of electricity during a net power-producing experiment. This broke the record of 40 kW set by a Japanese system in 1982.

Tidal energy:

- Tides are generated due to gravitational pull between the earth and the moon and sun.
- The difference between high tide & low tide could be utilized to operate hydraulic turbine.



Tidal power, also called **tidal energy**, is a form of hydropower that converts the energy of tides into electricity or other useful forms of power. The first large-scale tidal power plant (the Rance Tidal Power Station) started operation in 1966.

Although not yet widely used, tidal power has potential for future electricity generation. Tides are more predictable than wind energy and solar power. Among sources of renewable energy, tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability. However, many recent technological developments and improvements, both in design (e.g. dynamic tidal power, tidal lagoons) and turbine technology (e.g. new axial turbines, cross flow turbines), indicate that the total availability of tidal power may be much higher than previously assumed, and that economic and environmental costs may be brought down to competitive levels.

Historically, tide mills have been used, both in Europe and on the Atlantic coast of North America. The earliest occurrences date from the Middle Ages, or even from Roman times.

Tidal power is extracted from the Earth's oceanic tides; tidal forces are periodic variations in gravitational attraction exerted by celestial bodies. These forces create corresponding motions

or currents in the world's oceans. The magnitude and character of this motion reflects the changing positions of the Moon and Sun relative to the Earth, the effects of Earth's rotation, and local geography of the sea floor and coastlines.

Tidal power is the only technology that draws on energy inherent in the orbital characteristics of the Earth–Moon system, and to a lesser extent in the Earth–Sun system. Other natural energies exploited by human technology originate directly or indirectly with the Sun, including fossil fuel, conventional hydroelectric, wind, bio-fuel, wave and solar energy. Nuclear energy makes use of Earth's mineral deposits of fissionable elements, while geothermal power taps the Earth's internal heat, which comes from a combination of residual heat from planetary accretion (about 20%) and heat produced through radioactive decay (80%). A tidal generator converts the energy of tidal flows into electricity. Greater tidal variation and higher tidal current velocities can dramatically increase the potential of a site for tidal electricity generation.

Because the Earth's tides are ultimately due to gravitational interaction with the Moon and Sun and the Earth's rotation, tidal power is practically inexhaustible and classified as a renewable energy resource. Movement of tides causes a loss of mechanical energy in the Earth–Moon system: this is a result of pumping of water through natural restrictions around coastlines and consequent viscous dissipation at the seabed and in turbulence. This loss of energy has caused the rotation of the Earth to slow in the 4.5 billion years since its formation. During the last 620 million years the period of rotation of the earth (length of a day) has increased from 21.9 hours to 24 hours; in this period the Earth has lost 17% of its rotational energy. While tidal power may take additional energy from the system, the effect is negligible and would only be noticed over millions of years.

The world's first commercial- scale and grid-connected tidal stream generator – Sea Gen in Strangford Lough. The strong wake shows the power in the tidal current. Top-down view of a DTP dam. Blue and dark red colors indicate low and high tides, respectively.

Tidal power can be classified into three generating methods:

Tidal stream generators (or TSGs) make use of the kinetic energy of moving water to power turbines, in a similar way to wind turbines that use moving air. Tidal barrages make use of the potential energy in the difference in height (or *head*) between high and low tides. Barrages are essentially dams across the full width of a tidal estuary.

Wave energy:

– The wave energy is developed due to wind interacting with the surface of the ocean. wind get 1 to 5% of sun energy and part of this is transfer to wave this can be used for power generating.

UNIT-4

HYDROPOWER

Basic principles and features

The basic principles are explained in the lecture notes on Energy Sources and Generation of Energy Carriers, see sections 4 and 6.3.2.

Sustainable potential

Also the sustainable potential is discussed in the lecture notes on Energy Sources and Generation of Energy Carriers, see section 4. The emphasis there is on large scale hydropower generation. Small scale use of hydropower can be quite important locally even though the contribution to the overall national energy balance is marginal.

In Sweden, small hydropower plants with a capacity below 1500 kW is contributing with about 2 TWh(el) annually. The potential for expansion of small hydropower in Sweden has been estimated to about 2,5 TWh(el).

Technological state of the art

The technology for exploitation of hydropower in large and small scale is well developed and fully commercial.

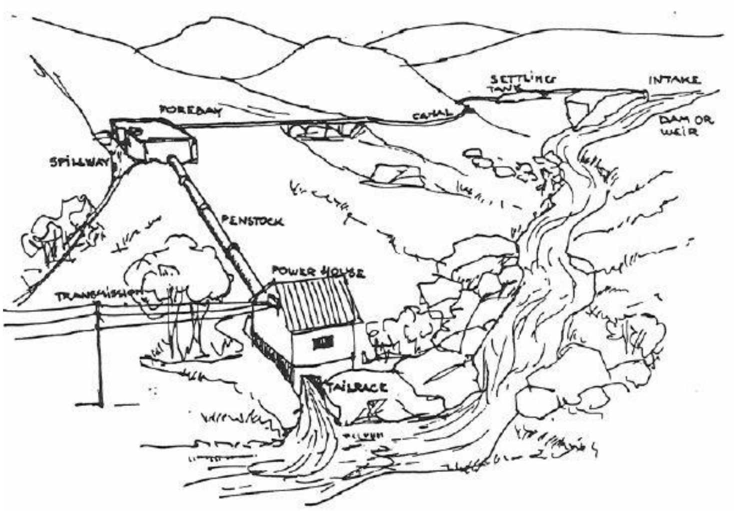
Economy

A hydropower plant does not normally cost much to operate. The driving energy is available at zero cost. The economy is almost entirely depending on the initial investment for civil work, like dams and water channels, machines, buildings and installation of the machines. Building of a power line from the site of the power plant to the national grid or an isolated group of consumers may also require a significant investment.

The necessary investment varies depending on the conditions on site. The range can be 1300 – 6000 SEK/annual kWh. With an interest rate of 5% and an economic life of 40 years, the capital cost for generation will be 86 – 396 SEK/MWh(el). Maintenance costs range between 10 and 40 SEK/MWh(el)

Environmental considerations

Exploitation of hydropower resources will always lead to landscape changes. The picture is seldom as idyllic as the illustration of small scale hydropower generation in figure 4 implies. A water-fall or rapids will disappear or at least show a reduced water flow. Large parts of the original river may be left dry. If a man-made water reservoir is included in the project, the dam as such means a change in the landscape. More important is the flooding of land caused by the dam and the appearance of the shores when the water level in the reservoir is low. The effects on aquatic life can be significant. In particular migrating fish will be affected.



Flooding of large land areas may make it necessary to relocate people and when that is not necessary their possibilities to use agriculture, fishing and other similar activities as main economic activities may be eliminated or reduced.

Also cultural heritage may be affected. The seriousness of these effects is very site specific. The effects may be mitigated by various means but at some cost. Few large hydropower projects today can be implemented without considerable disturbances for the local population.

Possible future

Despite the large local environmental disturbances caused by exploitation of large hydropower resources, a considerable expansion of hydropower all over the World can be expected. The effects are after all local and those that are directly affected can be compensated at least for economic losses. It is likely though those environmental concerns will be more important when projects are designed.

Nuclear Energy

Energy is one of the main requirements of sustaining human civilization. Conventional sources of energy, which account for over 85% of the total energy consumed by the mankind, are fossil fuels. Fossil fuels were formed over millions of years from remains of plants and animals by action of pressure and heat and are now found beneath the earth's surface. When such fuels are burnt, they release chemical energy trapped in them. Fossil fuels consist of coal, petroleum and natural gases. Coal is a solid hydrocarbon with nearly 75% of the world's deposit being found in China, USA and the Russian Federation. Though most abundant and the lesat expensive of the three, burning coal causes a lot of environmental problems as it releases harmful chemical SO , which can cause *acid rain.* In addition, release of large amount of carbon dioxide is responsible for global warming.

Oil and natural gas deposits are limited and they are being depleted at a very fast rate. Though the nature makes them, fossil fuels are *non-renewable* sources of energy as it takes nature millions of years to make them while humans consume them at a fast rate. Nuclear energy is produced from practically unlimited amount of energy trapped in all matter. Production of nuclear energy does not produce particulate impurities like NO, SO etc. and also does not release CO. In this sense, nuclear energy is a clean fuel. However, there are several issues connected with disposal of radioactive nuclear waste and decommissioning of old nuclear power plants, which makes the production of nuclear energy a contentious subject. In addition, the technology that produces nuclear power can also be used to produce nuclear bombs, which makes transfer of nuclear technology a delicate issue. Nuclear energy is made available by **fission** and by **fusion**. In the following, we will discuss the principle behind production of nuclear energy.

Mass - Energy Equivalence

According to Einstein's special theory of relativity, a particle of mass has equivalently an amount of energy given by the relation

$$E = mc^2$$

where 'C' is the speed of light in vacuum which has a numerical value.

The theory of relativity introduces the concept of *rest mass* , which is the mass an object has when it is at rest relative to an inertial frame. If the mass of an object in such a frame is $\mathbf{M_0}$, the object has an equivalent energy given by . In addition to the rest energy, the object may have a kinetic energy **K.**

$$E_0 = m_0 c^2$$

Because of motion that it has with respect to the inertial frame. The total energy of the object may be written as

$$E = m_0 c^2 + K$$

Since the product of mass and the square of the velocity of light has the dimensions of energy, it is possible to express k as a product of some mass δm times $\mathbf{c^2}$, so that the energy of the object may be written as $E = mc^2$ where $m = m_0 + \delta m.$ In this expression ***m*** is the relativistic mass of the body, which depends both on the rest mass of the body and the state of motion of the body. According to the special theory of relativity, for a body moving with a speed with respect to an inertial frame,

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Nuclear fusion is essentially the antithesis of the fission process. Light nuclei are combined in order to release excess binding energy and they form a heavier nucleus. Fusion reactions are responsible for the energy of the sun. They have also been used on earth for uncontrolled release of large quantities of energy in the thermonuclear or 'hydrogen' bombs. However, at the present time, peaceful commercial applications of fusion reactions do not exist. The enormous potential and the problems associated with controlled use of this essentially non delectable energy source are discussed briefly in this chapter.

Fusion Reactions

The concept of nuclear fusion has been described in Chapter 12. It is summarized in Figure 14-1, which is analogous to Figure 13-2 for nuclear fission. As the nuclei of two light atoms are brought closer to each other, they become increasingly destabilized, due to the electric repulsion of their positive charges. Work must be expended to achieve this and so the energy of the two nuclei increases. If this “activation energy” is provided to overcome the repulsive forces, fusion of the two nuclei into a stable heavier nucleus will take place and a large amount of energy will be released. The net energy output is potentially larger in the case of fusion than in the case of fission.

The reaction described in Illustration 14-1 (fusion of deuterium and tritium into helium) is only one of the possible reactions that could be the basis for the fusion power reactors of the future. The others are the following:

$$ {}_1H^2 + {}_1H^2 = {}_1p^1 + {}_1H^3 \quad (+\ 4.0\ \text{MeV}) $$

$$ {}_1H^2 + {}_1H^2 = {}_0n^1 + {}_2He^3 \quad (+\ 3.3\ \text{MeV}) $$

$$ {}_1H^2 + {}_2He^3 = {}_1p^1 + {}_2He^4 \quad (+\ 18.3\ \text{MeV}) $$

$$ {}_3Li^6 + {}_0n^1 = {}_2He^4 + {}_1H^3 \quad (+\ 4.8\ \text{MeV}) $$

Deuterium and tritium are the main ingredients in most fusion reactions. Deuterium is a stable form of hydrogen; it is found in ordinary water. Tritium is a radioactive form of hydrogen, not found in nature. In contrast to the situation with fission, where tritium is produced (and thus contributes to radioactivity), here it is consumed. As shown above, it can be obtained from lithium, Li-6, a relatively abundant metal found in mineral ores. A simple calculation, based on the fact that there is one deuterium atom in every 6500 atoms of hydrogen, shows that in 65,000 pounds of water there is about one pound of deuterium. Now, water is in general an abundant resource on our planet. This fact, together with the fact that enormous amounts of energy are released in fusion reactions, makes fusion an essentially non delectable energy source. To quote a physicist at the Princeton University's Plasma Physics Laboratory, the leading fusion research center in the U.S., “the top two inches of Lake Erie contain 1.6 times more energy than all the world's oil supplies” (*Business Week*, October 15, 1990, p. 62). The reader can easily become convinced that such comparisons are not exaggerated. Another simple calculation shows that if only 1% of the deuterium in world's oceans – equivalent to 1040 atoms of deuterium – is used to produce tritium, this would be equivalent to using up all the world's fossil fuel reserves 500,000 times. These are impressive numbers. Unfortunately, however, significant technical difficulties stand in the way of commercial development of this technology.

Illustration 14-1. Calculate the energy released in the following fusion reaction:

$$\underset{\text{(deuterium)}}{{}_1H^2} + \underset{\text{(tritium)}}{{}_1H^3} = \underset{\text{(helium)}}{{}_2He^4} + \underset{\text{(neutron)}}{{}_0n^1}$$

Compare this energy with that calculated in Illustration 13-1 for the fission of uranium-235.

Solution.

Knowing the masses of the individual nuclei involved in this fusion reaction allows us to calculate the mass decrease.

$$\underset{(2.014102)}{{}_1H^2} + \underset{(3.016050)}{{}_1H^3} = \underset{(4.002603)}{{}_2He^4} + \underset{(1.008665)}{{}_0n^1}$$

$$5.030152 \quad > \quad 5.011268$$

So, 0.018884 a.m.u are converted to energy for every nucleus of deuterium (or tritium) that undergoes fusion. Therefore,

$$\Delta E = \Delta m\, c^2$$

$$= (0.018884 \text{ a.m.u.}) \left(\frac{1.66056\text{x}10^{-27} \text{ kg}}{1 \text{ a.m.u.}}\right) (3\text{x}10^8 \frac{\text{m}}{\text{s}})^2 =$$

$$= (2.82\text{x}10^{-12} \text{ J}) \left(\frac{6.242\text{x}10^{12} \text{ MeV}}{1 \text{ J}}\right) = 17.6 \text{ MeV/nucleus}$$

$$= \left(17.6\frac{\text{MeV}}{\text{nucleus}}\right) \left(\frac{1 \text{ nucleus}}{2 \text{ nucleons}}\right) = 8.8 \text{ MeV/nucleon (of deuterium)}$$

This energy is one order of magnitude higher than the energy (per nucleon) released in the fission of U-235.

A Fusion Reactor

Fusion offers several advantages over fission. One advantage is that the reserves of fusion able isotopes are much larger than those of fissionable isotopes; in fact, they are essentially unlimited. Another advantage is that the products of fusion reactions are less radioactive then the products of fission reactions. Among the products of the fusion reactions listed above, only tritium and the neutrons are radioactive. The last advantage of fusion lies in its inherent safety. There would be very little fusion able material at any given time in the reactor and the likelihood of a runaway reaction would thus be very small.

Furthermore, the reaction is so hard to achieve in the first place that small perturbations in reactor conditions would probably terminate it. Heating of the reacting mixture to a very high temperature, to overcome the repulsive forces of positively charged nuclei; (b) compressing the mixture to a high density so that the probability of collision (and thus reaction) among the nuclei can be high; and (c) keeping the reacting mixture together long enough for the fusion reaction to produce energy at a rate that is greater than the rate of energy input (as heat and compression). The first challenge is that of providing a huge amount of energy to the reactants. This is why fusion is called a *thermonuclear* reaction. Table 14-1 shows the mind-boggling temperature thresholds ("ignition temperatures") needed to accomplish some of the fusion reactions shown above.

Heating requirements for selected fusion reactions

Fusion Reaction				Threshold Temperature (°C)
D + D	=	$_2He^3 + n$	+ 3.3 MeV (79 MJ/g)	400,000,000
D + D	=	T + p	+ 4.0 MeV (97 MJ/g)	400,000,000
D + T	=	$_2He^4 + n$	+ 17.6 MeV (331 MJ/g)	45,000,000
D + $_2He^3$	=	$_2He^4 + p$	+ 18.3 MeV (353 MJ/g)	350,000,000

D=deuterium; T=tritium; p=proton; n=neutron.

The second and third challenges are collectively referred to as the *confinement* problem. It is easily understood that the reacting mixture – called 'plasma' at the high temperatures involved
– cannot be brought together (or confined) in ordinary vessels. The presence of solid vessels is ruled out because they would carry away the heat necessary to reach the very high ignition temperatures. Magnets (magnetic confinement) and lasers (inertial confinement) are used instead (in designs that are too complicated to concern us here). Current research efforts in the development of nuclear fusion technology are focused on achieving the so-called *breakeven point*. The production of a plasma at sufficiently high temperature and particle density, held together long enough to produce at least as much energy as is being consumed in this process, is being pursued. In addition to the temperature requirement, the so-called *Lawson criterion* must be met, meaning that the product of particle density (in nuclei per cubic centimeter) and confinement time (in seconds) must exceed 1014. This criterion can be satisfied, for example, by having 1014 nuclei/cm3 held together for one second (using magnetic confinement), or by having 1025 nuclei/cm3 held together for 10-11 seconds (using inertial confinement).

Although the ultimate objective is still elusive, a number of important milestones have been reached. In late 1991 a group of European scientists made perhaps the most significant one. They successfully fused tritium with deuterium, thus releasing a 2-second pulse of energy equivalent to 2 megawatts (see "Breakthrough in Nuclear Fusion Offers Hope for Power of Future," NYT of 11/11/91; "Hot Fusion Test Using New Fuel Shows Promise," WSJ of 11/11/91; "Europeans ahead of U.S. efforts to tap fusion energy, experts say," PI of 11/12/91; "Fusion needs an infusion," *USA Today* of 11/12/91; "Harnessing the physics of the sun," USNWR of 11/25/91). More recently, at the Tokamak reactor in Princeton, NJ, a record-breaking one- second 10.7 MW burst – mentioned on p. 257 – was achieved with a 50-50 deuterium-tritium fuel (see "Experimental Fusion Reactor At Princeton Sets a Record," NYT of 11/9/94).

Bringing fusion to the level of technological viability for electricity production and to commercial scale will take several decades and billions of dollars of further research and development. Even with support from the Department of Energy, a demonstration plant is not expected to be built in the U.S. until 2025. This support has not been as large in recent years as it was in the late 1970s and early 1980s, as Figure 14-2 shows. According to (probably) optimistic estimates, the construction of a commercial plant might be achieved by 2040, but only if this R&D support is increased substantially. Given the tremendous costs involved, international collaboration is being pursued. Design and construction of the International Thermonuclear Experimental Reactor (ITER), which will go beyond short fusion bursts, is being financed by the U.S., Japan, Russia and the European Union; it is expected to cost some $10 billion and the jury is still out regarding its successful completion (see “U.S. joins other nations hoping for better nuclear plants,” NYT of 7/28/92; “Dunkin' dough: Nuclear fusion can ill afford the managerial turmoil surrounding its most prominent experiment,” *Economist* of 7/30/94; and “Cold Calculations Chill the Hot Pursuit of Cheap Fusion Power,” NYT of 12/10/96).

The “Cold Fusion” Confusion

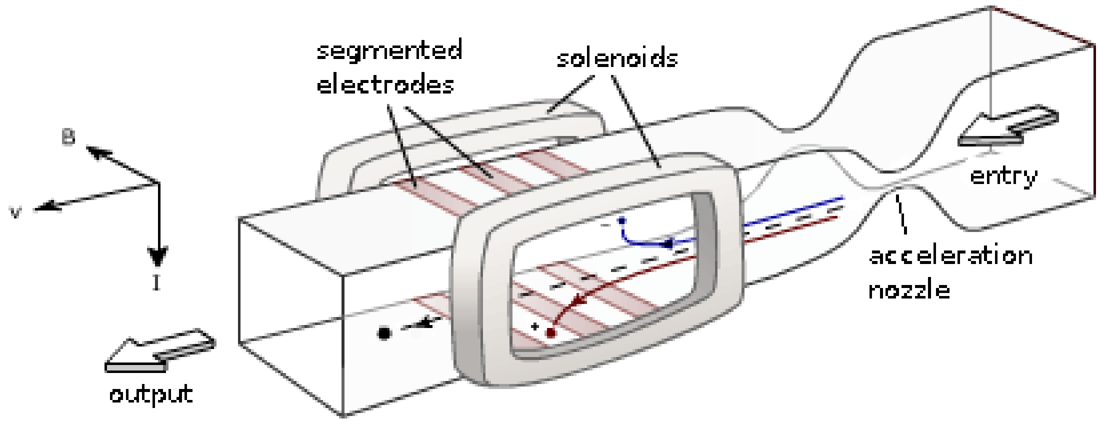
In March of 1989, two chemists called a press conference at the University of Utah to announce a startling discovery which had eluded physicists for decades. They claimed to have produced “fusion in a jar.” This reaction was claimed to have occurred at room temperature within a palladium electrode immersed in a beaker of deuterium-containing water:

$$_1H^2 + {}_1H^2 = {}_2He^4 + 23.85 \text{ MeV}$$

This new nuclear reaction – if indeed possible at such extremely low temperatures – would produce a larger amount of energy than the traditional ones (see Table 14-1). It is not surprising, therefore, that a frenzy or activity followed this announcement. For their media coverage, see Investigation 14-1. Many months of frantic research activity were spent by scientists, in dozens of laboratories all over the world, to reproduce these results. The scientists themselves got caught up in the media ‘show’ and there were almost daily claims and counter- claims about the validity of this new approach to harnessing fusion. The final verdict, at least for the time being, was disappointing: the claims were too good to be true. Bursts of heat were indeed detected, suggesting that some unusual process is taking place within the palladium electrode, but no characteristic byproducts of the possible reactions (neutrons, gamma rays or enough tritium) were detected. There is no question that, if indeed possible, this reaction would rank as one of the major discoveries in the history of mankind and would solve most of world's energy problems. This idea has probably led the two scientists to announce their results before verifying them thoroughly. Society will thus have to continue to seek more complicated – and more expensive – solutions to its energy problems.

Generator (**MHD generator**):

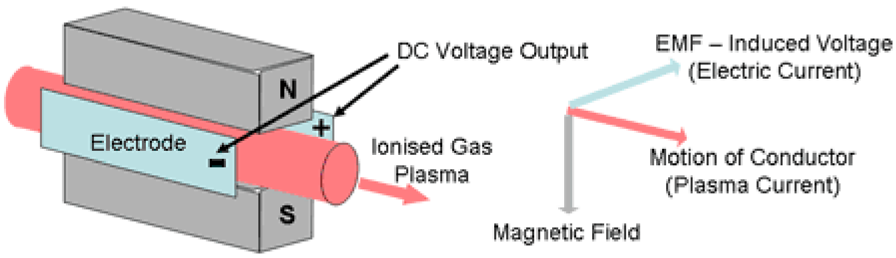
A magneto hydrodynamic **generator** (**MHD generator**) is a magneto hydrodynamic device that transforms thermal energy and kinetic energy into electricity. **MHD generators** are different from traditional electric generators in that they operate at high temperatures without moving parts.



MHD Generator

Faraday linear nozzle with segmented electrodes

Magneto hydrodynamic power generation principle:



Magnetohydrodynamic Power Generation (Principle)

A **magneto hydrodynamic generator** (**MHD generator**) is a magneto hydrodynamic device that transforms thermal energy and kinetic energy into electricity. MHD generators are different from traditional electric generators in that they operate at high temperatures without moving parts. MHD was developed because the hot exhaust gas of an MHD generator can heat the boilers of a steam power plant, increasing overall efficiency. MHD was developed as a topping cycle to increase the efficiency of electric generation, especially when burning coal or natural gas. MHD dynamos are the complement of MHD proposers, which have been applied to pump liquid metals and in several experimental ship engines.

SOLAR POND

- In the continuous or discontinuous energy supply system, the energy storage is required to balance the energy of mismatches between the demand and the supply of energy.
- Especially in solar energy system the energy available only particular duration and only day time, hence thermal energy storage is required to improve performance and reducing total cost.
- Solar pond is a device to collect and store the solar thermal energy in the form of sensible heat.
- It consists of an expanse of water about 2 m deep with a thick durable plastic liner laid at the bottom. Salts like magnesium chloride, sodium chloride or sodium nitrate are dissolved in the water, concentration varying from 20 % to 30 %.

There are 3 distinct layers of water in the pond as:

1. The top layer - Surface convective zone:
- Normally, it has a small thickness, about 0.3 m to 0.5 m.
- It has a low, uniform concentration (low salt content, salinity < 5 %) as well as a fairly uniform temperature close to atmospheric temperature.
2. An intermediate insulating layer with a salt gradient - Non-convective zone:
- It is much thicker, about 1.0 m to 1.5 m and occupies more than half the depth of the pond.
- Both concentration and temperature increases with depth in this zone.
- This layer establishes a density gradient that prevents heat exchange by natural convection.

3. The bottom layer - Lower convective or storage zone:
- Normally, it has a thickness about 0.5 m to 1 m and high salt content (salinity about 20 %).
- Both concentration and temperature are nearly constant in this zone.
- This zone serves as the main heat collection as well as thermal storage medium

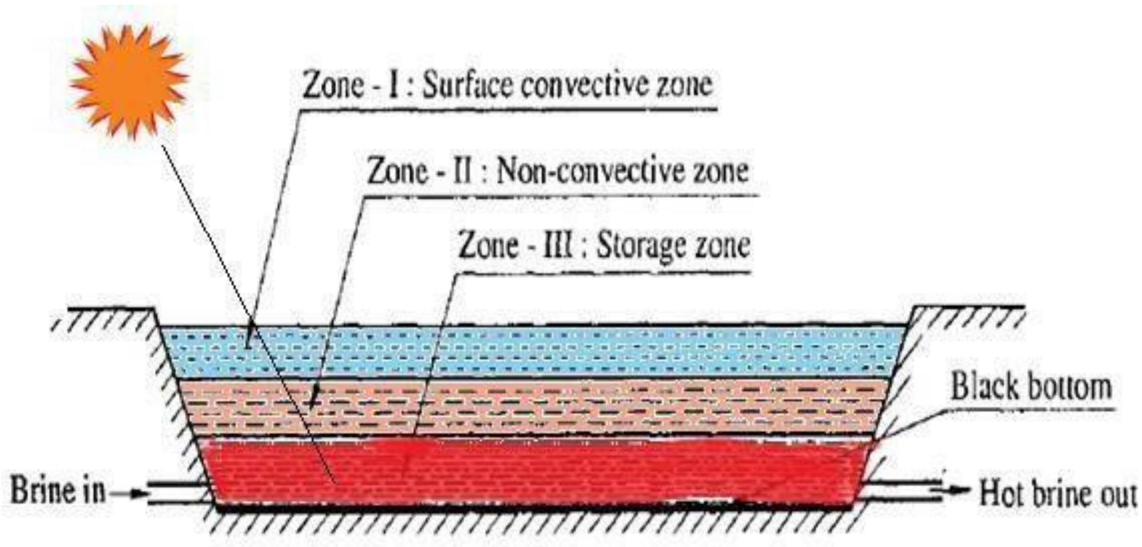


Fig. Solar pond

- If the water is relatively translucent, and the pond's bottom has high optical absorption, then nearly all of the incident solar radiation (sunlight) will go into heating the bottom layer. When solar energy is absorbed in the water, its temperature increases which causes thermal expansion and reduced density.

- If the water were fresh (without salts) the low-density hot water would float to the surface, causing circulation of water by convection. The temperature gradient alone causes a density gradient that decreases with depth.
- The situation is changed if the pond contains salts water at bottom with layer of fresh water above it. In this case, the salinity gradient forms a density gradient that increases with depth and this counteracts the temperature gradient, thus preventing heat in the lower layers from moving upwards by convection and leaving thepond.
- Because of its salt content, the solar pond bottom is denser than the cooler fresh water at the top, and hence it does not tend to rise.
- A relatively stable layer of heated salt water is thus produced at the bottom of the pond with a lighter layer of cooler fresh water, which acts as a heat insulator, above it.
- Normally, the temperature at the bottom of the pond will rise to over 90 °C while the temperature at the top of the pond is usually around 30 °C.
- A solar pond can be used for various applications, such as heating and cooling of buildings, industrial process heating, desalination, refrigeration, heating animal housing, drying crops on farms, heat for biomass conversion and solar power generation.
- The heat trapped in the salty bottom layer can be used for many different purposes, such as the heating of buildings or industrial hot water or to drive an organic Rankine cycle turbine or Stirling engine for generating electricity.

Temperature and concentration profile for a typical solar pond

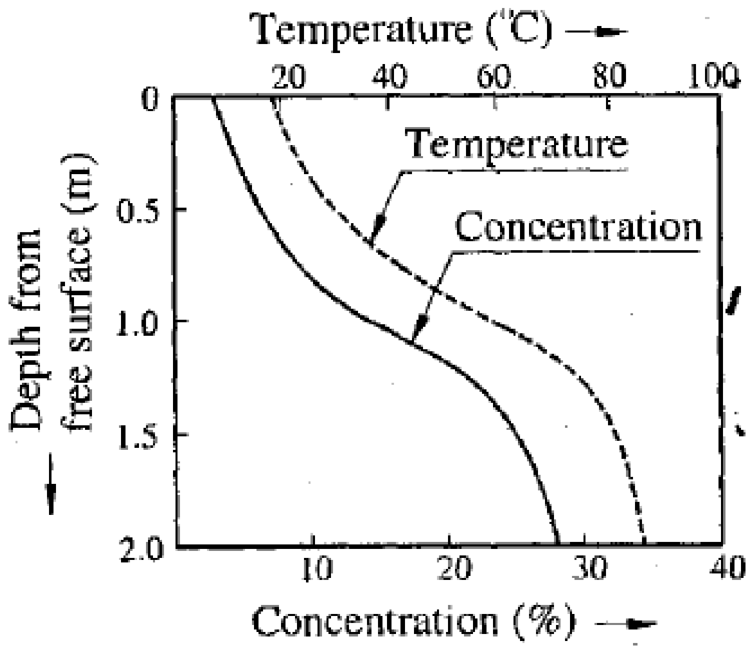


Fig. Temperature and concentration profile

SOLAR POWER PLANTS

- Solar power generation technologies can be broadly classified into two broad categories:
- Solar Photovoltaic technologies: Photovoltaic converters are semiconductor devices that convert part of the incident solar radiation directly into electrical energy.
- Solar thermal power plants: Solar thermal power plants produce electricity by converting the solar radiation into high temperature heat using mirrors and reflectors.

Classification solar thermal power plants

1. Classification based on temperatures

a. Low temperature cycles:
- Maximum temperature is limited to 100°C.
- For low temperature cycle, the thermodynamic cycle preferred is Rankine cycle.

b. Medium temperature cycles:
- Maximum temperatures ranging from150°C to 300 °C.
- For medium temperature cycle, the thermodynamic cycle also preferred is Rankine cycle.

c. High temperature cycles:
- Work at temperatures above 300 °C.
- For high temperature cycle, the thermodynamic cycle preferred is the Rankine cycle, the Brayton cycle and the Stirling cycle.

2. Classification based on types of collectors

a. Solar pond power plant
b. Solar distributed collector thermal power plant
c. Central receiver system or Power tower -Heliostat
d. Solar chimney power plant

LOW TEMPERATURE SOLAR THERMAL POWER PLANT

i. Low temperature power generation cycle using liquid flatplate collectors:
- Array of flat plate collectors are used to receive the solar radiation.
- The booster mirrors are used with collector to get maximum solar energy.
- The hot water at temperature close to 100°C is stored in a well insulated thermal storage tank.
- Hot water from storage tank is circulated through the heat exchanger (vapour generator), and give up heat to the working fluid (low boiling temperature fluid) of Rankine cycle.

- Low boiling temperature fluid evaporates at about 90 °C and pressure of a few atmospheres. Vapour generated in generator is then passes through turbine. After expansion in the turbine, low pressure vapour is condensed in the condenser and then liquid again supply to the vapour generator with help of liquid pump.
- Normally, the working fluids used are methyl chloride, toluene or refrigerants like R11, R113, and R114.
- This power plant is very simple, but it required large investment cost per kW because of large collector area involved.
- Overall efficiency of power plant is very low about 2%.

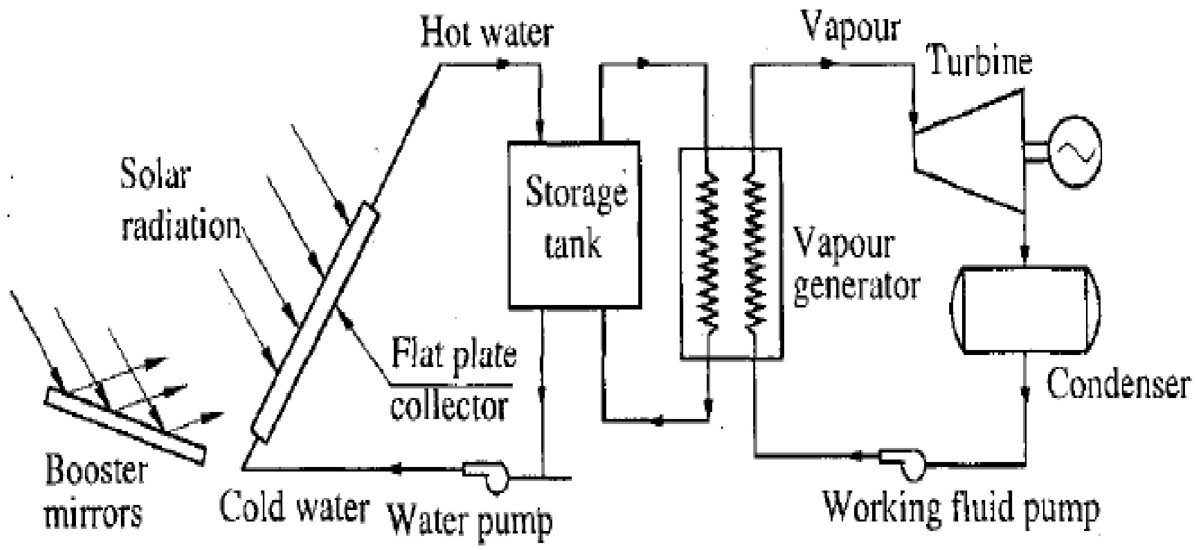


Fig. Low temperature power generation cycle using liquid flat plate collectors

ii. Low temperature power generation cycle using solar pond

- Solar pond is used to receive and to store the solar radiation.
- The system works on Rankine cycle using low boiling temperature working fluid.
- The bottom layers of brine reach 70 to 85 °C while the top remains 25 °C.
- The hot brine from bottom is slowly withdrawn in the laminar flow pattern from the pond and used to evaporate low boiling temperature working fluid of Rankine cycle in the vapour generator.
- The vapours of working fluid flows under high pressure to the turbine and thereby, expanding through the turbine and electrical generator coupled to it. Expansion in the turbine, low pressure vapour is condensed in the condenser and then liquid again supply to the vapour generator with help of liquid pump.

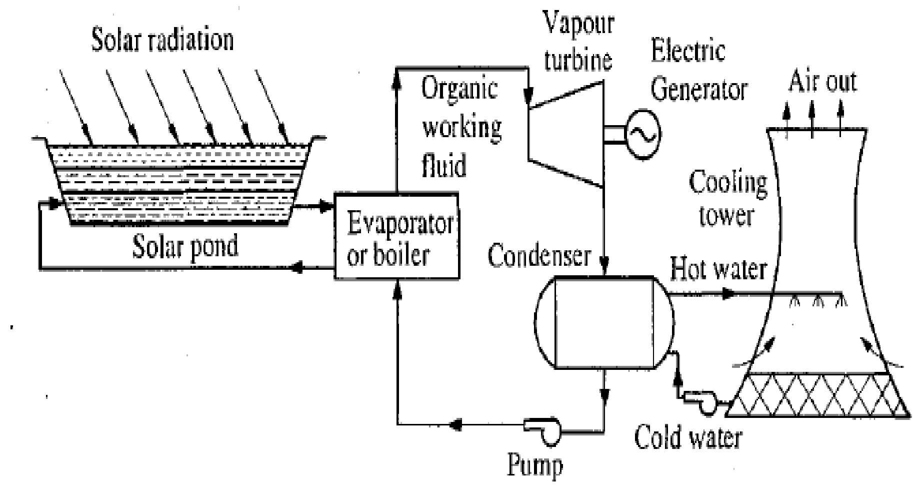


Fig. Low temperature power generation cycle using solar pond

MEDIUM TEMPERATURE SOLAR THERMAL POWER PLANT

- In this system, an array of parabolic line focusing type concentrating collectors is used to receive the solar energy because of low cost and require sun tracking in one plane only as compared to para-boloidal concentrating collectors.
- It is work at maximum temperatures ranging from 150 to 300 °C.
- This power plant consists of a parabolic cylindrical reflector to concentrate sunlight on to a collecting pipe within a pyrex or glass envelop, a storage tank, steam generator, steam turbine, condenser, pump and electrical generator.
- Incoming solar energy is absorbed by water, and this heat is transferred to storage tank and finally to steam generator where steam is generated. This steam is utilized to run a turbine. After expansion in the turbine, low pressure steam is condensed in the condenser and then water again supply to j steam generator with help of liquid pump.

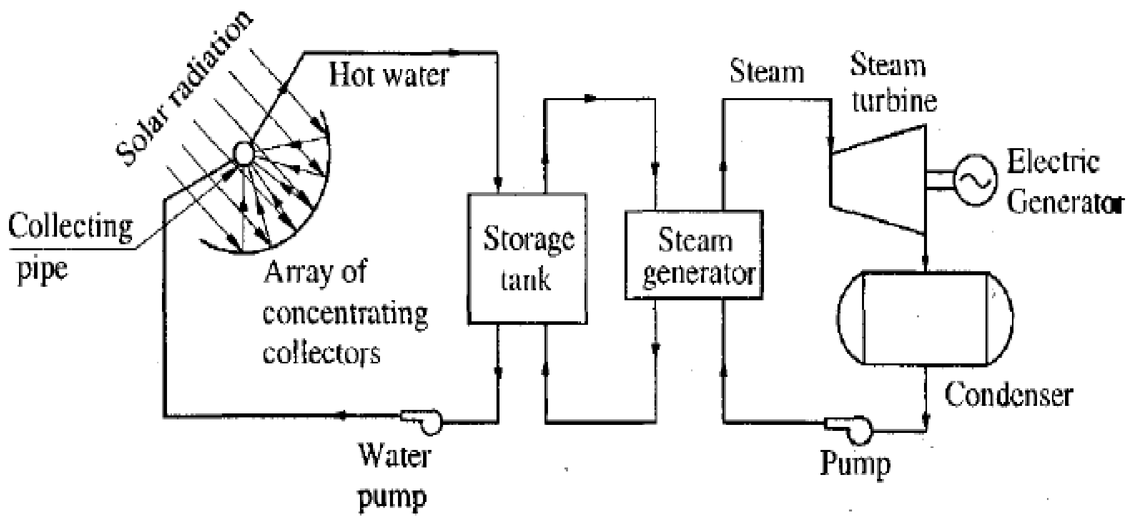


Fig. Medium temperature solar power plant

HIGH TEMPERATURE SOLAR THERMAL POWER PLANT

i. Solar distributed collector thermal power plant

– In this power plant, solar energy is collected by several individual collectors located in solar field. A very large area of few km2 is covered by the field
– The Parabolic through collectors with line focus are used

The main components of plant are:

1 Parabolic through collectors distributed in the solar field
2 Piping system for primary heat transport (water) circuit
3 At transport fluid pump
4 Storage tank
5 Steam generator
6 Secondary fluid (steam)circuit
7 Steam turbine
8 Condenser and condensate pump

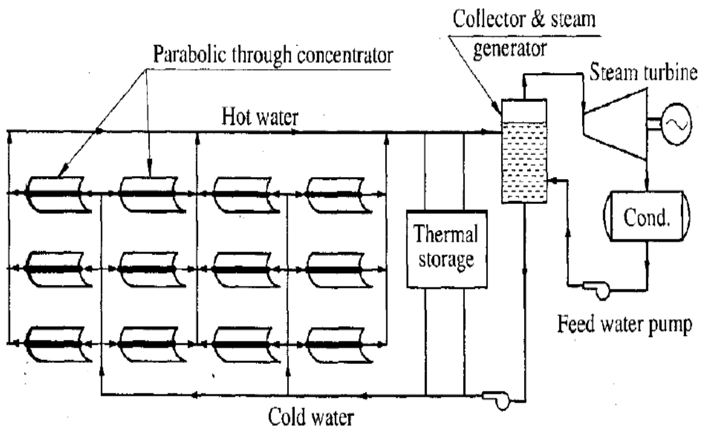


Fig. Solar distributed collector thermal power plant

– Incoming solar energy is collected in the collector which absorbed by water, and this heat is transferred to storage tank and then to steam generator where steam is generated. This steam is utilized to run a turbine.
– After expansion in the turbine, low pressure steam is condensed in the condenser and then water again supply to the steam generator with help of feed water pump after feed water heating in the feed water heater.
– The operating temperature of parabolic through collectors with line focus with sun tracking in one plane is in the range of 200 °C to 300 °C.
– In the solar distributed collector thermal power plant, parabolic through collectors with line focus are generally recommended for medium size electrical power plant (typically size 50 MW) used for applications such as standalone power plant for farm or community centre, captive

power plant for small industry.

– The small solar distributed collector thermal power plant (typically size 2 MW) may be preferred for cogeneration plant (to deliver steam, hot water and electric power) and irrigation water pumping.

ii. Solar Central Receiver or Solar Tower thermal power plant:

– In this solar-thermal power plant, a wide field of heliostats focuses the sun's power onto a single collector to heat a medium such as water or molten salt.
– The system consists of

1 The field of oriented flat mirrors or array of heliostats
2 Tower with the central receiver on top of it
3 heat conversion sub system
4 Heat storage device

- The fields of heliostats comprise many mirrors. The movement of most modern heliostats employs a two-axis motorized system, controlled by computer based on the latitude and longitude and the time and date.
- In the central receiver at the top of the tower on which solar radiation reflected from fields of heliostats is concentrated. The central receiver has a heat absorbing surface by which the heat transport fluid is heated.
- In most of case water is a heat transport medium and working fluid of Rankine cycle. Another possibility is to use a gas as heat transport medium and also working fluid of Brayton cycle of a gas turbine.
- Thermal buffer storage is provided so that the plant can continue to operate for a maximum period of 30 minute in case of cloud cover. Short term storage of heat can be provided by fire bricks, ceramic oxides, rocks, eutectic salts, fused salts, sulphur or lithium metal, sodium metals etc.
- Heliostat costs represent 30-50% of the initial capital investment for solar power plant depending on the energy policy and economic framework in the location country.

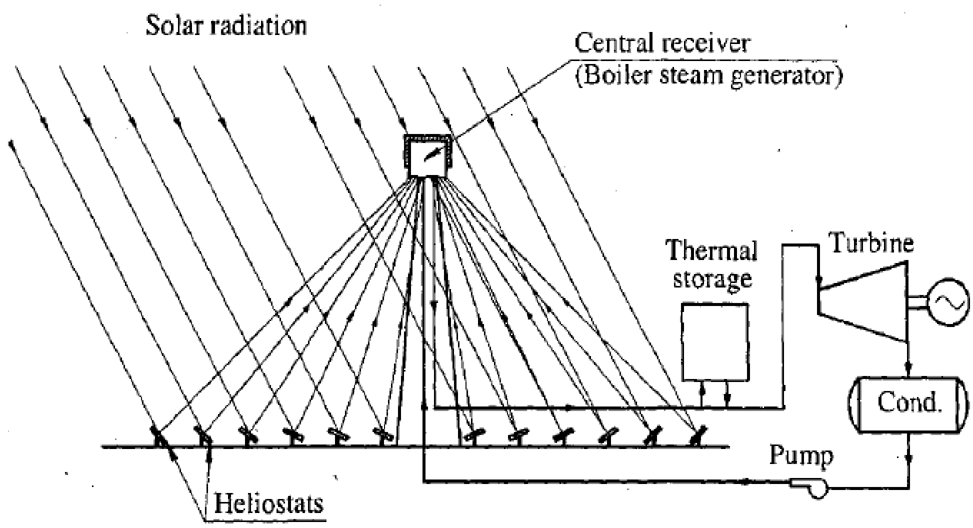


Fig. Solar distributed collector thermal power plant

e. Central receiver system or Power tower -Heliostat

f. Solar chimney power plant

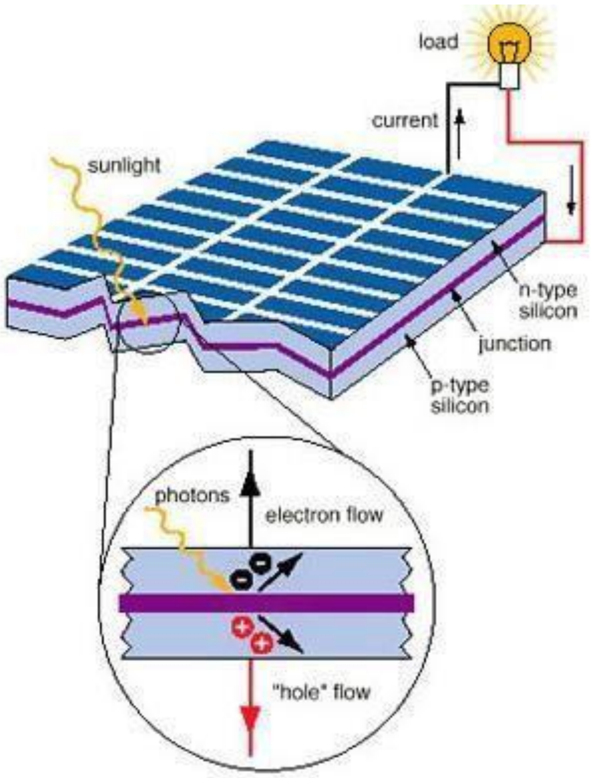
UNIT-5

PHOTOVOLTAIC SYSTEM OR SOLAR CELLS

- Solar cells are devices which convert solar energy directly into electricity via the photovoltaic effect.
- Solar cell principles:
- It is based on the photovoltaic effect.
- In general, the photovoltaic effect means the generation of a potential difference at the junction of two different materials in response to visible or other radiation.

The solar cell works in three steps:

1. Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
2. Electrons (negatively charged) are knocked loose from their atoms, causing an electric potential difference. Current starts flowing through the material to cancel the potential and this electricity is captured. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.
3. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.
4. Semi-conductors like silicon, cadmium telluride, gallium arsenide etc. are a suitable material for absorbing the energy of photon of sunlight.



Photovoltaic Solar Systems

What is a solar cell?

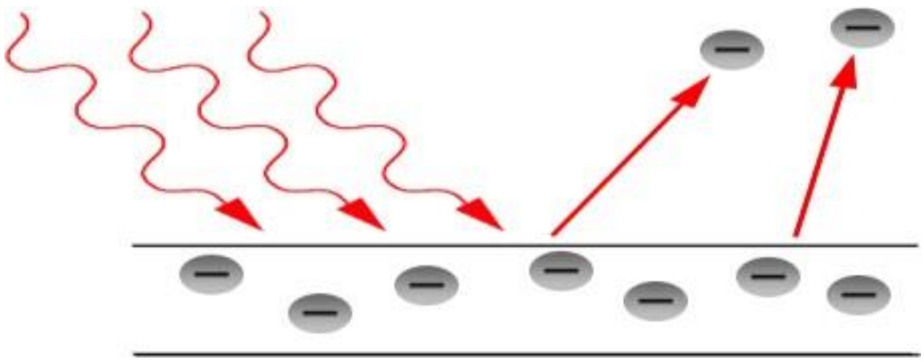
- Solid state device that converts incident solar energy directly into electrical energy

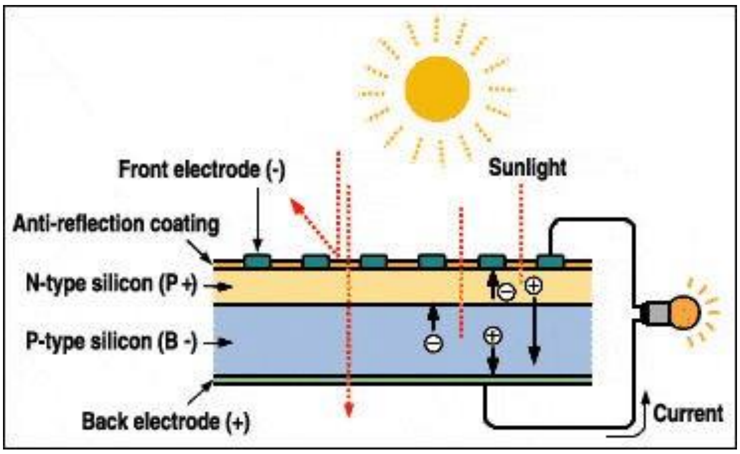
Advantages:

1. Efficiencies from a few percent up to 20-30%
2. No moving parts
3. No noise
4. Lifetimes of 20-30 years or more

How Does It Work?

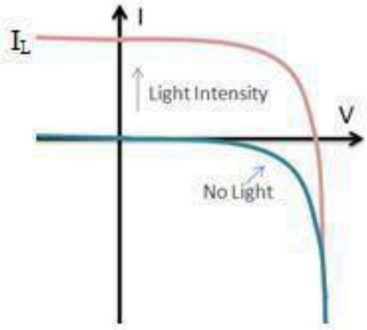
- The junction of dissimilar materials (n and p type silicon) creates a voltage
- Energy from sunlight knocks out electrons, creating a electron and a hole in the junction
- Connecting both sides to an external circuit causes current to flow
- In essence, sunlight on a solar cell creates a small battery with voltages typically 0.5 v. DC

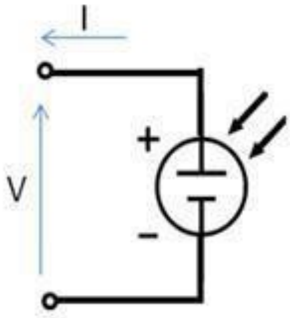




I-V Characteristics of a solar cell Theory of I-V Characterization:

PV cells can be modeled as a current source in parallel with a diode. When there is no light present to generate any current, the PV cell behaves like a diode. As the intensity of incident light increases, current is generated by the PV cell, as illustrated in Figure.





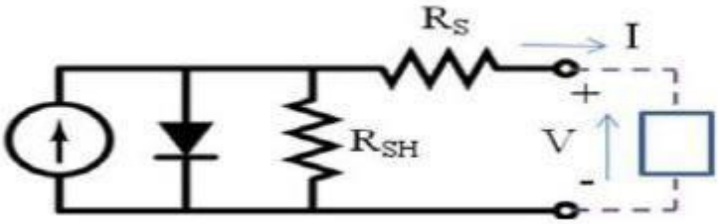
• In an ideal cell, the total current *I* is equal to the current *Iℓ* generated by the photoelectric effect minus the diode current *ID*, according to the equation:

$$I = I_\ell - I_D = I_\ell - I_o\left(e^{\frac{qV}{kT}} - 1\right)$$

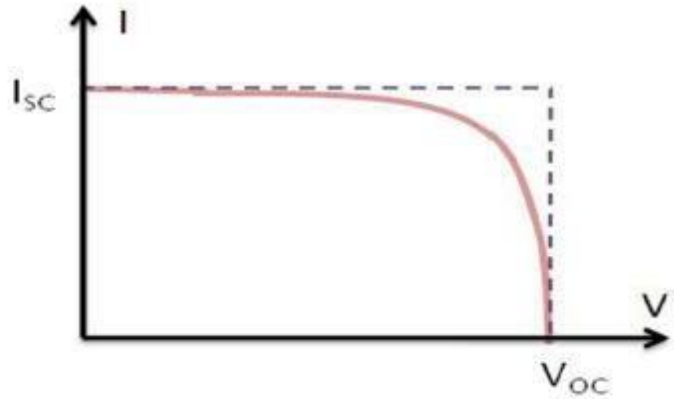
where *I0* is the saturation current of the diode, q is the elementary charge 1.6x10-19 Coulombs, k is a constant of value 1.38x10-23J/K, T is the cell temperature in Kelvin, and *V* is the measured cell voltage that is either produced (power quadrant) or applied (voltage bias).

• Expanding the equation gives the simplified circuit model shown below and the following associated equation, where *n* is the diode ideality factor (typically between 1 and 2), and *RS* and *RSH* represents the series and shunt resistances that are described in further detail later in this document:

$$I = I_l - I_0\left(exp^{\frac{q(V+I\cdot R_S)}{n\cdot k\cdot T}} - 1\right) - \frac{V + I\cdot R_S}{R_{SH}}$$



The I-V curve of an illuminated PV cell has the shape shown in the following Figure as the voltage across the measuring load is swept from zero to *VOC*,



Short Circuit Current (ISC):

The short circuit current ISC corresponds to the short circuit condition when the impedance is low and is calculated when the voltage equals 0.

I (at V=0) = ISC

ISC occurs at the beginning of the forward-bias sweep and is the maximum current value in the power quadrant. For an ideal cell, this maximum current value is the total current produced in the solar cell by photon excitation.

ISC = IMAX = Iℓ for forward-bias power quadrant

Open Circuit Voltage (VOC):

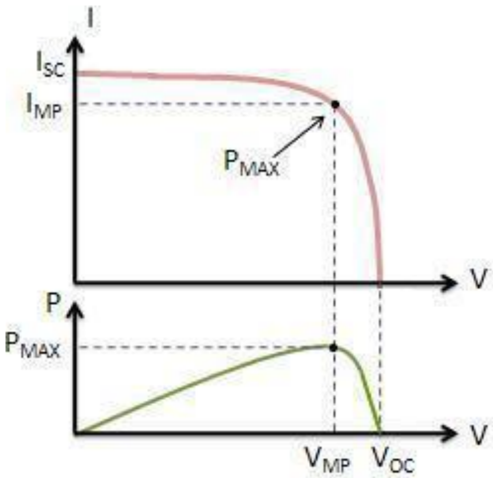
The open circuit voltage (VOC) occurs when there is no current passing through the cell.

V (at I=0) = VOC

VOC is also the maximum voltage difference across the cell for a forward bias sweep in the power quadrant.VOC= VMAX for forward-bias power quadrant

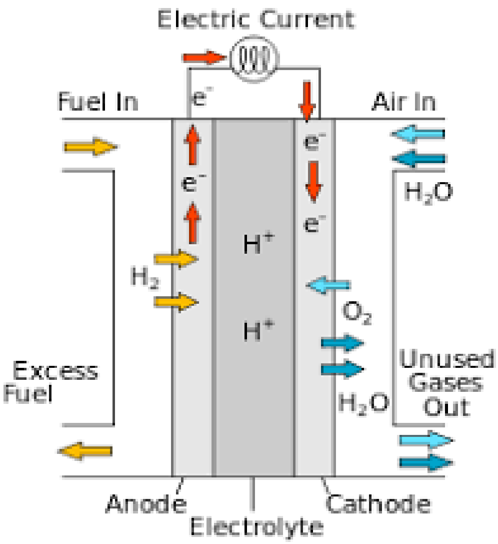
Maximum Power (PMAX), Current at PMAX (IMP), Voltage at PMAX (VMP):

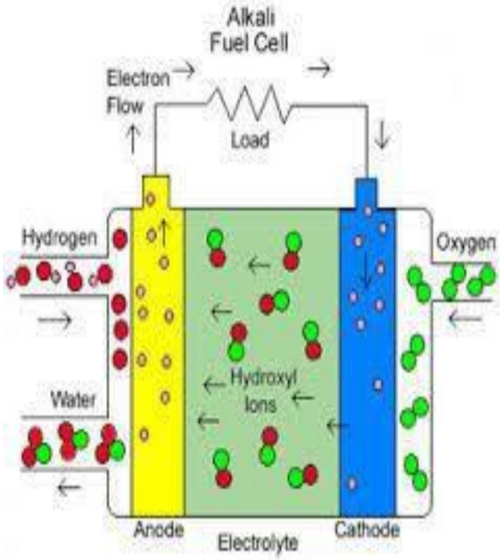
The power produced by the cell in Watts can be easily calculated along the I-V sweep by the equation *P=IV*. At the *ISC* and *VOC* points, the power will be zero and the maximum value for power will occur between the two. The voltage and current at this maximum power point are denoted as *VMP* and *IMP* respectively.



Fuel cell:

A **fuel cell** is an electrochemical cell that converts the chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen fuel with oxygen or another oxidizing agent. **Fuel cells** are different from batteries in requiring a continuous source of fuel and oxygen (usually from air) to sustain the chemical.





Faraday's law :

Faraday's law of induction is a basic **law** of electromagnetism predicting how a magnetic field will interact with an electric circuit to produce an electromotive force (EMF)—a phenomenon called electromagnetic induction.