

SCHOOL OF MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

UNIT – I – Non Conventional Energy Systems – SME1617

I. Introduction

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 energyetc.
- 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) SUPPLIMENTRY 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 of 7,678 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:

Country	Production		% share	Reserve life (years)
	Year			
	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

Table 1.1 The production of coal by country and year

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.
- Crudeoilproductionduring2010-11 at 37.71 Mt. Therefining 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 1 st April 2011.

NATURAL GAS

- Natural gas is a mixture of various compounds of hydrocarbons and small quantities of nonhydrocarbons.
- 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 terawatthours 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 energyetc.
- The mankind's have started the use of these sources recently, hence they are known as nonconventional energy sources. The share of these sources in world's electricity generation is around 3% in2011.
- 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.

Table 1.2 wind power generating

		countries	
COUNTRY	TOTAL CAPACITY	Y INCOUNTRY	TOTAL CAPACITY IN
	2011(MW)		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

- Top ten wind power generating countries are given in table 1.2

India's non-conventional sources

- 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. Windenergy
 - 3. Energy from biomass and biogas
 - 4. Ocean thermal energyconversion
 - 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 greenhouses
- 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.

UNIT –II – Non Conventional Energy Systems – SME1617

II. Solar Energy

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 customaryto 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.



Fig 2.1 Solar radiation

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 to 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.





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

Fig 2.3 Phrheliometer

Solar Radiation Geometry

Definitions:

(a) Solar altitude angle(α):

Altitude Angle is the angle between the Sun's rays and projection of the 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 $\Theta z=M/2-\alpha$

(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 23.50 on June 22 to 23.50 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 150 per hour.

(g) Slope (β):

Angle between the collector surface with the horizontal plane is called $slope(\beta)$.

(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



Fig 2.4 Solar Angles

surfaces	
$\beta = 0^{\circ} \text{Eqn}(1) \text{ becomes}$	
$\cos\theta = \sin\phi \sin\theta + \cos\phi \cos\phi = \sin\alpha = \cos\theta z$	Eqn (3)
• Case3	
Surface facing south y =0	
$\cos \theta T = \sin \phi (\sin 6 \cos \beta + \cos 6 \cos \omega \sin \beta)$	
= $\cos \phi (\cos 6 \cos \omega \cos \beta - \sin 6 \sin \beta)$	
$=Sin6Sin(\phi-\beta)+Cos6cos\omega Cos(\phi-\beta)$	Eqn (4)
• Case4	
Vertical surfaces facing south (β =90°, y=0)	
$\cos\theta z=Sin\phi\cos6\cos\omega-Cos\phiSin6$	Eqn (5)

Day Length:

At the time of sunset or sunrise the zenith angle $\theta z=90^{\circ}$, we obtain sunrise hour angle as

$$\begin{aligned} \cos \omega s &= -\frac{\sin \varphi \sin \delta}{\cos \varphi \cos \delta} = -\tan \varphi \tan \delta\\ \omega s &= \cos^{-1} \{-\tan \varphi \tan \delta\} \end{aligned}$$

Since 15° 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,

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

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
Qu(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 4μ m, because the radiation emitted from the absorber plate will be having a h of greater than 4μ m.
- 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:



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. 3.7.7. Point focus solar collector (Paraboloid).

Fig 2.5 Solar Collectors

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.

UNIT –III – Non Conventional Energy Systems – SME1617

I. 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:
- \Box The wind speed
- □ The cross-section of wind sweptby 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

$m = A V m^3 k$

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

$$K.E=1/2(\rho A V)V^{2}$$

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.



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 the world.

- 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



Fig 3.2 Photographic view of wind mills

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 windspeed

- 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 openarea.

3. Altitude of thesite

- 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: 1/7 H

VD

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 the system.

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.



Fig 3.3 Wind mill sites

- 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.

Sr	State	Potential	Installed capacity
No.		(MW)	(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

Table 3.1 The break-up of projects implemented in prominent wind potential states

UNIT –IV – Non Conventional Energy Systems – SME1617

II. 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 forbio-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 produce bio-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 m³ is adequate. The biomass requirement is estimated to be 1200 liters for a family.



Fig 4.1Floating Gasholder drum design (a conventional Indian design



Fig 4.2 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.



Fig 4.3 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 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.
- vi. 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.

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III. Other Renewable Energy Sources

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 to500°c
- It can be used for power generating.



Fig 5.1 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.

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 NH3, R-12, propane gas.
- _



Fig 5.2 Photographic view of OTEC

- 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 20°C to 25°C. 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.



Fig 5.3 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.

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.

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/annualkWh. Withan 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.

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