Alternative Sources of Energy: A Review

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Abstract— **Electricity requirements of world including India are increasing at an alarming rate and power demand has been running ahead of supply. It is a well-known fact that fossil fuels (coal, petroleum, natural gas) and other conventional energy resources, presently being used for power generation, may not be either sufficient or suitable to keep the pace of development with ever increasing electricity demand of the world. Also generation of electricity by thermal: coal based steam or nuclear and diesel power plants causes pollution (air, water, noise) and land degradation problems which is likely to be more acute in future due to increasing large generating capacity on one side and greater awareness of people in this respect. Recent severe energy crisis has forced the world to develop new and alternative methods of power generation which could not be adopted so far due to various reasons in the past. This paper elucidates about the few renewable energy sources i. e. solar, wind, tidal, geo-thermal energy and biomass, their power potential and present contribution in the Indian power sector.**

Index Terms— **Solar thermal collector and PV, wind turbine, gravitational force and tides, hot springs**

I. INTRODUCTION

Earth, the most beautiful planet is blessed with fossil fuel resources which have been greatly aided in material development. We are living in brief period during which most part of humanity has access to fossil fuels. Availability of cheap and abundant supply of energy is also a matter of concern. As shown in Fig. 1, development of energy over the time as total energy consumption in 1900, 3% of world energy came from oil, 36% from biomass and 61% from coal [1]. It shows that we moved from renewable energy (biomass, mostly wood) to fossil fuels (first coal, then oil and natural gas) and appears to be moving back to a mix of renewable technologies. The large scale use of commercial energy has led man to a better quality of life but fossil-fuel resources are finite, depleting fast and fossil fuel-era is gradually ending.

Due to fuel scarcity, air, water and noise pollution; land degradation and global warming issues; rapid rise in the cost of coal, petroleum products and nuclear fuels due to rise in power demand with increase in population as well as usages, it is worth to develop renewable energy based technologies to meet the future energy demands and match the pace of development. Among renewable, solar and wind energy has great potential in India.

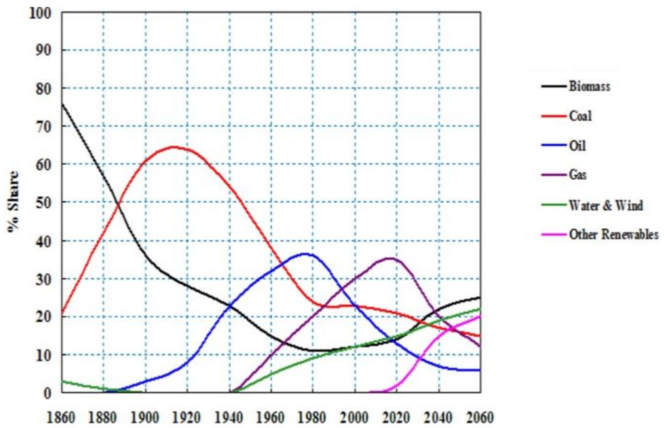

Fig. 1 World Market Share of Energy Since1860 to 2060 [1]

India has emerged as one of the leading destination for investors. This is due to lower cost of manpower and good quality production. As per IMF [2], India is the tenth largest economy and third in purchasing power (GWD). It has 16% of world population while energy use is 4.2%. Domestic sector consumes 40% of total energy in which household shares 80%. Per capita energy consumption is about 2.88 GJ and household energy demand has increased @ 8.1% per year [3]. Total power and demand-supply gap is shown in Fig. 2.

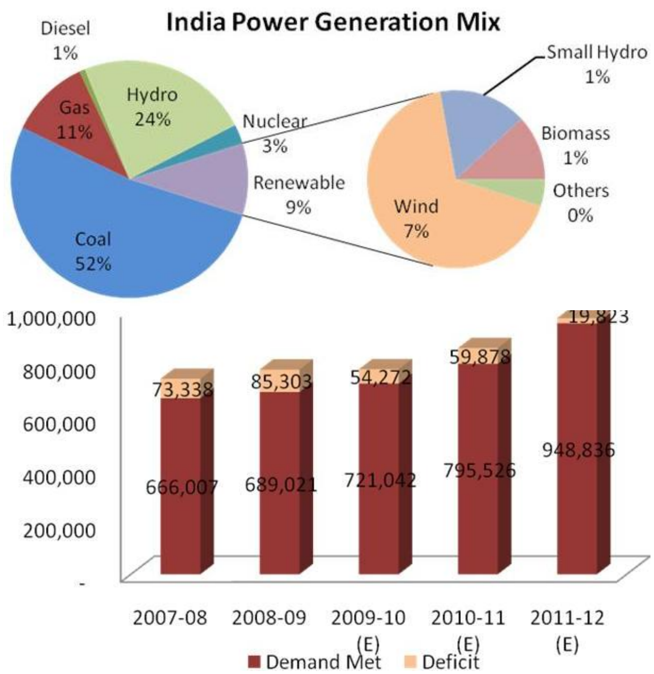

Fig. 2 India Energy Scenario and Power Deficit [3]

Manuscript received June 20, 2014.
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India has vast renewable energy sources and largest programs for renewable systems. Indeed, it is the only country to have exclusive ministry of new and renewable energy (MNRE) for renewable energy development. Based on promotional efforts put in by MNRE, significant progress is made and renewable energy shares about 12.5% in total power production. About 29, 989.12 MW power was produced from RE sources by Dec 2013 and planned to add another 25 GW to its wind and solar power by 2017, doubling the total capacity to 50 GW [4].

II. Solar Energy

Sun is the source of all energies and earth receives about 1×10^{18} kWh/year energy at the rate of 8×10^{13} kW, more than 10,000 times the world present needs. India blessed with good sun-shine as shown in Fig. 3. Most parts of country receives mean daily radiation in the range of 5 to 7 kWh/m^2 and have more than 275 clear sunny days per year [5], hence it offers good solar potential if systems are made affordable, reliable by integrating with conventional energy backup.

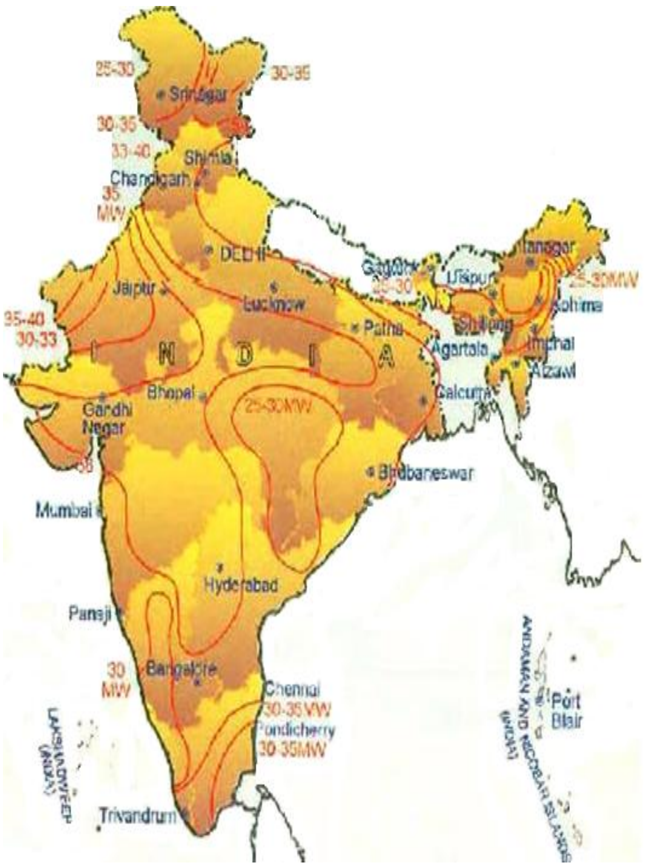

Fig. 3 Solar Radiation over India [5]

The solar power can basically be classified as (i) solar thermal and (ii) solar photovoltaic power generation. Large part of rural India is still not connected to electrical grids, so one of the applications of solar power can be in water pumping to replace 4 to 5 million diesels powered water pumps, each consuming about 3.5 kW and for off-grid lighting the houses. About 35,000 km² area of the Thar Desert has been planned for solar power projects, sufficient to generate 700 to 2,100 GW. Jawaharlal Nehru National Solar Mission under the National Action Plan on Climate Change to generate 1,000 MW power by 2013 and up to 20,000 MW grid-based solar powers with 2,000 MW of off-grid will cover 20 million m^2 with collectors by the end of 2020.

A. Solar Thermal

Solar is applied successfully for water heating, industrial process heating, drying, refrigeration and air conditioning, cooking, water desalination/purification and in power generation etc. Solar thermal plants are particularly suited to large scale heat or hot water generation for domestic, commercial, agricultural and industrial sectors. Medium temperature air and hot water for residential and commercial uses, both in rural and urban areas, can be provided cost-effectively by flat plate solar collectors and high temperature (power) applications can be meet out by parabolic/paraboloid type concentrating solar collectors as shown in Fig. 4 (a, b)

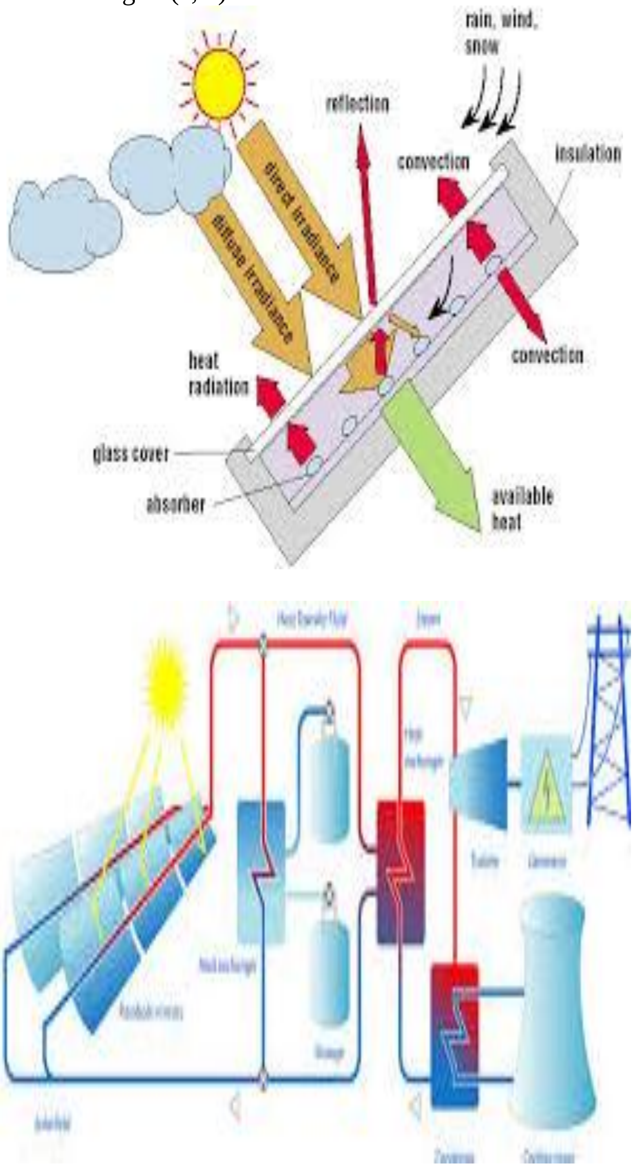

Fig. 4 Solar Thermal Power Generation: (a) Flat plate and (b) Parabolic Solar Collectors [6]

An estimated 15 million domestic solar hot water heaters are installed worldwide, about two thirds of them in developing countries [6]. China's solar hot water industry has mushroomed in 1990s, with growth rates of 10% to 20% and up to 10 million households now served with solar hot water [7]. Status of Indian state-wise solar power generation by 2012 is shown in Table 1.

B. Solar Photovoltaic Energy

Photovoltaic (PV) power is direct conversion of sunlight into electricity without intervene the heat engine. PV devices are solid state; therefore, they are rugged, simple in design and require very little maintenance. The biggest advantage of solar PV devices is that plant can work standalone to generate power from microwatt to megawatts as shown in Fig. 5 (a). So, they are used in calculators, watches, water pumps, remote buildings, communications, satellites and space vehicles as power sources, and even in megawatt-scale solar PV power plants [8].

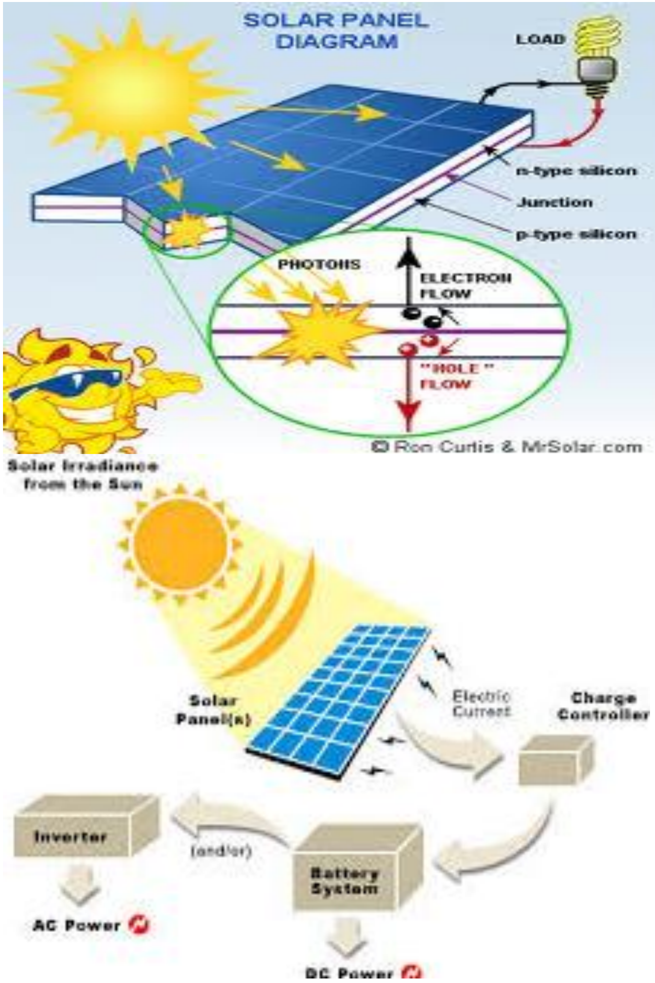

Fig. 5 Solar Energy (a) Power Generation Mechanism and (b) SPV Power Generation Cycle [8]

PV cells are made of silicon (Si), gallium arsenide (GaAs), copper indium diselenide (CIS), cadmium telluride (CdTe) and a few other materials. The common denominator of PV cell is a p–n or equivalent junction to enable photovoltaic effect. The p–n junction is the heart of a PV cell which converts sunlight into electricity as shown in Fig. 5 (b). The junction consists of a layer of n-type Si joined to a layer of p-type Si with Si-crystal structure across the junction. The n-layer has an abundance of free electrons and p-layer has an abundance of free holes. Under thermal equilibrium, if the photon energy equals or exceeds the semiconductor band gap energy of junction material, then it is capable of creating an electron-hole pair (EHP). For Si, the band gap is 1.1 eV then

Table 1: Installed Capacity, India (Aug, 2012) [4]

Sr. #	State	Capacity
1	Gujarat	709.54 MW
2	Rajasthan	198.70 MW
3	Andhra Pradesh	21.80 MW
4	Chhattisgarh	4.0 MW
5	Punjab	9.3 MW
6	Tamilnadu	15.1 MW
7	Haryana	7.8 MW
8	Uttar Pradesh	12.4 MW
9	Jharkhand	16.0 MW
10	Uttarakhand	5.1 MW
11	Karnataka	14.0 MW
12	West Bengal	2.1 MW
13	Madhya Pradesh	7.4 MW
14	Maharashtra	20.0 MW
15	Delhi	2.5 MW
16	Orissa	13.0 MW
17	Lakshadweep	0.8 MW
18	Andaman and Nicobar	0.1 MW
	Total	**1059.64 MW**

photon will have sufficient energy to generate an EHP. As photons enter a material, optimization of photon capture suggests that there is transmission of photons within a diffusion length in p–n junction, causes current to flow in the circuit. India plans to generate 1 GW by 2014 and up to 20 GW grid-based in which 2 GW off-grid solar power to cover 20 million m^2 collectors by 2020. Status of major SPV power plants is given in Table 2.

Table 2: Major Solar PV Power Plants in India [4]

Sr. #	Solar Power Project	Capacity
1	Welspun Energy (Phalodi, Rajasthan)	50 MW
2	Charanka Solar Park (Charanka, Guj)	214 MW
3	Adani Power Plant (Bitta, Gujarat)	40 MW
4	Mithapur (Tata Power, Gujarat)	25 MW
5	Azure Power (Sabarkantha, Gujarat)	10 MW
6	Moser Baer clean energy (Banaskantha, Guj)	30 MW
7	Green Infra energy (Rajkot, Gujarat)	10 MW
8	Waa SPP (Surendranagar, Gujarat)	10 MW
9	Shivganga SPV (Karnatka)	5 MW

III. WIND ENERGY

Wind power generation is the fastest growing, matured, competitive and pollution-free but costly technology. Wind mills as in Fig. 6, installed since long back and still used for pumping water. The worldwide installed capacity of wind power reached 283 GW by the end of 2012. China (75,564 MW), US (60,007 MW), Germany (31,332 MW) and Spain (22,796 MW) are ahead of India's fifth largest installed capacity. As on 31 December 2013 the installed capacity of wind power in India was 2014 9 MW, spread across Tamil

Nadu (7154 MW), Gujarat (3,093 MW), Maharashtra (2976 MW), Karnataka (2113 MW), Rajasthan (2355 MW), Madhya Pradesh (386 MW), Andhra Pradesh (435 MW), Kerala (35.1 MW), Orissa (2 MW), West Bengal (1.1 MW) and other states (3.20 MW) and about 6,000 MW additional will be installed by 2014 [9].

Fig. 6 Wind Power: Wind Mill and its Components [4]

Wind accounts for 8.5% of India's total installed capacity and generate 1.6% of total power. Suzlon is the leading Indian company with installed capacity of 6.2 GW. Vestas is another company active in India's wind energy initiatives.

IV. TIDAL ENERGY

Tidal power generation is an immature technology and has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus restricting its availability. As shown in Fig. 7, during high tide, the incoming water is contained in a large storage and when the tide went out, stored water is passed through the water wheels/turbines that produce mechanical power which is finally converted into electrical energy. The rise and fall of tide is consistent, which makes it predictable and reliable.

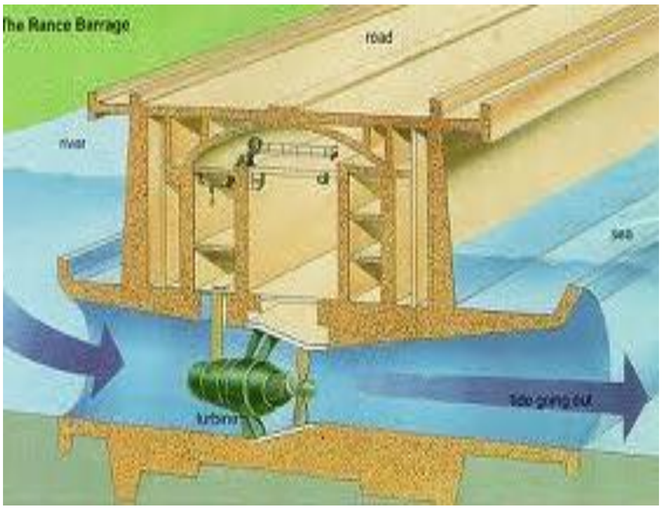

Fig. 7 Power Generation from Tidal Energy and Proposed Tidal Poer Plant in India [4]

The worldwide installed capacity of tidal power stations are Sihwa lake (254 MW, S Korea), Rance (240 MW, France), Annapolis (20 MW, Canada), Jiangxia (3.2 MW, China) and a 50 MW (in Gulf of Kutch) is proposed.

V. GEOTHERMAL ENERGY

Geothermal plants operate over relatively low temperature 50° to 250°C depending on site-conditions in comparison to coal or nuclear plants which operate at about 550°C. At low temperatures, heat to electricity conversion efficiency is low. In geothermal power plants, hot geothermal fluid runs turbine to produce power. Geo-thermal resources in India are as shown in Fig. 8

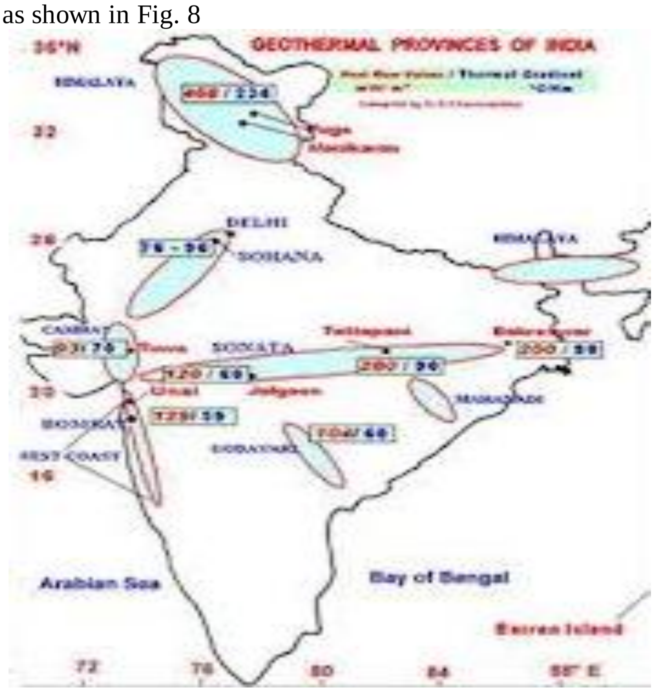

Fig. 8 Major Geothermal Resources in India [4]

Geothermal power plants fall into three categories: direct steam, flash and binary plants. In direct steam plants, the steam is routed directly from well (core) to a steam turbine for generating electricity. Flash plants are used at sites that produce high-temperature waters (between 175° and 300°C). binary cycle power plants as shown in Fig. 9, convert lower temperature geothermal water (90° to 175°C) to electricity by first routing the fluid through a closed-loop heat exchanger where it heats a hydrocarbon working fluid into gas then gas is used to turn the turbine.

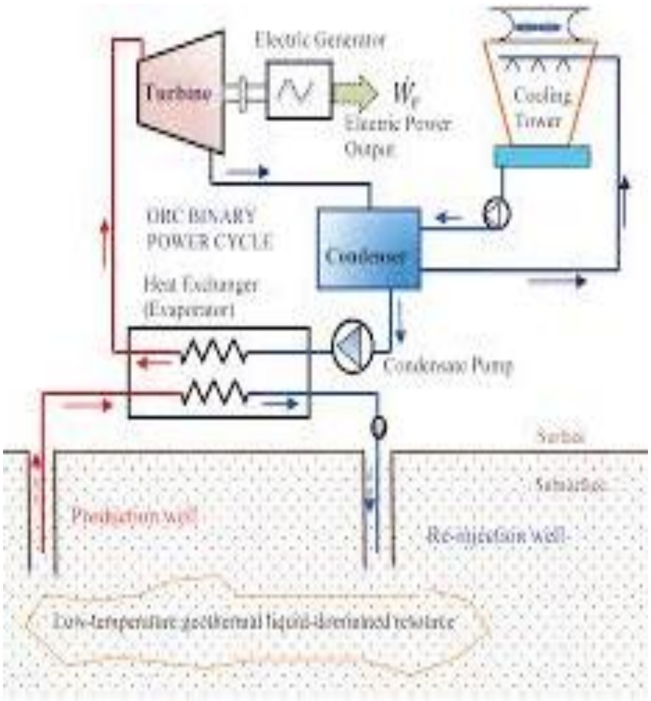

Fig. 9 Geothermal Binary Power Plant [4]

Geothermal power is a relatively pollution-free energy resource derived from nature. Estimates of electricity generating potential of geothermal energy vary from 35 to 2,000 GW. Current worldwide installed capacity by 2013 is 10,715 MW with the largest capacity in the USA (3,390 MW), the Philippines (1894 MW), Indonesia (1333 MW), Mexico (980 MW), Italy (901 MW), New Zealand (895 MW) Iceland (664 MW), Kenya (215 MW), Costa Rica (208 MW) and El-Salvador (204 MW), generate more than 15% of their electricity from geothermal sources. A pollution-free geothermal resource, require further research to become economical.

VI. ENERGY FROM BIOMASS

India is rich in biomass and has a potential of 16,881 MW (agro-residues and plantations), 5000 MW (bagasse cogeneration) and 2700 MW (energy recovery from waste). Biomass power generation in India is an industry that attracts investments of over INR 6 billion every year, generating more than 5000 MW electricity and yearly employment of more than 10 million man-days in the rural areas [4] as in shown in Fig. 10.

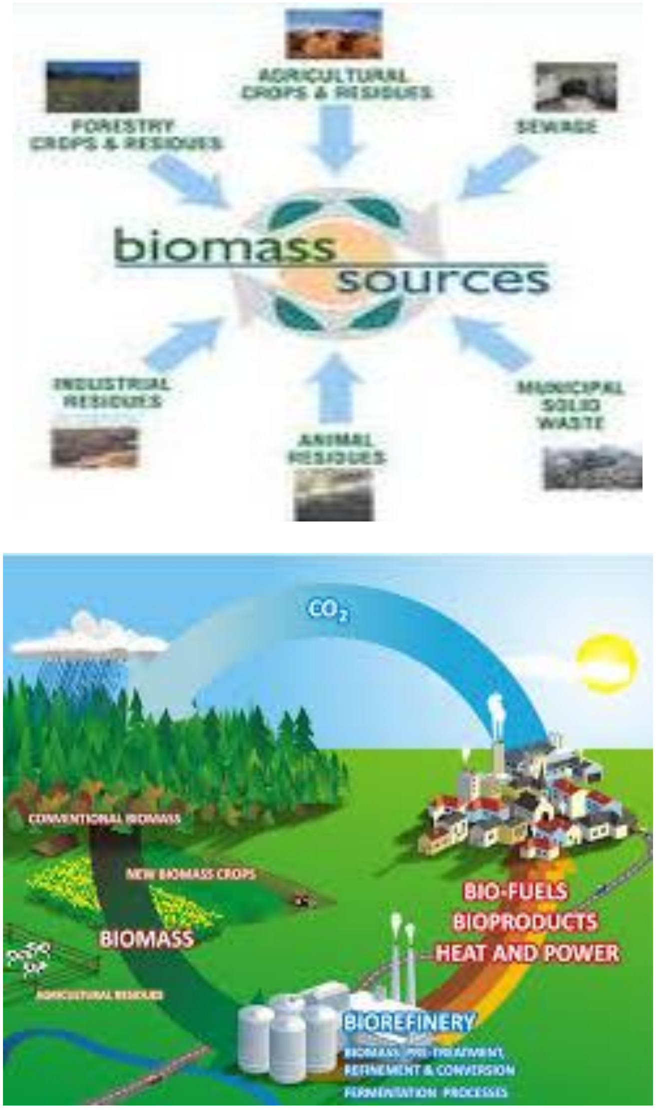

Fig. 10 Biomass Resources and Energy Production

It is estimated that there is power potential of 19,500 MW capacity from biomass conversion technologies like combustion, gasification, incineration and bagasse based cogeneration etc. in sugar mills. So far only 380 MW of this potential has been tapped and there is wide scope for benefit of rural population. Crop wastes, cellulosic biomass and crops raised to produce energy feed stocks on barren lands are good energy sources for industry, electricity production, home heating and cooking in modern stoves or gasifiers. Technologies for efficient biomass cook stoves have developed rapidly and about 220 million improved biomass stoves are in use by 2000.

A. *Biomass Gasifier*

India is promoting biomass technologies in rural areas, to utilise as rice husk, crop stalks, small wood chips, and agro-residues to produce electricity up to 2 MW capacities. In 2011, 25 rice husk based gasifiers for distributed power generation has been installed in 70 remote villages of Bihar and 60 others based on rice mills are being installed. The largest biomass power plant has been installed at Sirohi, Rajasthan of capacity 20 MW. The biomass gasifier projects of 1.20 MW in Gujarat and 0.5 MW in Tamil Nadu were successfully installed.

B. *Biodiesel*

Biofuel development in India is around the cultivation and processing of Jatropha plant seeds which are very rich in oil (40%). Jatropha oil has been used for several decades as a biodiesel to height the diesel fuel requirements of rural and forest communities (without refining) in diesel engines. Jatropha has the potential to provide economic benefits at local level and has potential to grow in dry marginal non-agricultural lands, thereby allowing villagers and farmers to leverage non-farm land for income generation [10].

Ethanol currently provides over 40% of the fuel consumed by cars and light trucks, presently occupying about 2.7 million hectare of land employing 350 distilleries in Brazil. It is estimated to have saved Brazil over $40 billion in oil imports, excluding costs of the program [11]. In 1999, almost 13 mega-tonnes of carbon emission such as lead, sulphur and CO have been greatly reduced. In addition, ethanol production supports about 700,000 rural jobs. Brazil supplies 60% of its primary energy from renewable sources, most of which comes from hydropower and biomass. In Africa, ethanol is produced in Kenya, Malawi and Zimbabwe for blending with gasoline, but Zimbabwe is the only one to mandate blending of ethanol with all gasoline sold.

C. *Biogas*

The biogas pilot programme aims to install small scale biogas plants for meeting out the cooking energy needs in rural India. During 2011, some 45,000 small scale biogas plants were installed. Cumulatively, India has installed 4.44 million small scale biogas plants. India started a new initiative of medium size mixed feed biogas-fertiliser pilot plants. This technology aims for generation, purification/enrichment, bottling and piped distribution of biogas. Such 21 projects has approved with aggregate capacity of 37,016 m^3/day of which 2 projects has been successfully commissioned by Dec 2011. India has additionally commissioned 158 projects under biogas based Distributed/Grid Power programme, with a total installed capacity of about 2 MW.

VII. CONCLUSIONS

The fossil fuel resources are finite and depleting fast, so energy crisis has forced the world to develop new and alternative sources of power. Electricity can be generated from renewable resources such as: solar, wind, tidal and geo-thermal energy and also from biomass conversion. Solar systems have good potential if they are made affordable, reliable by integration with hybrid systems serving as backup energy supply. Solar thermal systems are suited for large demands in water heating, industrial process heating, drying, refrigeration/air conditioning, cooking, water desalination/purification and power generation etc. Solar photovoltaic conversion is the direct conversion of sunlight into electricity. PV devices are rugged, require very little maintenance and can work as standalone to generate power from microwatts to megawatts at remote off-grid locations. A PV cell gives more electricity per unit weight as compared to a turbo-generator or a storage battery. Wind power is the fastest growing, matured, competitive and pollution-free technology but wind power plant construction is very costly. Tidal power suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges to run the water wheels. In geothermal, hot geothermal fluid is used to run turbine to produce power but require further research to become economical. The bio-gasifiers utilize surplus biomass to produce discrete power. Biofuel production provides economic benefits at local level for income generation. A biogas-fertiliser pilot plants can generate power, purify/enrich, bottling and piped distribution of biogas for meeting out the cooking energy needs. The emission of CO_2, CO, NO_x and SO_2 etc. are greatly reduced and help in environmental protection and global warning issues with the use of renewable energy technologies in power generation.

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