



## RESEARCH ARTICLE

### A REVIEW ON PRESENT TRENDS OF RENEWABLE ENERGY RESOURCES IN INDIA

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#### ABSTRACT

Power is the most important component of infrastructure and it is extremely essential for the economic development and social well-being of countries. The existence and development of self-sufficient infrastructure is important for the continual rise of the Indian economy. India's power sector is very much diversified. Sources of power generation vary from conventional sources such as natural gas, hydro, coal, oil and nuclear power to non-conventional sources such as solar, biomass, and wind. Due to population growth, the electricity demand in the country has risen dramatically and is believed to grow more in the future. In order to meet the increasing demand for electricity in India, huge addition to the installed generating capacity is needed. In the few past years, India's energy utilization has been rising at a moderately faster rate due to economic development. In this paper, the present trend of Renewable energy sources (RES) in India has been discussed. In the present scenario, use of renewable sources for energy generation has become the need of the hour. The Installed and Generating Capacity of each source in India has been discussed. The negative environmental impacts has been presented too. In addition, the paper also focuses on upcoming renewable sources of energy which are still developing and how one day they can be useful because of their vast undiscovered potential.

#### INTRODUCTION

India currently stood third among forty countries in Ernst and Young Renewable Energy Country Attractiveness Index (<http://www.ey.com/in/en/newsroom/news-releases/ey-india-ranks-third-on-renewable-energy-country-attractiveness-index>). India ranks fourth in the electricity consumption in the world after United States of America (USA) (13,500 kWh per capita), China (5919.8 kWh per capita) and Russia (1200 kWh per capita). As of now (2016-2017 year) the average consumption per capita in India is 1075 kWh (<http://www.eia.gov/countries/analysisbriefs/India/india.pdf>). The utility electricity sector in India had a total installed capacity of 316.00 GW as on 28<sup>th</sup> February 2017 (<https://factly.in/indias-per-capita-electricity-consumption-lowest-among-brics-nations/>). Renewable energy plants consists of 30% of total installed capacity of the electricity sector. India is the world's third largest producer of electricity. The per capita electricity consumption is lesser when compared to many countries despite lower tariff rates in India. Greenhouse gases especially Carbon Dioxide (CO<sub>2</sub>) has increased from 280 ppm in the pre-industrial time to 407.05 ppm in 2017 (Wuebbles and Sanyal, 2015). If the increase continues like this then there will be a very bad impact on our environment which will put everyone's life in danger ([https://www.revolvy.com/topic/Electricity%20sector%20in%20India&item\\_type=topic](https://www.revolvy.com/topic/Electricity%20sector%20in%20India&item_type=topic)). Hence, we should shift to energy resources which are clean and everlasting. These energy resources are termed as renewable energy resources.

In comparison to the other sources of power such as thermal, nuclear etc. renewable energy resources has yet to walk a long way to compete with them (5) as shown in Fig. 1. Some of the commonly used renewable energy resources in India are tidal energy, wind energy, solar energy, biomass energy etc. These renewable sources of energy are reliable and affordable. About 60% of renewable power in India comes from wind energy and other major contributor is solar energy.

#### Sources of Energy in India

Energy sources are considered as heart of power distribution network in any country. In Fig. 1, the Indian energy source distribution is shown. It is specifically divided into 4 sources which are thermal, hydro, nuclear and renewable energy source ([https://en.wikipedia.org/wiki/Energy\\_policy\\_of\\_India](https://en.wikipedia.org/wiki/Energy_policy_of_India)). It is also evident that thermal energy is the largest source of energy. From the total energy produced in India, thermal comprises of 68% which is further divided into three energy sources namely gas, coal and diesel with 8%, 59% and almost 1% abundance respectively (Khazode *et al.*, 2020).

#### Conventional sources of energy

Conventional or exhaustible sources of energy in India mainly includes Coal, Gas and Diesel which is the main source of energy till now and comprises of 66.64% of the overall energy generation in India. These sources of energy has been used for a long time. But when compared with conventional sources of energy, the non-conventional sources of energy (tidal energy, wind energy, solar energy, geo-thermal energy, etc.) are not often used (Hussain *et al.*, 2017).

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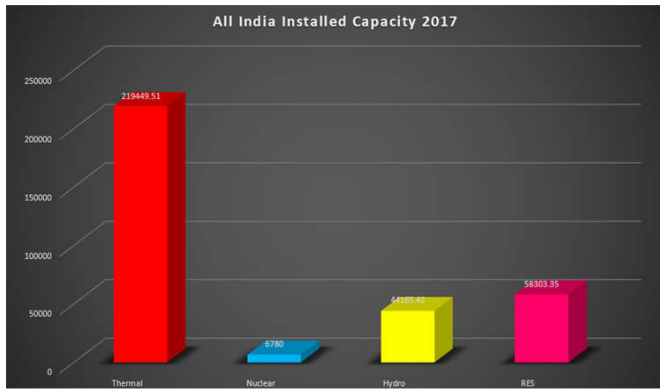


Fig. 1. All India Installed capacity (in MW) of power utilities

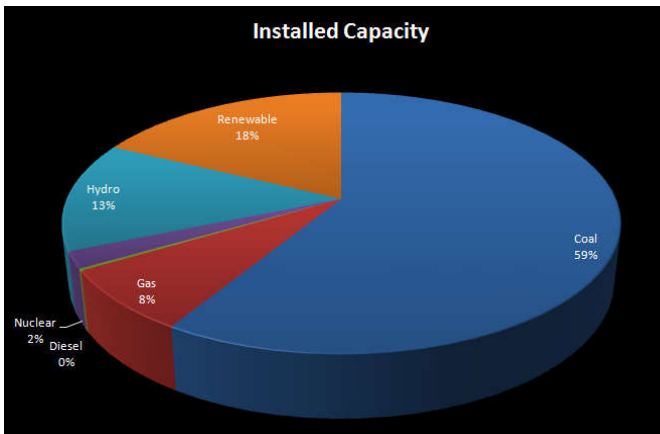


Fig. 2. Energy sources in India

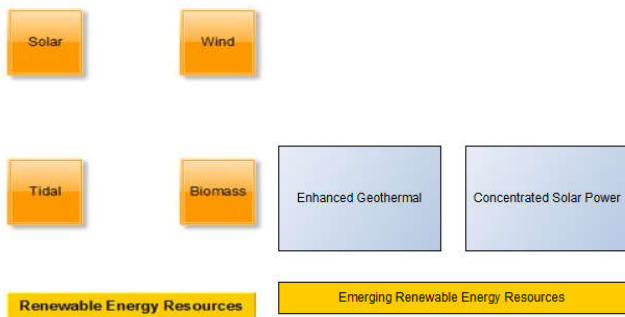


Fig. 3. Mainstream and Emerging renewable energy sources in India

**Non-Conventional Sources of energy**

Non-conventional sources of energy include Wind, Solar, Geothermal, Hydro, as well as various other new sources like marine energy, concentrated solar photovoltaics (CSP), enhanced geothermal energy (EGE), cellulosic ethanol, and artificial photosynthesis (AP) (Asif and Muneer, 2007). Some of them are frequently used while some of them are still developing but have a very high potential. They are shown in Fig. 3. They comprise of 17.70% of total power generation in India. Being clean sources of fuel, they have the potential to play an important role in the India’s future (Asif and Muneer, 2007). They are extracted from regular sources that are renewed always. India is blessed to have various sustainable power source assets namely geothermal, biomass, wind based, biogas, hydro and sun based. Indian power domain is among the main players of sustainable power source consumption particularly wind energy (Arulalan and Dhanasekaran, 2013).

**Table 1. All India energy generation from Renewable Energy Resources as per from the Month of April-August 2017 in GW**

Source Wise All India Generation from Renewables	For the Month Of	
	August , 2017	August , 2016
Wind	512.08	6819.39
Solar	1665.22	925.49
Biomass	264.57	347.74
Bagasse	281.64	238.98
Hydro	1101.26	1227.44
Others	32.53	11.83
<b>Total</b>	<b>10857.3</b>	<b>9570.87</b>

Table 1 shows that as of Aug 2017, India is producing 10.875 Giga-Watt (GW) of clean energy based on renewable technologies-based electricity. Moreover, the production of energy is increased by 14% from the last year itself that is 9.570 GW of energy. The increased use of fossil fuels leads to environmental issues, increased health risks to the living creatures on earth, depletion of ozone, and climatic changes. Greenhouse emissions such as Methane (CH<sub>4</sub>), CO<sub>2</sub>, Chlorofluoro Carbon (CFC’s), ozone and halons are responsible for holding or trapping heat radiation in the atmosphere. Moreover, the non-renewable sources of energy are going to be depleted sooner or later so we need to change to an energy source which can run for a much longer period of time. Because of limited non-renewable sources there should be a gradual shift to non-conventional energy sources.

**Various types of renewable energy**

God has provided us with immense natural energy sources which do not harm or pollute the environment in any way possible. In India, they are developing very fast and maybe someday will be able to reduce the thermal and nuclear energy sources.

**Some of the most prominent RES in India are**

**Solar Energy**

India receives lots of solar energy. To fulfil the future energy needs correctly, power protection and reliability needs to be more desirable and alternative strength sources should be investigated. An efficient solution is the use of renewable energy sources. Considering the numerous accessible renewable assets of energy, solar energy is an important domain as it is widely accessible ([https://en.wikipedia.org/wiki/Solar\\_power\\_in\\_India](https://en.wikipedia.org/wiki/Solar_power_in_India)). Solar energy is highest in India compared to other renewable resources present here. The whole set up capacity of grid-linked solar power projects in India is 15.60 GW (Devabhaktuni *et al.*, 2013). Solar energy, particularly because it competes with other sources of energy in price is beneficial for the underprivileged in developing country. Solar energy is an extremely vital renewable asset considering its continually developing output efficiency and potential to be utilized in various fields. The valuable characteristics of solar energy makes it a vital resource.

**Solar energy is ideally preferred for developing countries for the below mentioned reasons**

Firstly, many developing countries are situated in areas with maximum access to the solar light. Secondly, most of the

accessible fossil fuels and other energy assets can only be utilized by exploiting the ecosystem, which results in ecosystem decline. Thirdly, rising global independence of fossil fuels increases the requirement for solar technology, quickens development of related research, and in this manner lessens the costs involved. Finally, within solar technology, passive solar design excel when considering renewable energy for flats and buildings, and can be added with solar panels to accomplish the greatest possible sustainability and comfort (Frank Sharp *et al.*, 2014). The Fig. 4 shows the installed capacity of solar power projects in MW in India (28). Data of some of the major solar projects has been shown. Largest capacity is of a solar project installed in Andhra Pradesh.

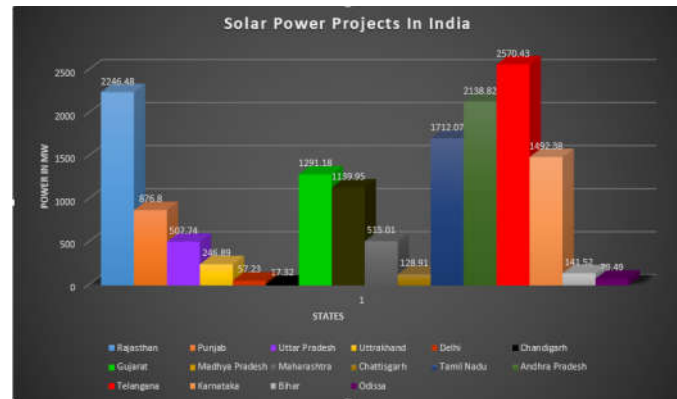


Fig. 4. Major solar power projects in India with capacity in MW

**Environmental Impacts**

The solar energy provides clean energy on a very large scale and has various advantages but some of its negative Environmental impacts are it can impact the existing use of land for a purpose, it may also interfere the basic wildlife activities of an area and it may also lead to soil compaction and increased erosion due to construction of solar facilities.

**Tidal Energy**

Tides are formed due to the combined effect of the gravitational attraction of the sun, moon and rotation of earth. Magnitude and timing of the tides rely on the form of the ocean bed, Coriolis acceleration, and geometry of shoreline (10). Tidal energy has a fantastic capacity to generate Energy even though it is a place particular source. India is enclosed by means of ocean on three sides. Due to this, the capacity to harness tidal energy has been identified by the government of India. Tidal energy is generated through vitality generators. Basically these extensive generators are submerged in places with huge tidal actions, and are designed to seize the kinetic motion of the sea tides to produce energy. The recognized financial electricity potential is of the order of 8000MW with approximately 7000MW in the Gulf of Cambay, approximately 1200MW within the Gulf of Kutch in Gujarat and about 100MW in the Gangetic Delta in the Sundarbans location in West Bengal.

**Environmental Impact**

The tidal energy is another free energy source and like every other RES has various advantages but some of its harmful impacts on the environment are the large turbines with sharp edges could prompt interruption in the mobility of the aquatic

species, Construction of tidal power plant can even kill fish population when they cross the turbines and Waste warmth that ends up in the water decreases its ability to store dissolved oxygen, hurting fish.

**Wind Energy**

Wind energy is the main contributor of sustainable power source in India. Starting in 2017, India is positioned fourth most astounding on the planet (15). At present India produces 30.12 GW of wind energy as indicated by Ministry of New and Renewable Energy (MNRE). It adds to the 75% of the aggregate sustainable power produced in India. States like Gujarat, Madhya Pradesh (MP), Tamil Nadu, Rajasthan, Maharashtra, Orissa, Kerala, West Bengal and Jammu and Kashmir are the main producers of wind energy in India. Government of India has planned to accomplish 60GW of wind energy in 2022 and100 GW by 2030. Despite of the high installed capacity plants, the real usage of wind power in India is less because we are not able to extract the complete energy provided from each plant as compared to the plants which we are installing. Absence of high speed wind results in fluctuation of energy in the generation of wind energy (Pachauri and Chauhan, 2012).

**Environmental Impacts**

Considering the fact that the wind power plants have moderately less effect on the planet when compared with the non-renewable energy power plants, a little worry is shown to the sound it generates. The wind turbine creates noise basically from the gearbox and the generator. Other moving parts of the turbines likewise delivers noise ranging from 50-60decibels (dB) (15). Visual Impacts and passing of flying creatures and bats that fly into the rotor of the windmill is likewise a worry. Despite these negative effects, we can't disregard the measure of clean energy it produces which is considerably higher and accordingly it can go about as a maintainable producer of clean energy in India in the coming future (Tripathi *et al.*, 2016).

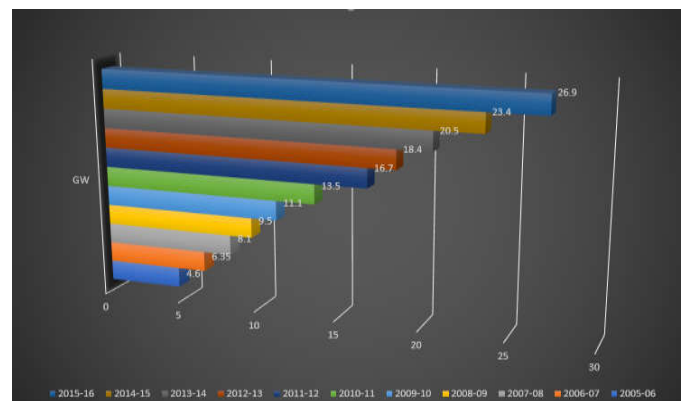


Fig. 5. Increase in capacity of wind generation in India

**Biomass**

Among the sustainable power sources, biomass assumes an essential part in any event in the rural zones in India. Biomass is the natural material achieved from living or dead creatures and is frequently alluded to plants or materials particularly known as dialect cellulosic biomass (Tripathi *et al.*, 2016). Biomass is plenty in nature and is separated on the basis of starting point, for example, aquatic biomass, forest biomass, urban waste biomass, industrial biomass, and field and ranch biomass. India generates every year around 450-500 million



tons of biomass. Biomass comprises of 32% of all the essential renewable energy utilization in India at present. Table 2 shows that India has introduced more than 5,940 MW biomass based power plants which comprises of 4,946 MW of interactive grid and 994 MW off-grid network. Out of the total power generation limit from the interactive grid, significant amount originates from biomass cogeneration and around 115 MW is obtained from waste to energy control plants. Whereas off-Grid limit consists of 652 MW non-bagasse cogeneration, mainly as captive power plants and around 18 MW of biomass energy is being utilized for addressing power needs in rural zones (Sreekanth *et al.*, 2012) and 164 MW of biomass energy is conveyed for thermal applications in enterprises.

**Table 2. Power from Interactive and off grid network biomass based power plants**

Network	Sector	Achievements (capacity in MW)
Interactive Grid	Biomass Power	4831.33
	Waste to Power	115.08
	Sub-Total Interactive Grid	4946.41
Off Grid	Biomass Cogeneration	651.91
	Rural Industries	182.39
	Waste to energy	160.16
	Sub Total Off Grid	994.46

Biomass can be changed into appropriate type of energy through various transformation techniques. In India, energy generation using biomass is mostly done in the rural or underdeveloped areas. This has very well resulted in electricity generation in these areas.

**Environmental Impacts**

The most helpful impact of biomass is the removal of use of petroleum derivatives, and the relative decrease in air contamination levels which has helped in minimizing acid rain. Another significant effect is the reuse of environmental CO<sub>2</sub>. One unsafe effect is that when the water required for cooling of the heater is dumped into the lakes and stream, it is substantially hotter than ordinary. The higher temperatures and the toxins in water can badly influence plants and fishes in that region (Tripathi *et al.*, 2016).

**Renewable Energy status and potential in India**

India has taken a vow to reduce the use of exhaustible resources and encourage the use of renewable resources for power generation. The government of India has stepped up to use renewable energy resources so that the load demands can be met. About 7.04 GW from Wind Power 5.8 GW from Solar Power, 0.93 GW from Biomass and 0.53 GW from Hydro power plants has been found in the last two years. India will accomplish about 40% of the combined Electric power limit from sustainable power sources by 2030, as announced by the government in the current United Nations Frame Work Convention on Climate Change. Solar Defense Scheme, Solar Park, Solar plan for CPUs, Solar PV control plants on Canal Tops and Canal Bank and Solar Rooftop arrangements Pradhan (Pradhan *et al.*, 2017) are propelled to meet the 175 GW of sustainable power energy till 2022. An objective of 16660 MW of inexhaustible power has been set which incorporates 4000 MW of wind energy, sunlight based 12000 MW, 250 MW of hydro energy and 400 MW of biomass based energy for the year 2016-17 as shown in Table3 and Fig. 6.

**Table 3. Target set for various non-conventional sources of energy for the coming years (Capacities in MW) [3]**

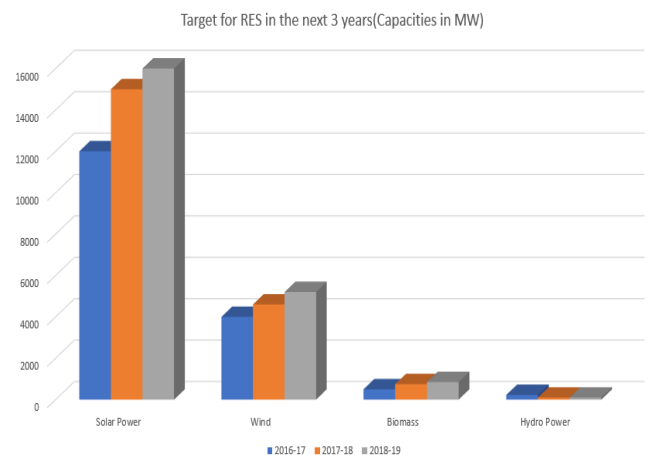
Sources	2016-2017	2017-2018	2018-2019
Wind	4000	4600	5200
Solar	12000	15000	16000
Hydro Power	225	100	100
Biomass	500	750	850
Grand Total	16725	20450	22150

**Some Emerging Technologies**

Apart from the main powerhouses of the RES like solar, wind etc. There are many newly emerging sources. Due to their low energy generation they are still in the developing phase but have vast potential. Some of the upcoming RES which are developing fast in India are describe below.

**Enhanced Geothermal Energy**

Geothermal energy is obtained or harnessed from the warmth of earth. It is harnessed from hot water geysers present naturally and even from very deep into the earth where molten magma is present. It has been estimated by Geological survey of India that the potential of geothermal energy is of the order of 10,000 MW. So, it can become a major contributor of power in future if it is harnessed properly and effectively. In India, this energy can be commercially utilized from the west coast of Maharashtra (Pandey, 2013).

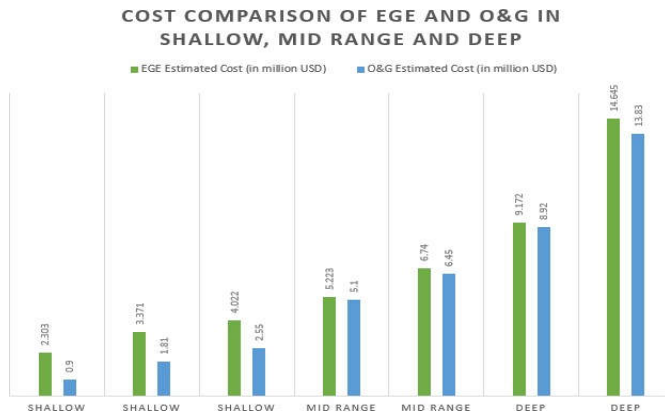


**Fig. 6. Target for the next 3 years**

The major drawback of geothermal energy is that it is restrained to the areas which have bounty of natural sources (Asif and Muneer, 2007). So, to beat this drawback an enhanced form of geothermal energy namely Engineered Geothermal Energy (EGE) has been developed. EGE doesn't depend on the naturally occurring reservoirs to extract geothermal energy. In this approach, a well is drilled to reach greater depths so that the rock temperature is high enough at those depths. Once, sufficiently hot rocks are found, the drilling is stopped and suitable equipments are installed in the EGE power plants to extract the heat which can be used to meet power requirements. It is observed that the cost of EGE is somewhat greater than cost of Oil and Gas at all levels. The difference is more noticeable in deep well depths. But, since EGE is a renewable energy source it should replace Oil and Gas sources as they are exhaustible and will finish off in some years of time.

**Table 4. Cost comparison of EGE vs Oil & Gas Estimated cost**

Well Depth	Well Category	EGE Estimated Cost (in million USD)	O&G Estimated Cost (in million USD)
1500	Shallow	2.303	0.9
2500		3.371	1.81
3000		4.022	2.55
4000		5.223	5.1
5000	Mid-Range	6.740	6.45
6000	Deep	9.172	8.92
7500		14.645	13.83



**Fig. 7. Cost comparison of EGE and Oil& Gas**

**Environmental impacts**

EGE has a huge potential to lessen the carbon emission. But this technology has some drawbacks also. It may result in minor earthquake or landslides in the areas where it is installed. EGE might cause small environmental issues if the plants are not maintained properly.

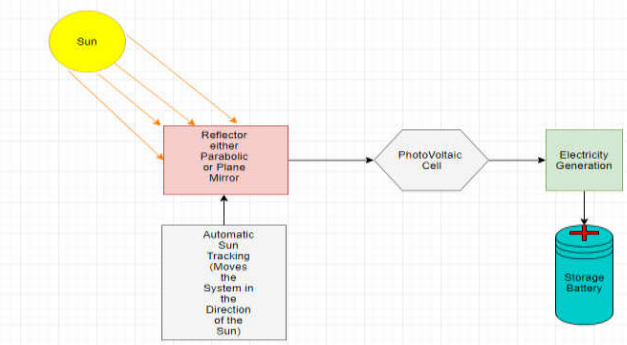
**Concentrated Solar Power/Photovoltaic**

The technology behind Concentrated Solar Power or CSP is that the heat produced by the solar radiation is used to generate electricity by concentrating it on a small area (Asif and Muneer, 2007). A system of mirrors and concentrators is used to focus the sun rays (Wessley *et al.*, 2017). The heat is converted to mechanical energy with the help of a steam turbine and then finally converted to electricity (Muller-Steinhagen and Trieb, 2014). There are four techniques which are commercially available in India but a technique called Parabolic Trough is the most prevalent ([https://www.nrel.gov/csp/solarpaces/by\\_country\\_detail.cfm/country=IN](https://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=IN)). CSP equipped with proper heat storage system can generate electricity after sunset or even in cloudy skies. Some of the Ongoing Projects in India on Concentrating Solar Power Projects in India are ([http://www.business-standard.com/content/manufacturing-industry/concentrating-solar-power-in-india-an-outlook-to-2024-114091500273\\_1.html](http://www.business-standard.com/content/manufacturing-industry/concentrating-solar-power-in-india-an-outlook-to-2024-114091500273_1.html)) Abhijeet Solar Project, Dadri ISCC Plant, Godawari Solar Project, National Solar Thermal Power Facility and Megha Solar Plant. The Rajasthan Desert has the potential to become the biggest solar power plant in India. As it receives large level of sunlight, CSP Plants in Rajasthan will be able to satisfy most of India’s energy needs in the upcoming years (Photovoltaics<http://www.seci.gov.in/content/innerpage/concentrated-solar-thermal-power.php>). Solar Energy Corporation of India (SECI) is

developing Pilot Concentrated Solar Power Projects to implement new techniques on commercial scale. Two CSP Plants, of power capacity of 50 MW are being developed (Photovoltaics<http://www.seci.gov.in/content/innerpage/concentrated-solar-thermal-power.php>). The 2015 Today markets has ranked India as 5<sup>th</sup>, in the most promising market for CSP (26).Project 1 of SECI is estimated to generate 50MW of power through Parabolic Trough technology. Project 2 is estimated to generate 50MW of power on Solar Tower Technology (Photovoltaics<http://www.seci.gov.in/content/innerpage/concentrated-solar-thermal-power.php>).

**Environmental Impacts**

The potential natural effects related with CSP are the usage of land, loss of habitat, usage of water, and the use of hazardous products in manufacturing can fluctuate enormously depending upon the technology, which incorporates two categories: Photovoltaic (PV) shown in Fig. 8 and the sun oriented cells or concentrating solar power plant (CSP) (Hairat and Ghosh, 2017).



**Fig. 8. CSP Module**

**Conclusion**

The emission of greenhouse gases especially CO<sub>2</sub> which is leading to global warming has been increased to a great extent. This is the peak time when we should switch from exhaustible to renewable energy resources to save our environment. India’s condition especially in Metro cities is in critical condition due to the emission from burning of non-renewable sources to extract energy. Especially in Delhi, the air quality is very poor and this lead us to seek some immediate remedy. There is a quick need to switch to some clean sources of power which is not harmful and can sustain for a longer period of time. So, through this paper using some charts and tables, the standing of India in the generation of Renewable energy has been depicted.

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