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Review Article

Impacts of Solar Power in India: A Review

Madhu Kumari[1], Dr. Prasoon Kumar Singh[2]

[1]Assistant Professor, DASH Department, National Institute of Foundry and Forge Technology, Hatia, Ranchi, Jharkhand, India.
[2]Assosciate Professor, Environmental Science and Engineering, IIT (Indian School of Mines), Dhanbad, Jharkhand, India.

Corresponding Author: Madhu Kumari

ABSTRACT

India, a country which has a rapidly growing economy with more than 1 billion people, is facing a huge energy demand. The country stands fifth in the world for the production and consumption of electricity. The electricity production has expanded over the years but we cannot deny the fact that the population of the country is also expanding at a steady pace. The power produced in the country is mostly from coal for lighting and firewood for cooking and heating, it is predicted that the country's coal reserves won't last beyond the year 2040-50. More than 72% of the population is living in villages and half of the villages remain without electricity. Till date there are 640,867 villages scattered everywhere. Around 18,452 villages are still un-electrified in various parts of India. Unfortunately, even after electrifying a village, most of the households don't receive any electricity. It's high time that our country should concentrate more on energy efficiency, conservation and sustainable energy. To meet this surging demand, solar energy is the best form of energy to fulfill the energy needs of India and bridge the energy demand-supply gap.

Keywords: Solar energy; renewable energy; sustainable energy; energy demand; India.

1. INTRODUCTION

The sun, as we all know, is a huge source of energy which has only been recently tapped into. It provides immense resources which can generate clean, non-polluting and sustainable electricity, thus resulting in no global warming emissions. In recent years, it was discovered that the power of the sun can be collected and stored, to be used on a global scale with the purpose of eventually replacing the conventional sources of energy. As the world is turning its focus to cleaner power, solar energy has seen a significant rise in importance. Solar energy is a renewable free source of energy that is sustainable and totally inexhaustible, unlike fossil fuels that are finite. It is also a non-polluting source of energy and it does not emit any greenhouse gases, i.e., H_2O (water vapor), CO_2 (carbon dioxide), etc. when producing electricity.

Solar power systems offer significant environmental benefits in comparison to the conventional energy sources, thus they greatly contribute to the sustainable development of human activities. Apart from the sustainable development of human activities, solar power systems can easily provide a village with electricity for various electrical appliances. They derive clean, pure energy from the sun. Installing solar panels helps combat greenhouse gas emissions and reduces our collective dependence on fossil fuel.

Traditional electricity is sourced from fossil fuels such as coal and natural gas. When fossil fuels are burned to produce

electricity, they emit harmful gases that are the primary cause of air pollution and global warming. By the use of sustainable energy like solar energy, we can assured that our environment is safe and clean for the survival of mankind.

India has 20% of the world's population but 40% of the world's population without electricity. Rural areas in India are electrified non-uniformly, with richer states being able to provide a majority of the villages with power while poorer states (Jharkhand, Manipur, Chhattisgarh, etc.) are still struggling to do so.

2. Objectives

In this paper, an attempt is made to assess;

(a) a cleaner and greener environment with the use of energy generated by solar power systems,
(b) a better economic prospect of the country in the future,
(c) rural electrification with the help of solar power systems instead of using non-renewable energy sources.

3. Renewable energy.

Renewable energy is the energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services. For example: wind energy, solar energy, hydro power, bio fuel etc. Directly or indirectly, renewable energy comes from either the sun or wind, and these can never be exhausted, that's why these are called renewable source of energy. A sustainable energy system can convert the energy emitted by the sun, sea waves, wind etc. to produce electricity, or heat. However, most of the world's population depends on the use of fossil fuels for the production of electricity or heat. In the year 2008, renewable energy has a contribution of 19% in the total energy consumption globally, in which about 13% of energy contribution is from traditional biomass, 3.2% of energy contribution from hydroelectricity and 2.7% of energy contribution is from other source of renewable energy like wind power, hydro power, solar power, geothermal energy.

3.1. Renewable energy in India.

Renewable energy in India comes under the purview of the Ministry of New and Renewable Energy (MNRE). Newer renewable electricity sources are targeted to grow massively by 2022, including a more than doubling of India's large wind power capacity and an almost 15 fold increase in solar power from April 2016 levels. [1]

TABLE I: Installed grid interactive renewable power capacity in India as of December 31, 2016 (RES MNRE)

Source	Total Installed Capacity (MW)	2022 target (MW)
Wind Power	28700.44	60,000.00
Solar Power	9012.66	100,000.00
Biomass Power (Biomass & Gasification and Bagasse Cogeneration)	7856.94	10,000.00
Waste-to-Power	114.08	
Small Hydro Power	4333.85	5,000.00
Total	***'50017.97***	**'175,000.00**

India was the first country in the world to set up a ministry of non-conventional energy resources, in early 1980s. As of September 30, 2016 India's cumulative grid interactive or grid tied renewable energy capacity (excluding large hydro) reached about 44.24 GW. 61% of the renewable power came from wind, while solar contributed nearly 19%. [1]

4. Solar energy.

Solar energy is the energy emitted by the sun in the form of solar radiation; it can be converted or stored to produce heat or electricity. It is a salient source of renewable energy, and can be broadly categorized into passive solar or active solar depending on how they capture and

distribute solar energy or convert it into solar power.

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared".

4.1. How do solar power plants work?

There are mainly two ways through which we can produce electricity from the sun:

Photovoltaic Electricity – This method uses photovoltaic cells that absorb the direct sunlight just like the solar cells you see on some calculators.

Solar-Thermal Electricity – This also uses a solar collector: it has a mirrored surface that reflects the sunlight onto a receiver that heats up a liquid. This heated liquid is used to make steam that produces electricity.

Photovoltaic Electricity: As light hits the solar panels, the solar radiation is converted into direct current electricity (DC). The direct current flows from the panels and is converted into alternating current (AC) used by local electric utilities. Finally, the electricity travels through transformers, and the voltage is boosted for delivery onto the transmission lines so local electric utilities can distribute the electricity to homes and businesses.

Solar-Thermal electricity: Solar collectors capture and concentrate sunlight to heat synthetic oil called therminol, which then heats water to create steam. The steam is piped to an onsite turbine-generator to produce electricity, which is then transmitted over power lines. On cloudy days, the plant has a supplementary natural gas boiler. The plant can burn natural gas to heat the water, creating steam to generate electricity. [3]

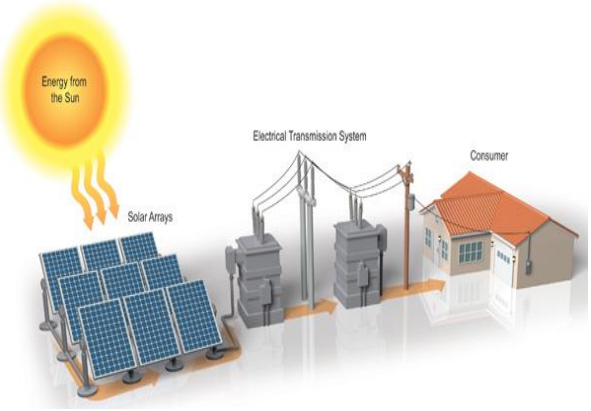

Fig. 1. How the photovoltaic solar plants work.

4.2. Solar power in India.

Solar power in India is a fast-growing industry; the government of India has been trying its best to expand its status. In the upcoming years, solar power is the key element of the government's expansion plans. In addition to the large-scale grid connected solar PV initiative, India is continuing to develop the use of off-grid solar power for localized energy needs. India has a poor electrification rate in rural areas. In 2015, only 55% of all rural households had access to electricity, and 85% of rural households depended on solid fuel for cooking.

India occupies 2% of the world's land mass and shares 16% of the world's population. It ranks 5th in the world in terms of primary energy consumption. Currently, it generates about 2% of the global electricity. Due to the occurrence of less (5% of the world reserves) and low grade coal, increasing population rate, urbanization, high living standard and industrialization, the demand of energy has been increased over the years. If India uses all of its existing domestic hydrocarbons, hydroelectric and non-conventional resources to meet its energy demand, it cannot sustain for more than a few decades. For large country like India, bulk imports of fuel or energy are neither affordable nor

strategically prudent. Thus, to meet energy demand solar power can play an important role. India has high soar insulation, providing an ideal combination for solar power in India. Much of the country does not have an electric grid, so one of the first applications of solar power has been for water pumping, to begin replacing India's 4 to 5 million diesel powered water pumps, each consuming about 3.5 kW, and off-grid lighting.

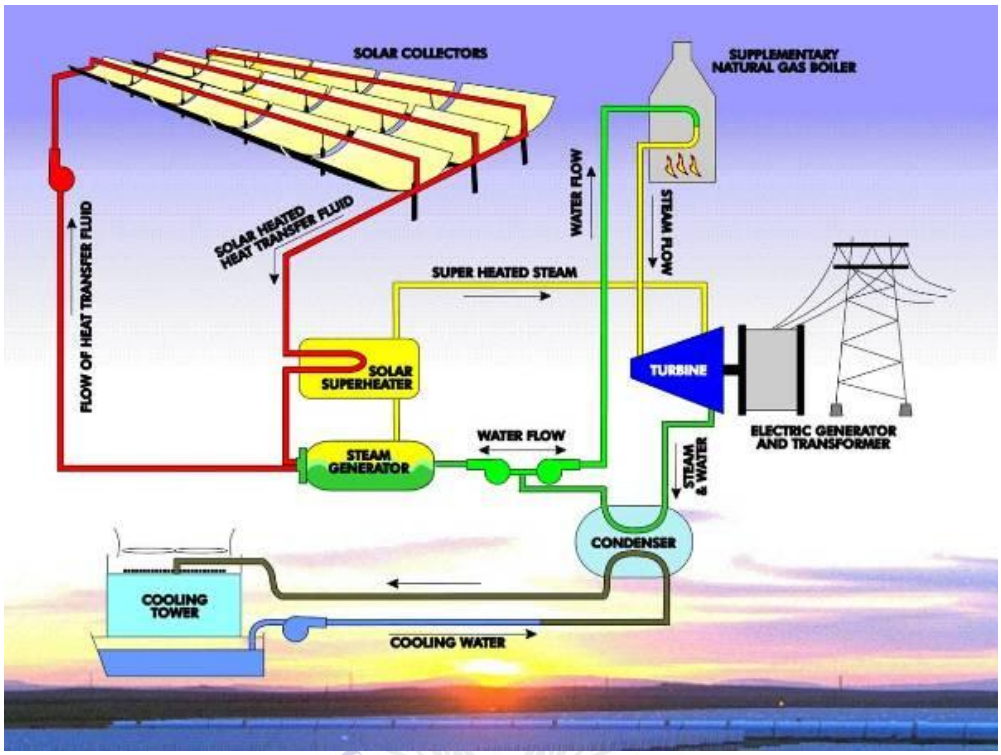

Fig.2 . How the solar-thermal power plant works.

With about 300 clear, sunny days in a year, the theoretically calculated solar energy incidence on India's land area is about 5000 trillion kilowatt-hours (kWh) per year (or 5 EWh/yr).The solar energy available in a year exceeds the possible energy output of all fossil fuel energy reserves in India. The daily average solar power plant generation capacity over India is 0.20 kWh per m^2 of used land area, which is equivalent to about 1400–1800 peak (rated) capacity operating hours in a year with the available commercially-proven technologies.

Almost all parts of India receive 4-7 kWh of solar radiation per sq. metres. This is equivalent to 2,300–3,200 sunshine hours per year. States like Andhra Pradesh, Bihar, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, and West Bengal, Jharkhand have great potential for tapping solar energy due to their location. Since majority of the population lives in rural areas, there is much scope for solar energy being promoted in these areas. The promotion of solar power in rural areas can help the villagers in many ways, from reducing the use of fossil fuels and candles for light and the use of firewood for cooking and heating to improving the education given to their children. The electricity generated by solar energy ensures that the schools in various villages have access to electric appliances like bulbs and fans, this can cause a major improvement in the education of the children.

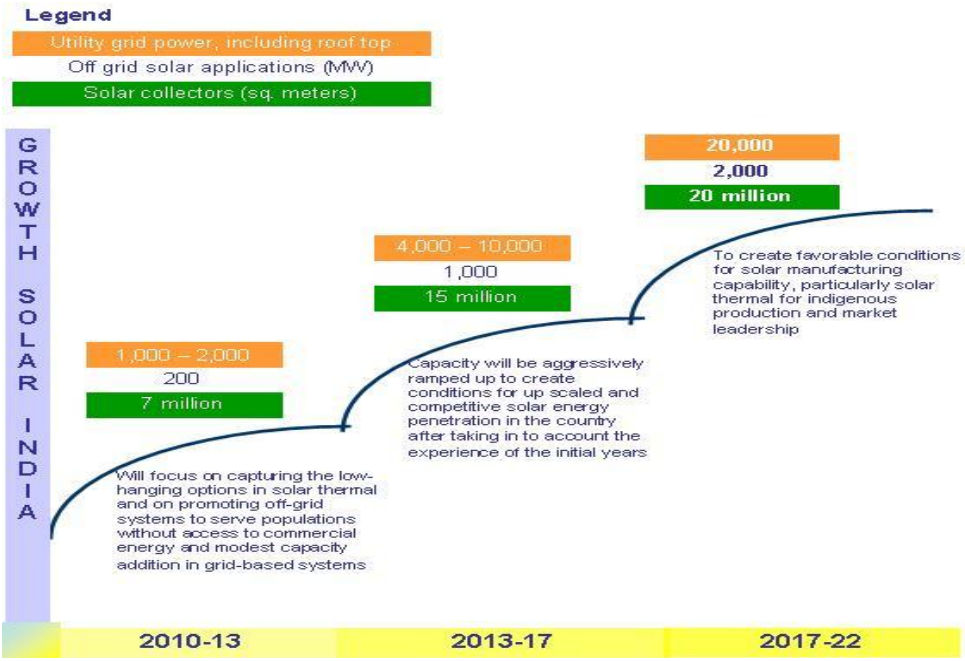

Fig. 3. Timeline of the Jawaharlal Nehru National Solar Mission.

Gujarat has been a leader in solar power generation in India due to several factors: a very high solar power potential, availability of wasteland, good connectivity, transmission and distribution infrastructure, and efficient utilities. These attributes are complemented by a strong political will and an investment, according to a report by the Low Emission Development Strategies Global Partnership (LEDS GP). The robust 2009 Solar Power of Gujarat policy framework, financing mechanism, and incentives, have contributed to creating an enabling a green investment climate in the state, and have led to ambitious targets for grid-connected solar power. The State of Gujarat has commissioned Asia's largest solar park at Charanka village. The park is already generating 2 MW solar power out of its total planned capacity of 500 MW. The park has been functioning on a multi-developers and multi-beneficiaries paradigm, and has been awarded for being the most innovative and environment-friendly project by the CII. [3]

4.3. Advantages of solar power in India.

(i) This is an inexhaustible source of energy and the best replacement to other non-renewable energies in India.

(ii) Solar energy is environment friendly. When in use, it does not release CO_2 or other gases which pollute the air. Hence it is very suitable for India, as India is one of the most polluted countries in the world.

(iii) Solar energy can be used for variety of purposes like heating, drying, cooking or electricity, which is suitable for the rural areas in India. It can also be used in cars, planes, large power boats, satellites, calculators and many more such items, that are apt for the urban population.

(iv) The energy emitted by the sun is due to nuclear fusion of hydrogen to helium. In the process, a huge amount of energy is liberated in the form of heat and light. So, even though solar energy is not infinite, it can go on for billions of years. In a energy-deficient country like India, solar energy is the best alternate means of power generation.

(v) A power or gas grid is not needed to derive solar energy. A solar energy system can be installed anywhere. Solar panels can be easily installed in houses, villages etc. hence, it is quite inexpensive compared to other sources of energy, i.e., fossil fuels and non-renewable resources.

(vi) The fall in the price of solar energy means that demand for coal and gas (a substitute to solar energy) is likely to fall,

either in the short term or long term. The falling price of solar power suggests there may soon be a market incentive to use solar energy rather than fossil fuels. This affects the economy of a country in a significant way and can help in job employments in a country like India, which faces problems with job employments.

TABLE II: **Some of the major photovoltaic power stations in India.**

Name of Plant	DC Peak Power (MW)	Notes
Abacus Holdings - Odisha	3	Commissioned 2011
Allahabad Solar Power Plant, Uttar Pradesh	5	Commissioned 4 March 2012.
Amruth Solar Power Plant - Kadiri, Andhra Pradesh	1	Commissioned March 2012
Azure Power - Awan Photovoltaic Plant, Punjab	2	December 2009
Azure Power - Rajasthan Photovoltaic Plant, Rajasthan	35	February 2013
Azure Power - Rajasthan Photovoltaic Plant, Rajasthan	5	December 2011
Azure Power - Sabarkantha, Khadoda village, Gujarat	10	Commissioned June 2011, 63 acres, using 36,000 Suntech Power panels.
B&G Solar Pvt Ltd - Mayiladuthurai, Tamil Nadu	1	India's First plant Commissioned under JNNSM scheme 10 June 2011
Bitta Solar Power Plant (Adani Power) - Bitta, Kutch District, Gujarat	40	Commissioned January 2012

4.4. Disadvantages of solar power in India.

(i) We cannot generate energy during the night time with solar energy. During daytime, if the weather may be cloudy or rainy, with little or no sun radiation, solar energy panels are less reliable as a solution.
(ii) Areas receiving less or no sunlight during daytime can't have solar panels installed.
(iii) Solar panels also require inverters and storage batteries to convert direct electricity to alternating electricity. While installing a solar panel is quite cheap, setting-up of other equipments become quite expensive and problematic.
(iv) Solar panels require considerable maintenance as they are fragile and can be easily damaged.

4.5. Impact of solar power on the environment.

Even though solar power plants don't emit harmful gases, or CO_2 which results in greenhouse effect, it still causes damage to the environment. The potential environmental impacts associated with solar power can be classified according to numerous categories, some of which are land use impacts, ecological impacts, impacts to water, air and soil, and other impacts such as socioeconomic ones can vary greatly depending on the technology, which includes two broad categories:
(i) Photovoltaic (PV) solar cells or,
(ii) Concentrating solar thermal plants (CSP).

Impacts on land use: Depending on their location, larger utility-scale solar facilities can raise concerns about land degradation and habitat loss. Total land area requirements vary depending on the technology, the topography of the site, and the intensity of the solar resource. The land used for installing solar power plants cannot be used for any other purpose, due to this, the amount of usable lands will reduce dramatically.
Impacts on soil, air and water resources: The construction of solar facilities on vast areas of land imposes clearing and grading, resulting in soil compaction, alteration of drainage channels and increased erosion. Central tower systems require consuming water for cooling, which is a concern in arid settings, as an increase in water demand may strain available water resources as well as chemical spills from the facilities which may result in the contamination of groundwater or the ground surface. Concentrating solar thermal plants (CSP), like all thermal electric plants, require water for cooling. Water use depends on the plant design, plant location, and the type of cooling system.

Fig. 4. PV Solar cells require large areas for set-up.

Fig. 5. CSP Power tower system requires water to cool down.

Hazardous materials: The PV cell manufacturing process includes a number of hazardous materials, most of which are used to clean and purify the semiconductor surface. These chemicals, similar to those used in the general semiconductor industry, include hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride, 1,1,1-trichloroethane, and acetone. [4]

5. Economic significance of solar energy in India.

The relationship between income levels, energy prices, and energy expenditure is fundamental to the evolution of India's economy. With years passing by, we have noticed that wealthiest 10% of the population spend only a quarter of their household expenditure on energy than the poorer, who spend most of their income on energy. This said, its quite clear that solar energy has been limited in various parts of India with low percentage of consumption. Even though, India has great potential in providing solar power systems across the country, it still lacks behind. The population has been dependent on the use of non-renewable energy for most of the time, switching to solar energy will be quite difficult.

Overall, the economy of India will suffer as well. If the demand for solar panels rises, the coal suppliers will lower the price of coal supplies, there will be tough competition and eventually when the prices have dropped, more than expected, the population will jump back to the use of fossil fuels.

6. Solar power in the world.

The world is finally turning to the use of renewable energy, this significant step ensures that the non-renewable resources won't end completely in the upcoming years. Even though, non-renewable resources won't be reduced immediately, we still have to keep in mind that the resources are used with care.

Many industrialized nations have installed significant solar power capacity into their electrical grids to supplement or provide an alternative to conventional energy sources while an increasing number of less developed nations have turned to solar to reduce dependence on expensive imported fuels. Long distance transmission allows remote renewable energy resources to displace fossil fuel consumption.

As of January 2017, the largest solar power plants in the world are the 850 MW Longyangxia Dam Solar Park in China for PV and the 377 MW Ivanpah Solar Power Facility in the United States for CSP. Other large CSP facilities include the Solnova Solar Power Station (Spain, 150 MW), Andasol Solar Power Station (Spain, 150 MW) and the first part of Shams solar power station (United Arab Emirates, 100 MW). [6]

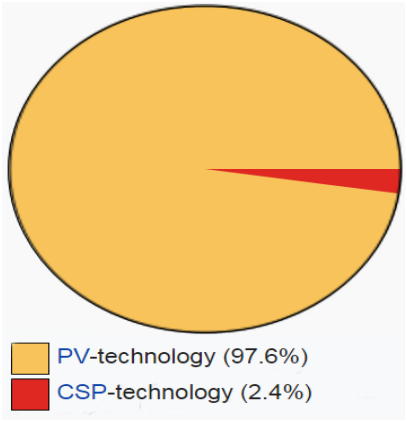

Fig.6. Worldwide electric capacity of solar power by technology. Total of 142 GW in 2013.

TABLE III: Installed Solar Power Capacity in 2015 (MW)

#	Nation	Total Capacity	Added Capacity
-	European Union	94,570	7,230
1	China	43,530	15,150
2	Germany	39,700	1,450
3	Japan	34,410	11,000
4	United States	25,620	7,300
5	Italy	18,920	300
6	United Kingdom	8,780	3,510
7	France	6,580	879
8	Spain	5,400	56
9	Australia	5,070	935
10	India	5,050	2,000
11	South Korea	3,430	1,010
12	Belgium	3,250	95
13	Greece	2,613	10
14	Canada	2,500	600

Worldwide growth of photovoltaics is extremely dynamic and varies strongly by country. By the end of 2014, cumulative photovoltaic capacity increased by more than 40 gigawatt (GW) and reached at least 178 GW, sufficient to supply 1 percent of the world's total electricity consumption of currently 18,400 TWh. As in the year before, the top installers of 2014 were China, followed by Japan and the United States, while the United Kingdom emerged as new European leader ahead of Germany and France. Germany remains for one more year the world's largest producer of solar power with an overall installed capacity of 38.2 GW. The newcomers of the year were Chile and South Africa, which entered straight into the world's Top 10 ranking of added capacity. There are now 20 countries around the world with a cumulative PV capacity of more than one gigawatt. Thailand, the Netherlands, and Switzerland, all crossed the one gigawatt-mark in 2014. The available solar PV capacity in Italy, Germany and Greece is now sufficient to supply between 7% and 8% of their respective domestic electricity consumption. [6]

7. Comparing solar power in India and Germany.

Germany:

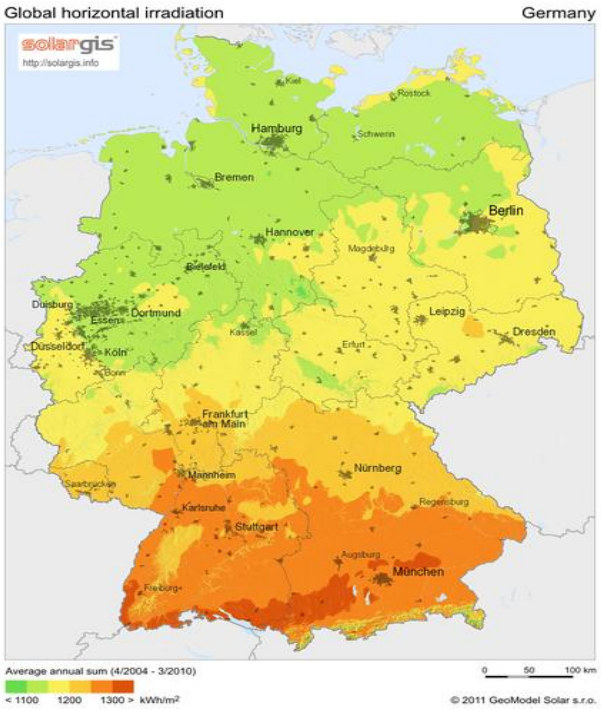

Fig.7. Solar potential of Germany.

➢ **Solar power in Germany** consists almost exclusively of photovoltaics (PV) and accounted for an estimated 6.2 to 6.9 percent of the country's net-electricity generation in 2014.

➢ The country has been amongst the world's top PV installer for several years, with total installed capacity amounting to 40,782 megawatts (MW) by the end of November 2016, behind 1. China

➢ About 1.5 million photovoltaic systems are installed all over the country, ranging from small rooftop systems, to medium commercial and large utility-

scale solar parks, that altogether contributed 35.2 terawatt-hours (TWh), or about 6.9 percent in 2014.

➢ The nation's largest solar farms are located in Meuro, Neuhardenberg and Templin, with capacities beyond 100 MW. [7]

India**:**

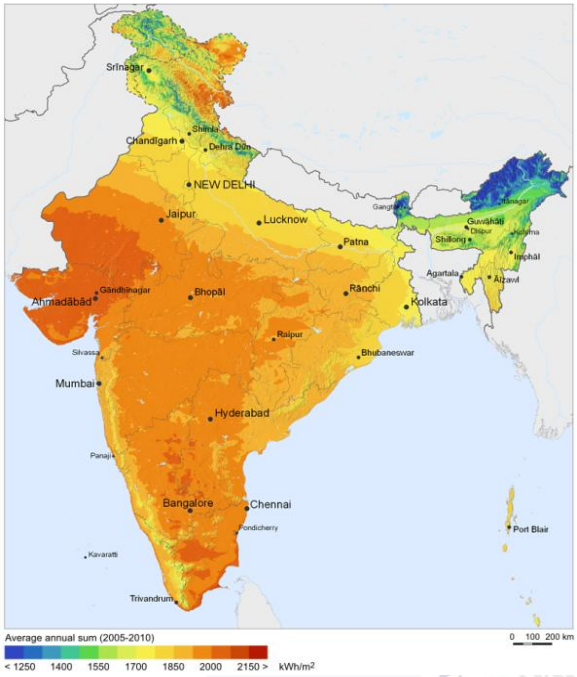

Fig.8. Solar resource of India.

➢ **Solar power in India,** has been growing at a fast pace in the recent years. As of 31 January 2017, the country's solar grid had a cumulative capacity of 9.24 gigawatts (GW).

➢ In addition to the large-scale grid connected solar PV initiative; India is continuing to develop the use of off-grid solar power for localized energy needs. Solar products have increasingly helped to meet rural needs, and by the end of 2015, a cumulative total of just under 1 million solar lanterns had been sold in the country, reducing the need for expensive kerosene.

➢ On 16 May 2011, India's first solar power project (with a capacity of 5 MW) was registered under the Clean Development Mechanism. The project is in Sivagangai Village, Sivaganga district, T amil Nadu.

➢ India saw a sudden rise in use of solar electricity in 2010, when 25.1 MW was added to the grid, and the trend accelerated when 468.3 MW was added in 2011. [3]

8. What is the future of solar energy in India?

In solar energy sector, many large projects have been proposed in India.

(i) Thar Desert has some of India's best solar power projects, estimated to generate 700 to 2,100 GW.

(ii) On March 1st, 2014, the then Chief Minister of Gujarat, Narendra Modi, inaugurated at Diken in Neemuch district of **Madhya Pradesh**, India's biggest solar power plant.

(iii) The Jawaharlal Nehru National Solar Mission (JNNSM) launched by the Centre is targeting 20,000 MW of solar energy power by 2022

(iv) Gujarat's pioneering solar power policy aims at 1,000 MW of solar energy generation.

(v) In July 2009, a $19 billion solar power plan was unveiled which projected to produce 20 GW of solar power by 2020.

(vi) About 66 MW is installed for various applications in the rural area, amounting to be used in solar lanterns, street lighting systems and solar water pumps, etc.

9. CONCLUSION

➢ India, home to 18% of the world's population, uses only 6% of the world's primary energy. India's energy consumption has almost doubled since 2000 and the potential for further rapid growth is enormous.

➢ In India, renewable energy such as solar energy can replace the use of fossil fuels in the upcoming years.

➢ Solar energy technology is currently making a major contribution in the field of economic development of the country.

➢ A brief assessment of global status of solar energy in this paper indicates that a minimum level of maintenance appears necessary to encourage solar power

deployment, and also shows the goal which is necessary for the growth of solar power in India.

➢ To improve the condition of rural areas, solar panels should be installed near villages to produce electricity for the villagers.

➢ India's solar power industry still has a long way to go but if it works at a steady pace and correct plans, the country will soon stop being dependent on non-renewable resources.

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