Solar Power Generation, Utilization and Management for facilitating Sustainable Development in India: Review

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ABSTRACT
The approach of the paper is to present a review of solar power generation, utilization and its management for facilitating sustainable development in India. It briefs about the allusive estimation of the solar energy and its utilization. The Solar Energy is a gigantic energy source that can be used for any of the day-to-day requirements, including engineering, the refrigeration, the water heating, the heat of industrial processes, transportation and sustainable production and even for the cleaning of environment. The solar radiation is the purest and cleanest form of the energy where no mass is attached, and it can be converted in to any forms easily. The solar energy that falls on the surface of the earth is sufficient to provide solution to all our requirements on this planet. Among all the sectors of India, power sector is largest one which is important for the growth of Indian economy. There is perpetual and rising demand of power in the all the sectors. So, to meet the increasing demand and to overcome the shortage of power, generation of power by renewable energy source is must for sustainability in this field. In the today’s scenario, generation of power from renewable energy source is necessary as compared to non-renewable energy sources. This paper emphasizes on the the scope of generation, usage and its management for sustainable development of India.

Keywords— Solar Power, Structures, Non-renewable Energy Source, Renewable Energy Source, Sustainable Development

1. Introduction
Renewable and non-renewable energy sources are the two primary types of energy sources available on the planet. The renewable energy sources (RES) fulfill one sixth of total energy demand of the globe [1]. The sources of renewable energy include solar, geothermal, wind, marine energies and hydropower. Renewable energy sources are devoid of pollutants and can be replenished. This is one of the biggest advantages of RES [2, 3]. The usages of RES have increased over past decade and are expected to increase by 80 percent in the next century [4, 5]. The Global energy scenario over next three decades has been presented in Table 1. In the current era, the world is moving towards the concept of sustainable development. The environmental impact of human activities is the most important parameters
measuring the sustainable development [7]. The literature review shows that with the advancement in technology and rapid industrialization, the usage of fossil fuels has immensely increased, which is responsible for global climatic change [8]. The developed Nations are moving towards sustainable development through measures of reduction in emission of greenhouse gases, conservation of forests, renewable energy consumption etc. [9]. Excessesive use of fossil fuels has alarm the risk of its depletion and there is acute necessity of searching for new energy sources to fulfill human demands [10, 11]. Moreover, use of fossil fuels had lead to greenhouse effect and environment pollution and necessity of cleaner fuel is required [12, 13]. This paper attempts to provide a critical review of the scope of available renewable energy sources, to fulfill the energy demands through its proper utilization and management.

Table 1: Global Solar energy scenario 2040 [14]

| Total consumption (million tons oil equivalent) |
|-----------------------------------------------|
| Year  | 2001  | 2010  | 2020  | 2030  | 2040  |
|-------|-------|-------|-------|-------|-------|
| Solar thermal energy | 4.1   | 15    | 66    | 244   | 480   |
| Photovoltaic Energy   | 0.1   | 2     | 24    | 221   | 784   |
| Solar thermal electricity | 0.1  | 0.4   | 3     | 16    | 68    |

2. Renewable energy sources

In future, renewable energy sources are indispensible options in the generation of the power and sustainable growth. RES can be recycled infinitely and there is no possibility of its depletion [15,16]. Fig. 1 illustrates the different sources of renewable energy. It can be further sub categorized into solar power, biomass, wind power and hydro power. Non-RES are frequently used for domestic purposes which are the major source of emission of greenhouse gases and air pollutants. [17,18]. Solar home systems, solar dryers, solar cookers, photovoltaic, thermal power generation, and water heaters are some of the most common uses of solar energy.[19,20]

Figure 1: Sources of Renewable Energy [21]
2.1. Solar Energy

Solar energy is abundantly available energy sources. Sun emits enormous amount of energy in a day sufficient to fulfill energy demand of the earth for whole year, but only 50% of Sun's energy is received by Earth and far lesser amount is used to meet energy requirements [22,23]. There is a extensive possibility for utilization of solar energy [24,26]. Generation of power by solar energy saves emission of 39 billion tons of carbon dioxide per year [27,29]. Among the domestic applications solar cooking is one of the most usual applications of solar energy. Solar cookers of different varieties are easily available and very economical. Solar water heater is another prevalent application of solar energy for domestic use and it is estimated that it can extenuate carbon dioxide emissions significantly [30]. Solar drying technology is the most efficient process dry vegetables and fruits clean and hygienic environment with zero energy costs and it results in saving of time energy and has lesser area requirements. It tremendously improves the quality of fruits and vegetables and reduces their deterioration comprehensively [31,32].

In country like India, the energy which is freely available throughout the year is solar energy. Its inherent advantage is its ample availability in remotest corner of our country [33]. India receives nearly 5,000 trillion kWh of solar energy per year, which is equivalent to 600 GW, due to its varied geological terrain. This is much more than the country's current total energy consumption. [34, 35].

The technologies used to generate solar energy can be divided into two categories:
- Solar thermal power plants are a type of solar thermal power plant that uses sunlight to generate electricity
- Photovoltaic Electricity Generation System (Solar PV)

2.2. Solar thermal powerplants

Solar thermal power plants convert solar radiation into high-temperature heat using mirrors and reflectors to generate electricity. This energy is used to generate steam by heating a working fluid. The steam is then used to spin a turbine or power an engine, which drives a generator and generates electricity. [36]. Solar collectors are one of the main components of solar thermal system. The solar collectors are a special kind of heat exchangers which convert solar radiation into electrical energy [37]. However, the initial cost for this type of power generation is quite high as compared to other sources of electricity generation but it involves least amount of carbon emission as shown in Table 2.

Table 2 When traditional technologies are compared to solar power generation in terms of cost and emissions is shown below [38].

| Electricity Generation technology | Carbon emissions (gC/kWh) | Generation costs (US¢/kWh) |
|-----------------------------------|---------------------------|-----------------------------|
| Solar thermal and solar PV systems | 0                         | 9–40                        |
| Pulverized gas turbine coal-natural | 100–230                   | 5–7                         |
2.3. Solar Photovoltaic Electricity Generation System

Solar photovoltaic cells are the source of generation of electricity in which solar energy is converted into electricity by use of photovoltaic cells. Photovoltaic models produce electricity directly from the sunlight without any gas emission and noise pollution. The development of new technology has reduced the cost of solar power generation drastically. The photovoltaic models require very large surface area even for generation of small quantity of energy [39, 40]. The inverter is the primary components of photovoltaic system its main function is to convert DC power to AC power, to meet the voltage and power quality requirements of substations. Due to abundance of silicon, the Silicon solar cells are the most preferred photovoltaic cells especially for space and Terrestrial applications. Photovoltaic system is promising sources of energy generation and it works with least carbon dioxide emission [41,42].

Fig. 2 Represents some thermal technologies which are in general practice.

![Figure 2: Solar Thermal Technologies [43]](image_url)

In the generation of electricity by solar photovoltaic, a minimal amount of the non-renewable energy is being utilized during its installation, manufacturing and transportation of solar PV modules and its components [44]. The energy consumption during the manufacturing, its installation and transportation of the solar PV systems is being is assessed LCA (life cycle assessment). It indicates the efficiency of plant as well as its economic analysis. Presently, India ranks at the sixth position in the generation of the electricity and it is about 4 % of the world’s electricity generation per annum[44-46]. The direct conversion of solar energy to electricity is mainly done through photovoltaic cells. PV's effect is determined by photon interactions with energies equal to or greater than the band gap of PV materials.. Basically, there are two classifications of the PV systems, which are basically Flat-plate PV systems and Concentrator PV systems. Flat Plate PV systems typically use flat plate[47].

Flat-plate collectors are a large number of cells mounted at a fixed angle on a rigid flat surface, which collects optimum sunlight throughout the year. Both direct sunlight and diffuse sunlight reflected from clouds, the ground, and objects are used in this system. Concentrator PV systems make use of specialised, effective solar cells and concentrating optics to boost the intensity of sunlight striking the cells, which is usually very low.
[48]. It comes in two different configurations: point-focus and line-focus. Reflective parabolic dishes or circular Fresnel lenses (which use saw-tooth grooves in a plastic sheet) are used in point-focus systems to focus sunshine onto a cell mounted at the focal point, while linear parabolic reflectors or linear Fresnel lenses are used in line-focus systems to focus sunlight on cells mounted along the focal line. Concentrator systems, in particular, use two-axis tracking to track the sun and capture as much direct sunlight as possible[49-50].

3. Generation and Utilization of Solar Power in India

Solar PV-based power generation is being given more importance in India in order to quickly increase the share of electricity production from renewable energy. The Indian government expects to produce 175 GW of electricity from renewables by 2022 as part of the Jawaharlal Nehru National Solar Mission [51]. Fig.3. demonstrate the solar radiation zone of India. The suggested goal is to produce five times the current amount of electricity from renewable sources. 100 GW of the 175 GW target will be created solely from solar energy, with the remainder coming from wind, biomass, and small hydro. Out of total solar-based energy, the Indian government seeks to generate 40 GW from rooftop solar PV. India currently has an installed capacity of 8.7 GW of solar PV power plants. [52].

Figure 3: Solar radiation zones as per TERI based on the IMD database [53]

The Ministry of New and Renewable Energy (MNRE) has devised a plan to establish a number of solar parks throughout the country, each with a capacity of solar projects of at least 500 megawatts. The Scheme suggests
that the Government of India provide financial support to construct solar parks with the aim of facilitating the creation of infrastructure required for the establishment of new solar power projects in terms of land allocation, transmission and evacuation lines, access roads, water availability, and other factors in a targeted way [54,55]. SECI, a central public sector company under the Ministry of New and Renewable Energy, has been implementing various schemes to grow the solar sector in India based on the availability of solar radiation. Fig. 4 shows the India Solar resource map which shows the areas of maximum and minimum radiation, which is exploited in finalizing solar parks.

Figure 4: India Solar Resource Map [56]
The state appoints a nodal agency to oversee the solar park’s construction. The Solar Park is a focused area for solar power generation project growth. Land needed for the construction of Solar Power Projects with cumulative capacity of 500 MW and above is identified and purchased as part of solar park growth, and various infrastructures such as transmission systems, water, road connectivity, and communication networks are constructed. [57]. By avoiding emissions equal to the solar park’s produced capacity, the state will be able to minimise its carbon footprint. Rajasthan and northern Gujarat receive the most annual global radiation, as can be seen. As of September 2015, Rajasthan had the highest share of solar power generation in India, with 28.4 percent, followed by Gujarat with 24.4 percent [58-60].

Table 3 shows current solar power plants in different state of India.

Table 3: Some Solar plants of India [61]

| Name of Solar Plants                                                                 | Peak Power (MW) | Commission Year |
|-------------------------------------------------------------------------------------|-----------------|-----------------|
| Charanka Solar Park, Charanka village, Patan, Gujarat                               | 224             | Apr-12          |
| Welspun Solar MP project, Neemuch, Madhya Pradesh                                   | 151             | Mar-13          |
| Mahagenco Solar Project, Maharashtra                                                | 130             | Mar-13          |
| Rajgarh Solar PV, Rajighar Madhya Pradesh                                           | 50              | Mar-14          |
| Welspun Energy Rajasthan Solar Project, Phalodhi, Rajasthan                          | 50              | Mar-13          |
| Talcher Kaniha Solar PV, Odisha                                                     | 10              | Mar-14          |
| Unchahar Solar PV, Unchahar, Uttar Pradesh                                         | 10              | Mar-14          |
| Sharda Construction, Latur, Maharashtra                                            | 10              | June-15         |
| Jalaun Solar Power Project, Uttar Pradesh                                           | 50              | Jan-16          |
| Mandsaur Solar Farm, Madhya Pradesh                                                | 250             | July-18         |
| Rewa Ultra Mega Power Project, Madhya Pradesh                                       | 750             | July-18         |
| Pavagada Solar Park, Karnataka                                                     | 2050            | Dec-19          |
| Bhadla Solar Park, Rajasthan                                                       | 2245            | Mar-20          |

3.1. Grid connected roof top solar PV System

Solar PV systems have become more feasible and appealing in recent years. The available roof-top area on the buildings can also be used to set up solar PV power plants, obviating the need for free land, as shown in Fig.5. Solar PV system power can also be fed into the distribution or transmission grid after conditioning for grid integration [62].
The following are the benefits of a grid-connected rooftop solar PV system:

- Production of environmentally friendly energy.
- For his own electricity needs, the consumer becomes a generator.
- A reduction in grid electricity consumption.
- Exporting excess energy to the grid.

Table 4 shows the financial benefit estimates for grid-connected rooftop solar PV systems.

Table 4: Financial benefits of the grid connected rooftop solar PV systems [64]

| System size     | 100 kWp         |
|-----------------|-----------------|
| System cost     | 0.8 - 0.9 crore |
| Subsidy         | 30%             |
| Expected electricity generation | 140000 - 160000 units |
| Payback period at Grid electricity cost | 5-6 years |
| Payback period with Accelerated | 4-5 years |
| Pay back at diesel power cost | 3-4 years |
| Plant life      | 25 years        |

4. Management of Solar Power

There is a huge potential of solar power generation in India as it passes through the line of equator, where there is availability of ample amount of solar radiant energy. [65] The Renewable energy potential and installed capacity as of November 2017 in India is elucidated in Fig.6.
Figure 6: Renewable energy potential and installed capacity as of November 2017 (in GW) [66]

- The Indian Ministry of New and Renewable Energy (MNRE) began a large-scale solar resource monitoring and meteorological station network in 2011 as part of the Solar Radiation Resource Assessment (SRRA) project. The Solar Radiation Resource Assessment (SRRA) project includes the following components:
  - SRRA field stations: 51 SRRA field sites in various parts of India have been installed with Automatic Solar Radiation and Weather Monitoring Stations (ASRWMS).
  - A central receiving and processing station collects data, performs quality checks and controls, processes it, and disseminates it. [67].

5. Conclusion

Energy is inextricably linked to long-term growth and the resolution of the economic crisis. It encompasses almost all facets of development, such as livelihood, health, education, agriculture, and job creation. The production and consumption of energy are important components of India's long-term growth. Sustainable development, economic growth, and environmental protection all require significant amounts of energy. Energy generations' policies must be oriented toward the promotion of energy systems based on renewable energy, energy efficiency, and cleaner fossil fuel technologies, which can simultaneously address social, economic, and environmental issues. Increasing the utilization of the solar energy can also aid governments to achieve energy security and diversity. Solar energy is also under utilised, despite its vast untapped potential. On the other hand, the lower cost of solar power generation, advancements in solar energy technology, and governments' interest in supporting solar energy as a result of its positive environmental impact would enable solar energy to grow in India, resulting in long-term growth. The importance of solar energy as a source of energy in India's view is not only to increase power generation, but also to improve energy reliability by taking into account environmental, social, and financial considerations.
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