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Role of Solar Power in Sustainable Development of India

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ABSTRACT

Bulk group of rural households, dependency on insufficient and poor quality energy sources are the features of Indian energy consumption pattern. Sustainability is the move towards the growth and development of India. Solar Energy is one of the renowned sectors to support the sustainability of India. Solar energy has giant potential in India due to its position in tropical belt. This paper deals with the new innovative applications of solar energy for sustainable development of India. Solar application in transportation, architecture, car parking, restaurants, lighting, mobile charging etc are described for sustainable development. The paper includes the existing applications of solar energy, the current status of solar energy in India, challenges in the progress of solar energy and concludes with some solutions to promote solar energy.

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1. INTRODUCTION

Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. From the concern of climate change, global warming and to ensure sustainable future sustainable energies are gaining importance [2-4]. Sustainable energy is the sustainable stipulation of energy that is clean and long lasting with very less emission of polluting gases i.e. solar energy, wind energy, biomass energy, geothermal energy, etc. and are also often called alternative sources of energy [5]. Amongst all the clean technologies, solar energy is an efficient renewable energy source to alleviate the emission of greenhouse gas and helps to trim down global warming [6, 7]. India receives solar energy equivalent to over 5000 trillion kWh per year with about 300 clear sunny days in a year [8, 9] and most of it remains unused for human well-being. Energy sector has great role in improving the quality of life [10]. Energy consumption pattern of India is characterized by a bulk group of rural households, dependent on insufficient and poor quality energy sources [11, 12]. Sustainability is the approach of India towards growth and development [13]. Solar Energy is one of the sectors that are recognized to support the sustainability of India. Solar energy has giant potential in India due to its position in tropical belt [14, 15].

Most of the power distribution companies in India are unable to meet their renewable purchase obligations due to high transmission and distribution losses. So, transfer of renewable purchase obligations to large power consumers which already pay high power tariffs and are close to grid-parity is one option for those states. Another key driver in the Indian solar market is to increase the demand for solar from these power consumers.
[16].

The removals of barriers are ongoing, and it provides strong support in expansion of the solarmarket. This paper deals with the role of solar power in sustainable development of India, which

includes the current status of solar power, barriers & remedies to barriers in solar industry and future scope of solar power in sustainable development of India.

Many solar energy technologies are not yet cost-competitive with conventional energy supplies. Considerable development in solar energy is impossible until major policy incentives are introduced. Many nations have realized the problem and supported solar energy enlargement through a broad range of financial, authoritarian, promotion and other instruments. Various policies are designed to promote renewable energy, including solar, at the global level as well as for a particular country, such as India [17]. Sustainable implementation of policies in developed and developing countries are helping in the growth of solar energy market, mainly for grid-connected solar PV and solar thermal water heating systems. This paper briefly presents key policies that support solar energy for both electric and direct heating applications.

2. EXISTING APPLICATION OF SOLAR ENERGY FOR SUSTAINABLE DEVELOPMENT

Application of solar energy for sustainable development is possible mainly in two ways, Passive and Active. Passive solar energy application collects the energy without converting the heat or light into other forms [18-20]. On the other hand, in active solar energy application the solar energy is stored or converted for diversified applications. This in turn can be classified as two different groups – Photovoltaic (PV) and Solar Thermal. Photovoltaic technology converts the solar radiation into electrical energy when it incident upon a semiconductor material [21]. In Solar thermal technology solar heat is used for thermal or heating application and for electricity generation. It is subdivided into two categories as – Solar thermal non-electric and, solar thermal electric [22-24]. The applications of solar thermal non-electric technology are solar water heaters, solar air heaters, solar cooking systems, solar cooling systems, etc. While solar thermal electric technology refers the use of solar heat to produce the steam for electricity generation. This methodology is known as Concentrated Solar Power (CSP). The CSPs available in the market are – Power Tower, Fresnel Mirror, Solar, Dish Collector and Parabolic Trough. Some applications of solar energy are shown in figure 1.

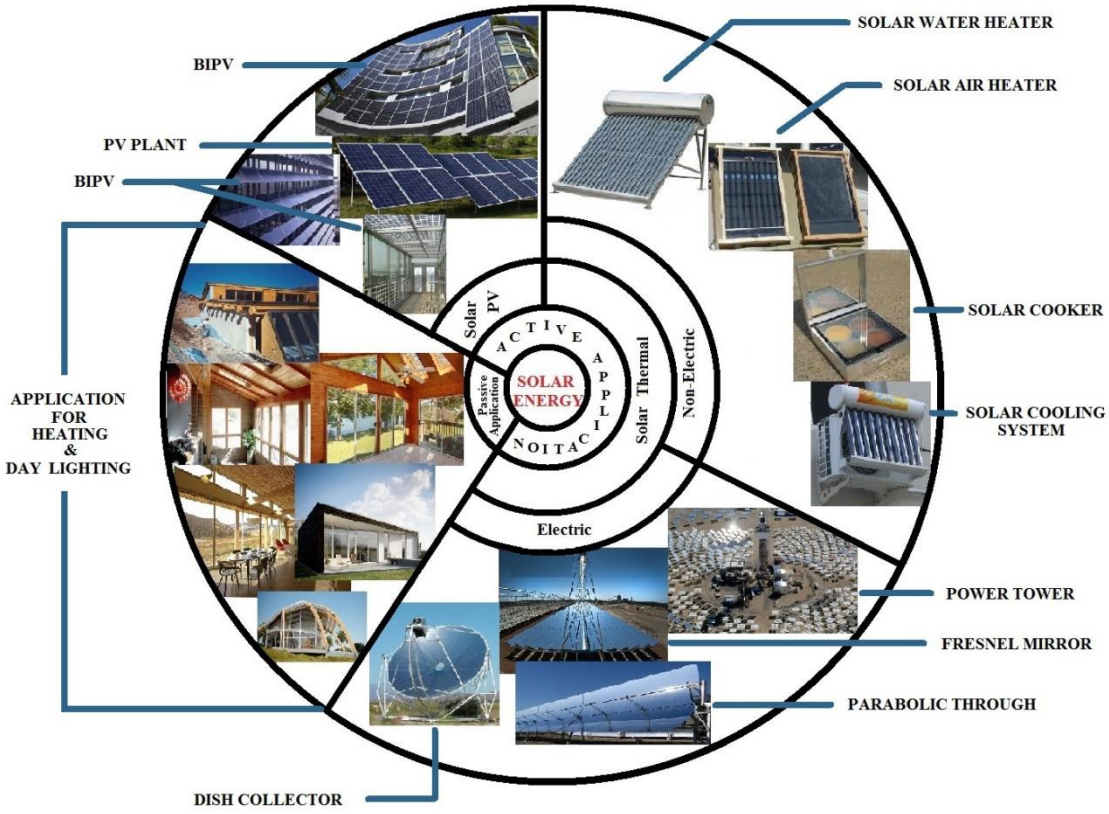

Figure 1. Some applications of solar Energy

3. CURRENT STATUS OF SOLAR ENERGY IN INDIA

The installed capacity in India can be understood by analysing the solar energy produced in recent past years in various states of the country. The amount of solar energy produced in 2007 was less than 1% of the total energy demand of India [25]. The grid-interactive solar power as on December 2010 was 10 MW [26]. Total installed capacity of solar projects under various schemes as on December 2014 was around 3.062 GW.

Table 1. State wise Installed Capacity of Solar Projects under various Schemes as on 15/12/2014

State	Total commissioned capacity till 15-12-2014 (MW)	% Contribution
Andhra Pradesh	234.86	7.821731
Arunachal Pradesh	0.025	0.000833
Chhattisgarh	7.6	0.253109
Gujarat	929.05	30.9409
Haryana	12.8	0.426289
Jharkhand	16	0.532861
Karnataka	67	2.231355
Kerala	0.025	0.000833
Madhya Pradesh	353.58	11.77556
Maharashtra	286.9	9.554861
Orissa	31.5	1.04907
Punjab	55.77	1.857353
Rajasthan	839.5	27.95854
Tamil Nadu	104.2	3.470256
Telangana	8	0.26643
Uttar Pradesh	29.51	0.982795
Uttarakhand	5	0.166519
West Bengal	7.21	0.24012
Andaman & Nicobar	5.1	0.169849
Delhi	5.465	0.182005
Lakshadweep	0.75	0.024978
Puducherry	0.025	0.000833
Chandigarh	2	0.066608
Others	0.79	0.02631
Total	3062.68	100

State wise contributions in total installed solar projects in India are tabulated in table 2.

Table 2. State wise contribution in total installed solar projects in India

Percentage of installed capacity from total installed capacity of solar projects in India	Name of States
<1%	Arunachal Pradesh, Chhattisgarh, Haryana, Jharkhand, Kerala, Telangana, Uttar Pradesh, Uttarakhand, West Bengal, Andaman & Nicobar, Delhi, Lakshadweep, Puducherry, Chandigarh.
1-5%	Karnataka, Orissa, Punjab, Tamil Nadu
5-10%	Andhra Pradesh, Maharashtra
10-15%	Madhya Pradesh
25-35%	Rajasthan, Gujarat

Table 2 shows the name of states with installed capacity less than 1%, 1-5%, 5-10%, 10-15%, 25-35% of the total installed capacity of solar projects in India i.e. 3.062GW.

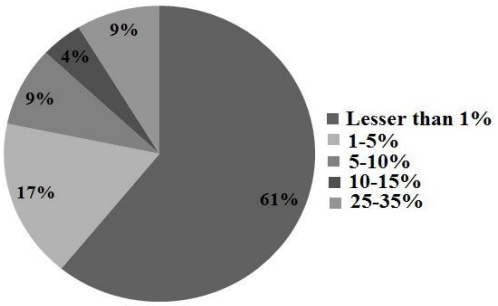

Figure 2. Percentage of States with different % contribution in Solar Projects

From figure 2 it is observed that in 61% states of India installed capacity of solar projects are lesser than 1% of total installed capacity of solar projects in India. In 17%, 9%, 4% states the same is respectively 1-5%, 5-10% and 10-15% of the total installed capacity of solar projects. Only in remaining 9% states the installed capacity of solar project is 25-35% of the total installed capacity of solar projects in India.

Scheme wise physical progress in solar power till December 2014 is tabulated in Table 3.

Table 3. Scheme wise Physical Progress in Solar Power till December 2014 [27]

Solar Power	Target	Achievement	Cumulative Achievements (as on 31.12.2014)
Grid-Interactive Power (MW)	1100.00	430.67	3062.68
Off-Grid (MW)	60.00	52.77	227.12
Solar Water Heating – Coll. Areas(Million m^2)	0.50	0.53	8.63

Table 3 shows that in 2014 the target for grid –interactive solar power was 1100MW, but at the end of the year achieved value was 430.67MW. For off-grid solar power target was 60 MW in the year of 2014, whereas achievement was 52.77 MW, much better than the grid –interactive achievement. For solar water heating system installed collection area is more than the target, which is a positive achievement.

4. INNOVATIVE APPLICATION OF SOLAR ENERGY IN SUSTAINABLE DEVELOPMENT OF INDIA

With the existing application of solar energy some innovative application is needed for sustainable development of India. Some innovative applications of solar Energy are listed consequently.

4.1. Solar in Transportation

Transportation is a broad field where solar energy has great scope of application. Solar vechile is the budding area of research now a day. An electric vechile powered by solar energy completely or partially is known as solar vechile. Solar vechile includes, solar car, solar tracking bus, solar rail, solar boat, solar aircraft, solar space craft.Solar energy can be used in vechiles for auxiliary power supply like for ventilation, for cooling fan of vehicles. The Venturi Astrolab in 2006 was the world's first commercial electro-solar hybrid car, and was originally due to be released in January 2008 [28]. A solar powered road panel to form a smart highway is a new concept by solar roadways [29]. This technology is based on combine programmable capability of transparent driving surface with underlying solar cells, electronics and sensors to act as a solar array.

4.2. Solar Lighting

Use of solar energy for lighting purpose is a very common and flowerished application area. But still it can be used more efficiently like, solar LED street lighting, Solar LED garden lighting, Solar LED Umbrella in resturants, Solar palm tree lighting in Institutes and Industries.

4.3. Solar Mobile/ I-Pad Charger

Solar cell phone or i-Pad charger is a small application of solar energy. But considering the total number of cell-phone users in India, it will save a huge energy used in cell-phone charging. This is a small but very effective application of solar energy.

4.4. Solar Car parking

A parking area covered with solar panels, elevated above the ground so that cars park in the shade under a shelter of photovoltaics is known as Solar Car parking. Depending on the size of the array covering the parking area a lot of power can be generated. Solar carport installed at Rutgers University is 28 acres in size and produces 8 megawatts of power at an instant. Solar carports have many benefits, including aesthetics look, like increases vehicle fuel efficiency, because it saves energy to cool car back up by cranking the air conditioner.

4.5. Solar Kitchen Restaurant

Solar kitchen restaurant is an idea to promote solar energy. This idea is already successfully implemented in Euorope. The Solar Kitchen Restaurant is based on a solar kitchen concept where cooking is by pure solar energy. The Solar Kitchen Restaurant will be built around a solar kitchen to relax and enjoy in a new and exciting way. Unlike the traditional way of cooking, solar heat affects the taste and texture of the dish in a surprising and positive way, producing a completely different taste experience [30].

4.6. Solar Bill board

Sometime billboards need to be installed in places where no electricity is available, or the nearest electric supply is some distance away. There use of LED billboard fed by solar system [31] is a simple solution rather than spending thousands on trenching and electrician costs.

4.7. Solar canal

The Canal Solar Power Project is a project launched in Gujarat, to use 19,000 Kilometre long network of Narmada canals across the state for setting up solar panels to generate 1MW electricity [32]. It was the first ever such project in India. The project is situated on the Narmada branch canal near Chandrasan village of Kadi taluka in Mehsana district. In India huge number of canals and rivers are present so canal solar panel can generate a massive portion of energy and also it will prevent the evaporation of water. Due to less temperature in the lower side of solar panel (as canal is present) efficiency of solar panel will be also high.

4.8. Solar Space Power Station

The concept of collecting solar power in space for use on Earth is known as solar space power station. It has been in research since the early 1970s. 55-60% solar energy is lost on its way through the atmosphere by the effects of reflection and absorption. Solar Space Power Station converts sunlight to microwaves outside the atmosphere, avoiding these losses, and the downtime due to the Earth's rotation.

4.9. Solar in Architecture

4.9.1. Solar paint

Mixture of nanometer-sized titanium dioxide particles coated with either cadmium sulfide or cadmium selenide and suspended in a water-alcohol mixture to create a paint-like paste that generates electricity when exposed to light [33]. Using solar paint the all walls of building can generate small amount of electricity from solar energy.This is an innovative and new application of solar energy.

4.9.2. Solar Fabric

A company called Pvillion [34] is currently making fabric with solar power capabilities for use in commercial applications. According to an article from New Scientist [35] researchers have built a PV cell in the layers around a fiber, creating a tiny cylindrical cell. Now solar collection could work silently and unobtrusively from everyday objects, not limited to rooftops and poles.

4.9.3. Solar Windows

Transparent glass solar panels can be used as solar window, which will allow windows to become power generators. If this solar window successfully developed and implemented then it can supply a sufficient amount of energy required in a building for everyday use.

4.9.4. Solar Fountain

Fountains always aesthetically please all of us for quite some time. Powering those pumps take a slow but steady toll on the planet. Solar panel can be used to supply the power for the fountain.

5. CHALLENGES IN ADVANCEMENT OF SOLAR ENERGY

Solar energy technology is budding overseas, so it incurs certain types of challenges too [36]. Challenges are broadly classified as Financial, technical and Institutional and tabulated in Table 4. Challenges are:

- The high cost of solar power generation. For such cases, the higher efficiency devices may take an important part in escalating to the energy targets in India. The solar energy prices in Indian market has come down to ₹ 7/kWh from ₹ 18/kWh (2011) while the thermal power prices is pushing to ₹ 4.5/kWh including subsidies [37].
- Solar projects are the capital centric, so the ineffective financing infrastructure for such projects will be the hindrance for the growth in this sector.
- The divergence of solar potential across different states.
- Lack of consumer awareness.
- Gap between Industry-Government co-operations.
- The lack of standards which leads to the dissolution of the market among the supplier and the producer.

Table 4. Different Types of Challenges Falling Under Solar Energy Technologies

Technology	Challenges		
	Financial	Technical	Institutional
Solar PV	Riskier when creditworthiness is assessed by the Financial Institutions because of their lack of experience in the field. Severe initial cost and lack of sustained financial options. The degrading cost of Balance of System is independent to the price reduction of solar module.	Limited supply of Balance of System components like inverters, batteries, charge controller and other power conditioning appliances. The efficiency constraints are 4-12% for thin-film and 22% for crystalline PVs. Cadmium used in CdTe technology is toxic and Tellurium is one of the rarest mineral. The increased demand of PV in 2004-05 surpassed the silicon supply and partially temporized the growth of solar sector.	Inadequate understanding of the fundamental systems and financial factors. Insufficient resources to educate numerous technicians. Limited number of effective and appropriate laws like Renewable Portfolio Standards (RPS) to motivate wider adoptions. Strategic issues like the need to protect financing from diverse sources and allowances from different agencies as for example MNRE, IREDA, the Planning Commission, and the Ministry of Agriculture and Rural Development.
Solar Thermal	The creditworthiness risk goes high due to lengthy payback periods and small revenue streams. Additional cost of Backup Heater is associated for the reliable heating in Water Heating System. The constraints of rooftop area in Building Integrated System curb the application. Use of Copper for water heating and distribution purpose adds to the overall cost. Domestic water heating system has lower financial entity.	Drawbacks of Concentrated Solar Power systems are the thermal losses and the energy storage system. Availability of limited fluids with higher heat carrying capacity to transfer the heat. The lack of integration has restrained in widespread application for solar water heating due to typical building materials, designs, infrastructure and existing appliances. Outsourcing of large scale appliances viz. the molten salt-in-tube receiver, and the volumetric air receiver both along with the energy storage system.	

6. CONCLUSION

Solar energy is the best solution in bridging India's energy demand-supply gap in the future. The price of solar power in India has come down from ₹ 18/kWh in 2011 to ₹ 7/kWh, while the price of thermal power is pushing ₹ 4.5/kWh with subsidies. It is clear that the alternatives of solar energy are going to be immensely more costly. The key findings of the study are concluded below:

Targets achieved in different section of solar energy are 39%, 88.3% and 100% respectively in Grid interactive solar power, offgrid solar power and solar water heating system.

In transportation industry solar vechiles like solar car, solar bus, solar rail, solar boat , solar aircraft and solar roadways are applications for sustainable development in India.

Solar lighting, solar mobile charger, solar car parking, solar kitchen resturent, solar bill board, solar canal, solar space power station, solar in architecture are the some other innovative application for sustainable development of India.

Challenges in solar industry are lowering the cost of production, increasing R&D, consumer consciousness, lack of standards and financing infrastructure. It is important to conquer these challenges for rapid growth and mass acceptance of the technology.

To promote solar energy research and development capacity have to be built in the private sector and in educational institutions. Millions of productive jobs will be created in the process of development of the infrastructure required for the new industries resulting from massive solar projects. Publicizing job creation, in addition to environmental and energy access reimbursement, will strengthen the economic case for clean energy policies and build public support for these initiatives. If these initiatives work as intended, it is only a matter before India becomes one of the world leaders in Solar Energy.

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