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Barriers in the Advancement of Solar Energy in Developing Countries like India

Bariery w rozwoju energii słonecznej w krajach rozwijających się na przykładzie Indii

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Abstract
The present paper puts an emphasis on the current energy market scenario and different types of barriers associated with the advancement of solar energy in a developing countries like India. Solar energy, best suited for urban environment, can be housed in a limited space and is characterized as a pollution free, environmentally friendly, as well as noise-free source of electricity. Among the available renewable energies, solar energy is considered to be an integral one, owing to its reduction in cost at an exponential rate day-by-day. The present study deals with the potential of solar energy market in the Indian sub-continent along with several other problems that it needs to overcome in order to be established as an independent system.

Key words: solar energy, solar market, renewable energy

Streszczenie
Artykuł omawia scenariusze związane ze współczesnym rynkiem energetycznym, wskazując na różnorodne typy barier, na które napotyka rozwój energii solarnej w krajach rozwijających się, takich jak Indie. Energia słoneczna doskonale sprawdza się w warunkach miejskich, przeznaczone do jej pozyskiwania instalacje nie potrzebują dużo miejsca i nie zanieczyszczają powietrza, a ponadto nie emitują hałasu. Wśród różnorodnych źródeł energii to właśnie energia solarna wydaje się być najbardziej korzystna, biorąc pod uwagę jej nieustannie malejące koszty. Niniejsza praca przedstawia potencjał rozwoju rynku energii słonecznej w Indiach, zwracając szczególna uwagę na problemy, które należy rozwiązać, aby mógł on funkcjonować, jako niezależny system.

Słowa kluczowe: energia słoneczna, rynek energii solarnej, energia odnawialna

1. Introduction

Solar energy refers to that source of energy which is directly produced from sunlight or the heat that sunlight generates. The fundamental materials for solar cell devices are semiconductors, which produce electricity using photon from solar rays. Another category under solar cell is the popular Photo-Voltaic (PV) technology which is also used worldwide for the generation of electricity. At remote places, debarred of electricity grids, PV power supply is the best suited and most economic option available.

Crystalline silicon PV cells are the most common photovoltaic cells in use today. They are also the earliest successful PV devices. Hence, crystalline silicon solar cells constitute a good example of typical PV cell functionality.

PV technology has many applications, both for stand-alone systems and also for integration into buildings. PV may be used, for instance, in monitoring stations, radio repeater stations, telephone kiosks, street lighting etc. A substantial market for PV technology involves commercially available battery chargers for boats and caravans, solar driven cars, garden equipment such as solar fountains, satellite solar panels etc.

Majority of the power distribution companies in India are suffering from heavy losses and are unable to meet their renewable purchase obligations (RPO). In such adverse situation, it makes sense for these companies to switch from conventional energy sources to renewable energy sources, in order to reduce cost of electricity generation and render service to community at a much cheaper rate. It is also expected that in the near future, the demand for solar energy among the power consumers will be an emerging issue in the Indian solar market.

The expansion of solar energy market is limited owing to the presence of several barriers. In order to sustain the growth of market, the associated barriers need to be identified and addressed adequately (Chakraborty et al., 2015, Sadhu et al., 2015, Goldman et al., 2005). Along development of solar market, the barriers are vanishing at a faster rate. Thus, elimination of barriers keeps the solar energy market lively. Consecutive sections of this paper describe the basic and detailed characteristics of these barriers.

Cost effectiveness of many solar energy technologies – as compared to conventional energy commodities at either the wholesale or retail levels – has not been achieved till date (Das et al., 2015). Therefore, any significant deployment of solar energy will not be possible unless major policy incentives are introduced. Governments of many countries have realized this and have supported solar energy development through a broad range of fiscal, regulatory, market and other instruments. A number of recent studies, such as the present in-depth analysis of various polices to promote renewable energy – including solar, both at the global level and for a particular country, such as India – are described in details in literature (Chakraborty et al., 2015, Chaurey et al. 2004). The strong growth in solar energy markets, notably those for grid-connected solar PV and solar thermal water heating, has been driven by a sustained implementation of policies in Europe, United States and some developing countries.

2. Current Market Status of Solar Energy Technologies

2.1. Solar Energy Technologies

Solar Energy Technology can be classified as passive or active. Passive solar energy technology collects the energy without converting the heat or light into other forms, i.e., through the incremental use of daylight or heat through building designs (Bradford, 2006, Chiras, 2002, Florida Solar Energy Center, 2000). On the other hand, active solar energy technology either stores or converts the solar energy for diversified applications. Active solar energy technology is classified into two different groups – Photovoltaic (PV) and Solar thermal. In Photovoltaic technology, solar energy is directly converted to electrical energy when sun rays incident upon a semiconductor device. Commercially used PV technologies are – (a) crystalline Si-based PV cells, and (b) thin film technology, made from diverse range of various semiconductor materials, e.g. amorphous Si (a-Si), Cadmium telluride (CdTe) and copper indium gallium (di)selenide (CIGS). Solar thermal technology utilizes solar heat for thermal electricity generation or heating application. Therefore, solar thermal technology is further subdivided into two categories viz., solar thermal non-electric and solar thermal electric (Sorensen, 2000, Wolff et al., 2008, Muller-Steinhagen et al., 2004). The applications of solar thermal non-electric technology involve solar water and air heaters, cooking systems, cooling systems, etc., while those for solar thermal electric technology involve the use of solar heat aimed at producing steam for electricity generation. The latter technology is known as Concentrated Solar Power (CSP). The CSPs available in the market are Power Tower, Fresnel Mirror, Solar Dish Collector and Parabolic Trough.

2.2. Current Market Status

Solar energy is accepted worldwide as the largest source of renewable energy supply (Mills et al., 2008, EPIA, 2011, PVRES, 2010). Figure 1 depicts the accelerated growth of solar energy throughout the recent years in India. In 2007, the amount of solar energy produced in India was even less than 1% of the total energy demand (Dincer, 2011). At the end of December 2010, the grid-interactive solar power was merely 161 MW (Roul, 2007). An amount of 25.1 MW of power was added in 2010 and 468.3 MW in 2011. By the end of April 2015, the installed grid connected PV energy generation is increased to 3.74 GW. India is the leader in terms of solar energy production per watt installed (Tembhekar, 2009).

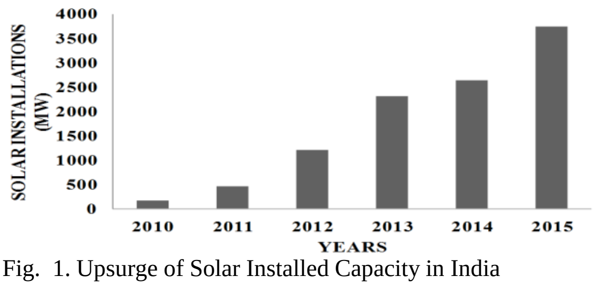

Fig. 1. Upsurge of Solar Installed Capacity in India

3. Different types of barriers involved in the advancement of solar energy technologies

The proliferation of solar energy technology meets certain types of barriers (JNNSM, 2012). In such context, this paper presents an in-depth discussion pertaining to the disparate barriers that impel the stationing of solar energy technologies for electricity generation and thermal purposes. By and large, barriers can be identified as – Economic, Technical, Institutional, Environmental and Social. The different types of barriers are described in the following sections.

3.1. Economic barriers

The economic barriers which hinder the advancement of solar thermal and solar PV are described below.

Solar Thermal:

i. The creditworthiness risk goes high owing to the high upfront cost coupled with the lengthy payback periods and small revenue streams.
ii. Additional cost is enforced for Backup Heater which is essential for reliable heating in Water Heating System.
iii. The limitation of rooftop area available for Building Integrated System hampers widespread application.
iv. The use of Copper for water heating and distribution purpose adds to the overall cost.
v. The cost of domestic water heating system is lower than the cost of solar thermal based water heating systems.

Solar PV:

i. Installation of solar PV plant is riskier when creditworthiness is assessed by the financial institutions, because of their dearth of experience with projects.
ii. In the developing countries, the immediate obstacles are the high initial installation cost and lack of viable financial support from banking sectors.
iii. The costs of different solar modules are decreasing day-by-day. However, the cost of the necessary items associated with them does not reduce at the same pace; thereby directly leading to a hike in the overall cost involvement in the establishment of a solar PV plant.
iv. Solar PV technology has a lower efficiency in comparison to conventional energy; hence coping with economic viability is a challenging task.

3.2. Technical Barriers

Solar Thermal:

i. The disadvantages of concentrated solar power systems are the high thermal losses and the energy storage system.
ii. The availability of standardized solar water heater does not meet the demands of assorted consumers' profiles; hence the orientation supply in the design of solar water is necessitated.
iii. The heat carrying capacity through fluid is a technological hindrance.
iv. The lack of integration between the typical building materials, designs, infrastructure and existing appliances, and with the standards, has restrained widespread application of solar water heating.
v. Considering the central receiver system, the favourable technologies are the molten salt-in-tube receiver, and the volumetric air receiver. Hence, both technologies, well-suited for large scale applications, are to be procured from abroad. The installation and use of such technology requiring skilled professionals are a dearth in the Indian context.

Solar PV:

i. Limited production of components like solar inverters, batteries and other power conditioning appliances associated with solar PV plant.
ii. In the context of the current market scenario, low efficiency of 4-12% for thin-film and 22% for crystalline PVs are big constraints.
iii. The use of Cadmium & Tellurium which are by-products of Zinc & Copper and needed for certain thin-film cells can only be available in abundance, provided the growth of zinc mining and copper processing industries is at rise.
iv. The supply-demand disparity of the materials for PV since 2004-2005 has led to localization of the growth of solar power generation.
v. There is no adequate infrastructure required to obtain concurred metering and billing.

3.3. Institutional Barriers

Solar Thermal and Solar PV:

i. Inadequate understanding amongst elite national and local institutions regarding the fundamental systems and financial factors.
ii. Insufficient resources to educate numerous technicians required to work efficiently under new solar energy infrastructure.
iii. Short-comings of effective and appropriate laws like Renewable Portfolio Standards (RPS) for expediency and lack of motivation for wider adoptions.
iv. Strategic issues including the need to protect financing from diverse sources and allowances from different agencies such as, for example, MNRE (Ministry of New and Renewable Energy), IREDA (Indian Renewable Energy Development Agency), the Planning Commission, and the Ministry of

Agriculture and Rural Development in a country like India.

3.4. Environmental Barriers

Solar energy is identified as one of the environmentally-friendly energy generation technologies; certain minor environmental issues associated with it are discussed below:

i. The requirement of large areas of land for solar energy projects attracts the attention of numerous environmental groups, according to whom clearing and preparing large area for solar project has no net environmental merit.
ii. Large PV plants encounter environmental barriers owing to non-availability of a bigger area of land required for large solar projects.
iii. The need of water resources for solar thermal plants is also a barrier. Large amount of water is needed for cooling the steam used to power the electric turbines. Gujarat and Rajasthan, characterized by dry and arid areas, suffer from shortage of water and thus the establishment of solar thermal project requiring huge water supply becomes an inadvertent environmental barrier.
iv. Safe disposal of batteries and CdTe solar panels becomes difficult in absence of proper recycling processes.

3.5. Social Barriers

The social barriers coupled with solar energy projects are not widely discussed because these obstacles are not widely reported in India. The boost of solar power is for the overall social development of India. 300 million people in India have no access to electricity. Hence, solar power is a step forward for the social development with the biggest support towards education and communication. Social acceptance of solar energy is very important and significant for the popularization of solar power technologies.

In spite of the abundance and numerous advantages of solar energy, its expansion meets with a gradually increasing discontent. Social barriers associated with solar PV and solar thermal are discussed below:

i. In the case of rooftop solar PV plant installation, neighbours can object to the shadow cast by the solar panels which blocks the sun rays from falling onto their building.
ii. Opposition to Solar projects arises when neighbouring communities are relocated from their ancestral land or deprived of access to grazing land due to the development of a large solar plant.
iii. Potential social barriers to solar energy advancement in India include the lack of information about the environmental benefits of solar power. Solar energy technologies are relatively new and most customers, being less familiar with it, are unable to make conversant choices.
iv. Although solar energy is technologically mature and its price is competitive in comparison to the conventional alternatives in many geographical settings, the conflict of choice owing to the lack of awareness in terms of cost involvement and facilities – when compared to fossil fuel-based or nuclear power based energy generation – still remains.
v. The long-term cost-effectiveness of solar energy against that of fossil fuels is not properly addressed in public discussions leading to a sustained misperception of solar energy as being an excessively expensive.
vi. In India, 72% of power generation is from conventional power plants. Hence, investors are more interested in sticking to the system of conventional power generation rather than switching to other possible alternatives.

In regard to the technical barriers, the main hindrance comprises low conversion efficiency of the PV modules, performance drawbacks of batteries and inverters, and sparse supply of raw materials like silicon. A major concern regarding the standalone PV system is the storage of electricity production, owing to shorter battery life in comparison to that of the entire module (Zhang et al., 2012, Margolis et al., 2006).

On the other hand, solar thermal application has two main technical barriers. Firstly, it is difficult to define the heat carrying capacity of the heat transfer fluids and secondly, the thermal losses from the storage systems (Zeng et al., 2014, Beck et al., 2004). Moreover, owing to the limitations in context to system design and assimilation, the operating expenses of the entire system are boosted up. Also, the lack of integration with building materials, designs, codes and standard results in an inadequacy of solar energy applications.

In the case of concentrated solar power, the associated technologies need to be focused more on large scale applications (Herrmann et al., 2004). The solar energy which is supposed to emanate and sustain itself in terms of energy-infrastructure, revolves around the topologies used by conventional energy technologies.

Even though the industrial production cost of the solar modules decreases, sellers still do not reduce the selling price, which results in a higher purchase rate for the consumers in the commercial market. This technology thus experiences a stalling faith in the growing commercial market, ignoring its social, environmental and hygienic benefits and thereby resulting in the lack of cost reduction (IEA, 2006).

Barriers are also associated with the financial issues and as such, finances themselves become another major barrier (Becker et al., 2000). The financial institutions assessing solar energy projects have lesser longevity, which is coupled with lengthy payback periods and small revenue system (Jacobsson et al., 2000, Anthony, 2006, Goldman, 2005).

Another impediment for both PV and solar thermal technology comes as Institutional; a type that rises from the originality of such a technology. This refers to hindrances like insufficient trained people, along with the limited availability of professionals who are capable of implementing adequate training. Moreover, installation and maintenance issues arise which can only be resolved with Institutional support.

A key policy for overcoming the social barriers is the engagement of local stakeholders in the planning process in order to nullify contradictory issues, build harmony and arrive at a general consensus. The local traditions, beliefs and superstitions of the community need to be considered before planning of the projects takes place, in order to avoid further problems in the progress stage of the solar project. Project developers need to involve the local communities to present their views regarding proposed projects. Pasqualetti and Miller (1984) calculated that, when all steps involved in the fuel cycle are considered, the total land needed for solar power is comparable to those needed for conventional resources such as coal. The base costs of solar power may exceed that of fossil fuels, but it is still more cost-effective than the recurring cost characterizing the latter. Stakeholder dialogues and positive outreach campaigns are necessary to reduce the opposition for solar energy. The awareness concerning the advantages of solar energy needs to be developed among common people.

Only through the combined efforts of government, private sectors, and civil society, the sustainable development of solar power in India is possible. In 2015, India has achieved the highest generation in solar capacity ever, with a total value of 1.112 GW. Indian government has announced scaling up of grid interactive solar project from 20 GW to 100 GW by the year 2021-2022 under National Solar Mission.

4. Conclusion

Solar energy possesses tremendous potential in bridging India's energy demand-supply gap in the near future. The price of solar power in India has decreased from a significant amount of Rs. 18/kWh in 2011 to Rs. 5.15/kWh in 2015, while that for thermal power is pushing up at price of Rs. 4/kWh with subsidies. It is thus clear that the possible alternatives to solar energy are going to be more expensive in near future.

There are various challenges for this industry, including lowering the production cost, increasing R&D activities, consumer consciousness, improvement of standards and more financial support. It is important to overcome these challenges for rapid growth and mass acceptance of the technology. Some of the immediate actions to enable growth include efficient implementation of renewable energy certificates, usage of carbon trading as a source of income, improvement of financing facility, encouragement in private investment, quick implementation of net metering scheme, policy mixing, rapid implementation of grid-powered energy in regions of Rajasthan and Gujarat, development of off-grid usage in various applications such as cellular towers and encouraging localized mini grids in areas that lack connectivity today. Research and development activities need to be strengthened in private sectors and educational institutions. Millions of productive jobs will be created from the need to develop infrastructure, which is required for the new industries and results from the establishment of 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. The combined effort of government, private sectors, and civil society will bring a revolutionary change in building solar power in India. If these initiatives work as planned, materializing the dream of converting India into a world leader in solar energy market would not be far away.

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