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Research Paper

Solar Technology Adoption in the Agriculture Sector in India - Opportunities and Challenges

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ABSTRACT
Energy consumption of India has already doubled since the year 2000 and it is expected to more than double by 2040, which will account for one-fourth of global increase in that same period. With a production capacity of 1,174 TWh (FY14), India is the fourth largest producer and fourth largest consumer of electricity in the world. India is although the third largest market in terms of gross electricity generation but it still has almost 250 million people without access to power. With a growing middle class and a population of more than 1.35 billion people India is expected to have some of the fastest growing energy needs that are certain to have a dramatic impact on the global economy and its energy market. The focus is on promotion of hydro, renewable energy and gas-based products, as well as adoption of clean coal technology. Renewable energy (RE) is fast emerging as a major source of power, with increases to 81 GW planned by 2021 to meet the growing energy demand, solar energy is one such important source. This paper critically reviews and analyzes the opportunities and challenges for solar technology adoption in the agriculture sector.

KEY WORDS: *Energy, Solar, Technology, Agriculture, India*

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I. INTRODUCTION

India's current energy scenario is encountering both challenges and opportunities. Coal production remains key to the energy mix. India produced 557 million tonnes (metric tons) of coal in 2012-13, and India's rapidly growing power industry consumed the majority of it - production goals are aiming for an increase to 795 million tonnes by 2016-2017 (Kimura et al, 2014). At the same time satisfying natural gas needs has become one of India's most urgent challenges as a decline in production means that the country has to rely on imports to meet the growing demand (Mondial, 2013).

Poverty, energy and major inequalities of access invasion the subcontinent. According to one census, 77 million households in India still use kerosene for lighting (Lam et al, 2012). A person is in energy poverty if he/she does not have a) the equivalent of 35 kg LPG per capita year (PCPY) from liquid and /or gas fuels or from improved supply of solid fuel sources and improved (efficient and clean) cooking stoves, and b) 120kWh electricity PCPY for lighting, access to the most basic services (drinking water, communication, improved health services, education improved services and others) plus some added value to local production (Palaniappan et al, 2010).

The problem is even more acute in rural India where up to 44 percent of households lack access to electricity (Athreya et al, 2010). In the case of rural villages, access issues and geographical hindrances make addressing the difficulty extremely costly and difficult. This does hamper rural development because energy may be a basic need for both household and agricultural needs and consequently affects job creation and income in rural areas, both small and enormous scale rural development schemes in India address energy security as a priority for improving the standard of rural life.

In light of the above challenges in relation to India being extremely coal dependent in the power sector and the lack of energy availability in rural areas, studies point to developing solar and nuclear capabilities as essential. If India is to reach the target of 40% renewables by 2040, $120-130 billion dollars will be required for the implementation of its renewable energy target of 175 GW by 2022 (TATA Power Solar, 2014). In light of the above challenges, there is a move towards alternative sources of energy. In addition to the Ministry of Power, the Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of Government of India (GOI) for all matters relating to new and RE. The objective of this Ministry is to develop and deploy new and RE for supplementing the energy requirements of the country. It is useful to point out where the demand for energy comes from and what causes the same before exploring the need to move towards non-conventional sources of energy.

In contrast to all other energy sources, the raw potential of solar in India is effectively limitless. If we were to envision a scenario wherein half the district of Barmer in the Indian state of Rajasthan (0.5% of India's land area) is covered with solar panels, installed dimensions of the area will get to 1,000 GW. The entire resultant electricity generation are going to be around 1,500 TWh per year, which interestingly is quite the entire electricity requirement of India. Solar plants can be set up very quickly and in very different sizes. Moreover, they contribute to India's energy security and lead to lower levels of local pollution and carbon emissions. Solar would be a strategic energy option for India.

India's Annual Solar installations to grow over five times by 2021, 10.86 GW of utility-scale solar and grid connected rooftop solar capacity will be added by 2020-21 (Pritwani, 2016). The Government of India's target would take the total renewable capacity to almost 175 GW by the end of 2022. This includes 60 GW from wind power, 100 GW from solar power, 10 GW from biomass power and 5 GW from small hydropower. Solar modules prices have declined by almost 80% since 2008 and wind turbine prices have declined by more than 25% during the same period. (IRENA, 2014) The MNRE is already assessing the possibility of setting a much higher target of 100 GW for solar by 2027 as envisioned by the Prime Minister's Office (PMO).

II. RESEARCH AIM

The research aims to opportunities and challenges for solar technology adoption by the entrepreneurs in agriculture sector.

III. RESEARCH METHODOLOGY

Secondary data was complied through published materials, such as regulatory and policy documents, presentations, for example - discussions by experts during conferences and workshops, conference proceedings, reports from industry associations, firm level project reports, company websites, consulting publications and magazines.

IV. SOURCES OF ENERGY IN INDIA

The sources of electricity production like coal, oil, and natural gas have contributed to one-third of worldwide greenhouse gas emission. It is essential to boost the quality of living by providing cleaner and more reliable electricity. India has an increasing energy demand to satisfy the economic development plans that are being implemented. The supply of accelarating quanta of energy may be a vital pre-requisite for the economic process of a country. The National Electricity Plan [NEP] framed by the Ministry of Power (MoP) has developed a 10-year detailed action plan with the target to supply electricity across the country, and has prepared an extra decide to make sure that power is supplied to the citizens efficiently and at an inexpensive cost.

According to the World Resource Institute Report 2017, India is liable for approx 6.65% of total global carbon emissions, ranked fourth next to China (26.83%), the USA (14.36%), and the EU (9.66%). Global climate change may additionally change the ecological balance within the world. Intended Nationally Determined Contributions (INDCs) are submitted to the United Nations Framework Convention on Global climate limate Change (UNFCCC) and therefore the Paris Agreement. The latter has hoped to realize the goal of limiting the rise in global temperature to well below 2°C.

According to a World Energy Council prediction, global electricity demand will peak in 2030. India is one among the largest coal consumers in the world and imports costly fossil fuel. Close to 74% of the energy demand is supplied by oil and coal . According to a report from the Center for monitoring Indian economy, the country imported 171 million tons of coal in 2013–2014, 215 million tons in 2014–2015, 207 million tons in 2015–2016, 195 million tons in 2016–2017, and 213 mil-lion tons in 2017–2018. Therefore, an urgent need to find alternate sources for generating electricity.

In this way, the country will have a rapid and global transition to renewable energy technologies to achieve sustainable growth and avoid catastrophic climate change. Renewable energy sources play a vital role in securing sustainable energy with lower emissions. It is already accepted that renewable energy technologies might significantly cover the electricity demand and re-duce emissions.

In recent years, the country has developed a sustainable path for its energy supply. Awareness of saving energy has been promoted among citizens to increase the use of solar, wind, biomass, waste, and hydropower energies. It is evident that clean energy is less harmful and often cheaper. India is aiming to attain 175 GW of renewable energy which would consist of 100 GW from solar energy, 10 GW from bio-power, 60 GW from wind power, and 5 GW from small hydro-power plants by the year 2022.

Investors have promised to achieve more than 270 GW, which is significantly above the ambitious targets. The promises are as follows: 58 GW by foreign companies, 191 GW by private companies, 18 GW by private sectors, and 5 GW by the Indian Railways.

Recent estimates show that in 2047, solar potential will be more than 750 GW and wind potential will be 410 GW. To reach the ambitious targets of generating 175 GW of renewable energy by 2022, it is essential that the government creates 330,000 new jobs and livelihood opportunities.

A mix of push policies and pull mechanisms, accompanied by particular strategies should encourage the progress of renewable energy technologies. Advancement in technology, tax deduction, proper regulatory policies, and attempts in efficiency enhancement due to research and development (R&D) are some of the pathways to conservation of energy and environment that should guarantee that renewable resource bases are used in a cost-effective and quick manner.

Table 1 shows the primary energy consumption of the world, based on the BP Energy Outlook 2018 reports. In 2016, India's overall energy consumption was 724 million tons of oil equivalent (Mtoe) and is expected to rise to 1921 Mtoe by 2040 with an average growth rate of 4.2% per annum. Energy consumption of various major countries comprises commercially traded fuels and modern renewables used to produce power. In 2016, India was the fourth largest energy consumer in the world after China, the USA, and the Organization for economic co-operation and development (OECD) in Europe.

Table 1 Projected primary energy consumption of the world between 1990 and 2040

Region	Consumption (million tones oil equivalent)											Change (%p.a.)	
	1990	1995	2000	2005	2010	2016	2020	2025	2030	2035	2040	1990-2016	2016-2040
USA	1966	2119	2310	2349	2284	2273	2334	2344	2341	2325	2299	0.6%	0.0%
Brazil	126	158	188	211	268	298	330	378	419	451	477	3.4%	2.0%
EU	1672	1661	1732	1819	1754	1642	1667	1623	1570	1513	1460	-.1%	-.5%
Russia	865	662	620	647	673	674	711	720	723	722	716	-.1%	0.3%
Middle east	264	351	423	565	734	895	980	1085	1189	1287	1382	4.8%	1.8%
Africa	222	244	274	327	389	440	509	603	710	840	1002	2.7%	3.5%
China	683	889	1008	1800	2491	3053	3387	3753	4017	4207	4319	5.9%	1.5%
India	195	251	316	394	537	724	880	1118	1365	1624	1921	5.2%	4.2%

The projected estimation of global energy consumption demonstrates that energy consumption in India is continuously increasing and retains its position even in 2035/ 2040. The increase in India's energy consumption will push the country's share of global energy demand to 11% by 2040 from 5% in 2016. Emerging economies such as China, India, or Brazil have experienced a process of rapid industrialization, have increased their share in the global economy, and are exporting enormous volumes of manufactured products to developed countries. This shift of economic activities among nations has also had consequences concerning the country's energy use.

PROJECTED PRIMARY ENERGY CONSUMPTION IN INDIA

The size and growth of a country's population significantly affects the demand for energy. With 1.368 billion citizens, India is ranked second, of the most populous countries as of January 2019. The yearly growth rate is 1.18% and represents almost 17.74% of the world's population. The country is expected to have more than 1.383 billion, 1.512 billion, 1.605 billion, 1.658 billion people by the end of 2020, 2030, 2040, and 2050, respectively. Each year, India adds a higher number of people to the world than any other nation and the specific population of some of the states in India is equal to the population of many countries.

The demand for renewables in India will have a tremendous growth of 256 Mtoe in 2040 from 17 Mtoe in 2016, with an annual increase of 12%, as shown in Table 2.

Table 2 Projected primary energy consumption of India (including renewable energy) from 2016 to 2040

	Level (Mtoe)											Change (%p.a.)	
	1990	1995	2000	2005	2010	2016	2020	2025	2030	2035	2040	1990-2016	2016-2040
Total	195	251	316	394	537	724	880	1118	1365	1624	1921	5.2%	4.2%
Oil (Mb/dl)	58	75	106	122	155	212	251	308	359	419	485	5.1%	3.5%
Gas (Bcf/dl)	11	17	24	32	54	45	57	72	89	106	128	5.6%	4.5%
Coal	110	140	164	211	290	412	485	593	710	824	955	5.2%	3.6%
Nuclear	1	2	4	4	5	9	11	16	27	35	44	7.1%	7.0%
Hydro	15	17	17	22	25	29	36	43	47	50	52	2.6%	2.5%
Renewable	0	0	1	2	7	17	41	86	133	191	256	35.1%	12.0%

Table 3 shows the primary energy consumption of renewables for the BRIC countries (Brazil, Russia, India, and China) from 2016 to 2040. India consumed around 17 Mtoe of renewable energy in 2016, and this will be 256 Mtoe in 2040. It is probable that India's energy consumption will grow fastest among all major economies by 2040, with coal contributing most in meeting this demand followed by renewables. The percentage share of renewable consumption in 2016 was 2% and is predicted to increase by 13% by 2040.

Table 3 Renewable energy consumption-BRIC countries (percentage): 2015–2035: source: BP Energy Outlook 2017

		India		China		USA		Russia		Brazil
Primary energy consumption renewables	2016	2040	2016	2040	2016	2040	2016	2040	2016	2040
	2%	13%	3%	18%	5%	17%	0%	2%	13%	24%

V. SOLAR ENERGY

Under the National Solar Mission, the MNRE has updated the objective of grid-connected solar power projects from 20 GW by the year 2021–2022 to 100 GW by the year 2021–2022. In 2008–2009, it reached just 6 MW. The "Made in India" initiative to promote domestic manufacturing supported this great height in solar installation capacity. Currently, India has the fifth highest solar installed capacity worldwide. By the 31st of December 2018, solar energy had achieved 25,212.26 MW against the target of 2022, and a further 22.8 GW of capacity has been tendered out or is under current implementation.

MNRE is preparing to bid out the remaining solar energy capacity every year for the periods 2018-2019 and 2019-2020 so that bidding may contribute with 100 GW capacity additions by March 2020. In this way, 2 years for the completion of projects would remain. Tariffs will be determined through the competitive bidding process (reverse e-auction) to bring down tariffs significantly. The lowest solar tariff was identified to be INR 2.44 per kWh in July 2018. In 2010, solar tariffs amounted to INR 18 per kWh. Over 100,000 lakh (10,000 million) acres of land had been classified for several planned solar parks, out of which over 75,000 acres had been obtained.

Till November 2018, 47 solar parks of a total capacity of 26,694 MW were established. The aggregate capacity of 4195 MW of solar projects has been commissioned inside various solar parks (floating solar power). The following Table shows the capacity addition compared to the target. It indicates that capacity addition increased exponentially.

Table-4: Solar capacity addition compared to the target between 2013–2014 and 2018–2019.

Year	Solar power additions in MW	
	Target	Achievements
2013-2014	1100	932.1
2014-2015	1100	1112
2015-2016	1400	3019
2016-2017	9100	5526
2017-2018	10000	9363
2018-2019	10000	3270

VI. APPLICATION OF SOLAR ENERGY IN THE AGRICULTURE SECTOR

Solar Powered Irrigation: An important innovation of solar power progress has been solar irrigation pumps which present an immense potential towards growth and development of agriculture. They can be set up in any remote agriculture field where grid is absent or otherwise no other supply of power is available. It just needs the availability of sunshine which can be easily found in rural areas given agriculture is already thriving there (crops cannot grow in the absence of sunlight). Solar Pumps would act as a replacement to electric and diesel pumps. In 2018-19, there were 14.33 million electric pump sets and 6.26 million diesel pump sets in the country.

Solar Panels: The second solar power application in agriculture is planting solar panels (crop) in fields. Solar panels can be set up over entire farmer fields to harvest crops as well as power. It is like having a second crop of solar power at a height of 15-20 feet with the food crop below on the field. Studies across the globe have proven that shade of solar panels have no negative impact on crop growth, if arranged in a particular configuration that allows sufficient sunlight and wind to pass through to the plants. This has also been observed in experiments in Gujarat, when solar panels are arranged like a chess board with gaps and at about 15 feet above the field (GERMI) to allow sufficient sunlight forcrops. This prototype method called 'solar sharing' was first adopted in Japan. Introduced by Akira Nagashima in 2004, the method entails installation of solar panels on agricultural land as a shaderoof like structure, but with gaps for air flow and sunlight passage for the crops beneath. The idea is based on the fact that beyond a certain optimal level, sunlight does not contribute to photosynthesis. Hence, excess sunlight can be tapped for generating power.

Cold storage- agriculture value chains: An area that may deserve attention by way of solar energy application is agri-value chain, starting with solar irrigated farms, solar powered cold storages/chillers in rural areas for fast perishable products like fruits, vegetables, milk etc, solar powered transport logistics (like reefer vans) and finally solar powered retail outlets, including solar powered push carts of small vendors. India is the second largest producer of horticulture in the world and faces substantial post- harvest losses. Cold storage is an important infrastructure for farmers and suppliers who face risk of crop losses due to perishable nature of the produce. Lack of power supply in remote rural areas as well its erratic supply make cold storage solutions even more critical. Use of diesel for power supply is neither sustainable nor cost effective. Installation of solar panels on roofs of storage units/warehouses where grid lines are practically absent can prove to be an important solution. Central Institute for Agricultural Engineering (CIAE), Bhopal, developed a 5x4.4x3 m and 20kwp plant with power storage at a cost of Rs, 20,00,000 for 15 years. For mangoes, it was found that there was an increase in the shelf life, reduction in weight loss and an improvement in quality. Such prevention of losses in food crops can reduce income loss to farmers. In a country with storage capacity of about 31 million metric tons68 which is less than 10percent of total production (NCCD) and where storage infrastructure highly falls short, it is an important technological innovation in agri-value chains.

Solar Paneled Roads: Route 66 in Missouri, USA is underway construction of solar paneled roads that would also produce energy. It is being developed by Solar Roadways, a company which raised funds through crowd funding and is dedicated to construction of solar roads and parking lots. The roads would be covered with tempered glass such that cars can drive on them. The hexagonal panels also have LED lights that would perform the task of signage eliminating the need of paint markers. Also, they would have heating features to prevent the accumulation of snow on the road which is a common problem in USA. Other than USA, France is also looking to make 600 miles of solar paneled roads.

Photovoltaic Technology: Solar photovoltaic (PV) cells were invented at Bell Labs in the United States in 1954, and they have been used in space satellites for electricity generation since the late 1950s. In this technology, solar rays collected via small plates that are semiconductor photovoltaic, are converted into electricity which may be used for agriculture and other purposes.

Solar Dryer: Preservation of food through drying is one of the oldest and the most widespread methods that can be used to enhance the strength of the food. Drying food is removing the moisture so that the product can be stored for a long time and be protected against corruption. By reducing the microbial enzyme activity and reducing the speed of chemical reactions, drying increases shelf life of the product. In addition, reducing the weight and volume of materials and packaging, facilitates transportation and storage of products and decreases the cost of these procedures. In the case of drying, in addition to preventing the loss, the marketing can be controlled at sensitive times and potatoes required by many consumers (such as barracks, restaurants, etc.) can be delivered in a dried form. Using the sun for dry crops and grain is one of the oldest used applications of solar energy. Solar dryers protect grain and fruits and vegetables, reduce losses, dry faster and more uniformly, and produce a better quality product than open-air methods.

VII. MAJOR GOVERNMENT INITIATIVES FOR RENEWABLE ENERGY

TECHNOLOGICAL INITIATIVES

The Technology Development and Innovation Policy (TDIP) released on the 6th of October 2017 was endeavored to promote research, development, and demonstration (RD&D) in the renewable energy sector. RD&D intended to evaluate resources, progress in technology, commercialization, and the presentation of renewable energy technologies across the country. It aimed to produce renewable power devices and systems domestically.

7.1 Tariff Policy Amendments, 2018

On the 30th of May 2018, the MoP released draft amendments to the tariff policy. The objective of these policies was to promote electricity generation from renewables. MoP in consultation with MNRE announced the long-term trajectory for RPO. The State Electricity Regulatory Commission (SERC) achieved a favorable and neutral/off-putting effect in the growth of the renewable power sector through their RPO regulations in consultation with the MNRE. On the 25th of May 2018, the MNRE created an RPO compliance cell to reach India's solar and wind power goals. Due to the absence of implementation of RPO regulations, several states in India did not meet their specified RPO objectives. The cell will operate along with the Central Electricity Regulatory Commission (CERC) and SERCs to obtain monthly statements on RPO compliance. It will also take up non-compliance associated concerns with the relevant officials.

7.2 Repowering Policy, 2016

On the 09th of August 2016, India announced a "repowering policy" for wind energy projects. An about 27 GW turnaround was possible according to the policy. This policy supports the replacing of aging wind turbines with more modern and powerful units (fewer, larger, taller) to raise the level of electricity generation. This policy seeks to create a simplified framework and to promote an optimized use of wind power resources. It is mandatory because the up to the year 2000 installed wind turbines were below 500 kW in sites where high wind potential might be achieved. It will be possible to obtain 3000 MW from the same location once replacements are in place. The policy was initially applied for the one MW installed capacity of wind turbines, and the MNRE will extend the repowering policy to other projects in the future based on experience.

7.3 The Wind-Solar Hybrid Policy, 2018

On the 14th of May 2018, the MNRE announced a national wind-solar hybrid policy. This policy supported new projects (large grid-connected wind-solar photovoltaic hybrid systems) and the hybridization of the already available projects. These projects tried to achieve an optimal and efficient use of transmission infrastructure and land. Better grid stability was achieved and the variability in renewable power generation was reduced. The best part of the policy intervention was that which supported the hybridization of existing plants. The tariff-based transparent bidding process was included in the policy. Regulatory authorities should formulate the necessary standards and regulations for hybrid systems. The policy also highlighted a battery storage in hybrid projects for output optimization and variability reduction.

7.4 The National Offshore Wind Energy Policy, 2015

The National Offshore Wind Policy was released in October 2015. On the 19th of June 2018, the MNRE announced a medium-term target of 5 GW by 2022 and a long-term target of 30 GW by 2030. The MNRE called expressions of Interest (EoI) for the first 1 GW of offshore wind (the last date was 08.06.2018). The EoI site is located in Pipavav port at the Gulf of Khambhat at a distance of 23 km facilitating offshore wind (FOWIND) where the consortium deployed light detection and ranging (LiDAR) in November 2017). Pipavav port is situated off the coast of Gujarat. The MNRE had planned to install more such equipment in the states of Tamil Nadu and Gujarat. On the 14th of December 2018, the MNRE, through the National Institute of Wind Energy (NIWE), called tender for offshore environmental impact assessment studies at intended LIDAR points at the Gulf of Mannar, off the coast of Tamil Nadu for offshore wind measurement. The timeline for initiatives was to firstly add 500 MW by 2022, 2 to 2.5 GW by 2027, and eventually reaching 5 GW between 2028 and 2032. Even though the installation of large wind power turbines in open seas is a challenging task, the government has endeavored to promote this offshore sector. Offshore wind energy would add its contribution to the already existing renewable energy mix for India.

7.5 The Feed-In Tariff Policy, 2018

On the 28th of January 2016, the revised tariff policy was notified following the Electricity Act. On the 30th May 2018, the amendment in tariff policy was released. The intentions of this tariff policy are (a) an inexpensive and competitive electricity rate for the consumers; (b) to attract investment and financial viability; (c) to ensure that the perceptions of regulatory risks decrease through predictability, consistency, and transparency of policy measures; (d) development in quality of supply, increased operational efficiency, and improved competition; (e) increase the production of electricity from wind, solar, biomass, and small hydro; (f) peaking reserves that are acceptable in quantity or consistently good in quality or performance of grid operation where variable renewable energy source integration is provided through the promotion of hydroelectric power generation, including pumped storage projects (PSP); (g) to achieve better consumer services through efficient and reliable electricity infrastructure; (h) to supply sufficient and uninterrupted electricity to every level of consumers; and (i) to create adequate capacity, reserves in the production, transmission, and distribution that is sufficient for the reliability of supply of power to customers.

VIII. CONCLUSION

The growth of India's energy consumption will be the fastest among all significant economies by 2040, with coal meeting most of this demand followed by renewable energy. Renewables became the second most significant source of domestic power production, overtaking gas and then oil in 2020. Agriculture is where solar power can prove to be largely inclusive. It can help irrigate farmers' fields, build cold storages in rural areas, and augment farmers' incomes by feeding the surplus power generated into the

grid. Harvesting solar power on farmers' fields can thus act as harvesting another crop, and can provide a sort of insurance even when rains fail. Rural India faces sparse and sporadic supply of power even where there are grid lines. In many far North and North-East regions, the rocky and mountainous terrains pose a hurdle for laying grid and transmission lines. Solar power can help to bridge this gap in power supply and can be a game changer.

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