SOLAR PROSUMPTION FOR SUSTAINABLE DEVELOPMENT IN RURAL INDIA

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***Abstract*: Real India lives in villages. Access to quality energy in rural places and sustainable development of the country are strongly correlated. And it's a key challenge to provide energy as the gap between energy needs and available energy is widening due to rapid urbanisation, industrialisation and burgeoning population in the country. Renewable energy sources, solar energy in particular is a promising source of energy to meet this challenge where there is no grid connectivity or lack of quality energy access, thus contributes to the sustainable development. Solar energy prosumers refers to the energy consumers who also produce the energy required using solar energy sources to be self-dependent or partially dependent on electricity grid. Energy prosumers play a key to bridge the gap between energy production and consumption. The current paper studies the enablers and inhibitors of solar prosumption at residential level and its contribution to socio, economic and environmental dimensions of sustainable development. Further, from the literature available in the field, the study developed a conceptual model.**

***Keywords*: Solar prosumption, Solar prosumer, Sustainable development, Energy, Enablers, Inhibitors.**

1. Introduction

Energy is a major contributor for sustainability in both developed and developing economies of the world. Quality access to energy and sustainable development of any country – social, economic and environmental – are highly correlated. India, being the fifth largest energy consumer in the world (FICCI report), and the demand for energy is ever increasing due to various reasons. There has been a huge gap between energy demand and supply. And the country highly dependent on fossil fuels for majority of its energy needs bridging this gap is always a a tough challenge. Energy generation through fossil fuels is one of the major causes of GHG (Green House Gas) emissions leading to the environmental pollution. And at the same time the fossil fuels are limited in nature, and it's the time for us to look for alternative resources to meet the current and future needs of energy in a sustainable energy. Renewable energy sources – wind, biogas, tidal, solar etc. – have the potential to cater the energy needs in a sustainable manner. Solar energy is the energy generation from the sun's radiation or heat, the most promising of the renewable energy sources with unlimited potential. Solar electricity may be used for power supply to remote villages and locations not connected to the utility grid. In the 1990s, the World Bank identified SHS as the least-cost solution to the problem of rural electrification and supported many SHS programs in developing countries. In India, by 2012, there were 500,000 SHS and 700,000 solar lanterns distributed across the country (P. Raman *et. al.* , 2012)Solar energy could also be applied in the areas of water pumping, village electrification, rural clinic and schools power supply, employment generation lighting of road signs, etc. (Sunday Olayinka Oyedepo, 2012).

The term 'prosumer' was first coined by Toffler in 1980s. In the energy context, energy prosumer is the consumer of energy who also produces to meet his/her energy needs, stores the surplus energy in storage devices such as batteries or sometimes sells the excess energy produced to the utility grid. Solar prosumption is a holistic approach to tackle rural energy access problems, poverty alleviation, children education and rural health.

2. Objective of the study

The current paper focussed to study the role of solar prosumption for sustainable development in rural areas of India.

3. Solar prosumers: The emerging face of energy sector

The concept of "prosumer" was introduced for the first time in 1980 by the futurist Alvin Toffler in his book "The Third Wave." The term "prosumer" refers to proactive consumers who are also active in the design and improvement of goods and services; but subsequently the term prosumer is evolved to explain a consumer who also take part in production (Toffler, A., 1980).

In the present context, the term prosumer is used to refer to energy consumers who also produce their own power from a range of different onsite generators (e.g. diesel generators, combined heat-and-power systems, wind turbines, and solar photovoltaic (PV) systems) (European Energy Union report, 2017). According to Ford, R., Stephenson, J., & Whitaker, J. (2016), energy prosumer is "a consumer of energy who also produces energy to provide for their needs, and who in the instance of their production exceeding their requirements, will sell, store or trade the surplus energy". Increased solar energy prosumption helps to mitigate the use and environmental problems caused by fossil fuel energy generation. It also contributes to the uplift of rural folk with increased access to health, education and job opportunities.

4. Benefits of solar energy

Solar energy is converted into electrical energy in photovoltaic cells in the process of photovoltaic conversion. Single cells have little power and are therefore combined in a series or in parallel in order to obtain sufficient power. The energy thus obtained is transferred through an appropriate controller to the battery, which is used for its storage. The role of this device is very important because it allows one to use free energy after sunset (Kapica J., 2014).

Solar energy offers several benefits to developed as well as developing economies of the world that has been documented over the past several decades Edenhofer et al., 2011). According to IEA-RETD report (2014) some of the benefits of solar energy include:
4.1 Energy availability. Solar power can help assure energy supply availability during periods of fuel supply disruption or geopolitical instability – particularly for countries that are energy importers and for places where there is no grid connect.

4.2 Energy affordability. Solar energy can help deliver affordable energy in several ways. First, solar energy is already a competitive alternative to conventional generation in islands and remote areas with diesel-dominated grids. Solar power can also shave system peak demand and can reduce market prices as a result (which is a benefit for other consumers and the economy as well because the input of expensive fuels is reduced).

4.3 Energy supply sustainability. The amount of fossil fuels that can be extracted will eventually be capped either by regulatory constraints (e.g. greenhouse gas regulation) or by resource exhaustion. Renewable energy will be able to continue to supply power if and when fossil fuels are no longer available or accepted.

4.4 Green growth. Solar energy development can create new and direct domestic jobs in the manufacturing, installation, and service industries, as well as indirect and induced jobs in the broader economy.
4.5 Rural development. PV can provide modern energy services to isolated areas that do not have a reliable power supply or that lack energy access entirely. Energy access can significantly improve livelihoods by creating new economic opportunities and improving health.

4.6 Carbon dioxide emissions reductions. PV can displace generation from fossil fuel technologies and thereby reduce emissions, thus mitigating climate change. PV systems also have lower lifecycle CO2 emissions associated with their manufacture than conventional power plants.

4.7 Air quality improvements. By displacing fossil fuels, PV also reduces the emission of sulphur dioxide, nitrous oxides, particulate matter, mercury, and other air pollutants that are hazardous to human health and to the environment.

4.8 Water consumption. Conventional power plants often require a large amount of water to sustain operations. With droughts on the rise in many parts of the world as a result of climate change, the conventional energy supply will increasingly be at risk as it competes for scarce water resources with other critical sectors. PV generation does not require water to operate.

4.9 Land use. Conventional power plants can use a significant amount of land for both operation, but also for waste disposal (e.g. coal and nuclear). PV can be readily integrated into existing infrastructure (e.g. building rooftops, parking lots, etc.) and avoid significant land use impacts, depending on how it is designed.

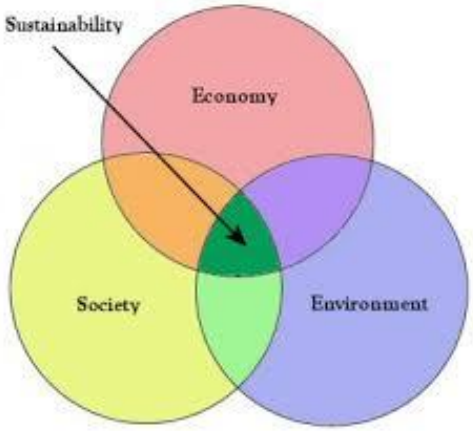
Energy security is a broad concept that focuses on energy availability and pricing. Specifically, it refers to the ability of the energy supply system – suppliers, transporters, distributors and regulatory, financial and R&D institutions – to deliver the amount of competitively-priced energy that customers demand, within accepted standards of reliability, timeliness, quality, safety and environmental impacts, under a wide range of geopolitical, economic, social, technological and weather circumstances (OECD report, 2015)

5. Sustainability: The need of the hour
The word sustainability or sustainable development has been popularised by the World Commission on Environment and Development (WCED), in its 1987 report entitled, 'Our Common Future'. The WCED commission defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43). Sustainable development seeks to balance the economic, environmental, and social dimensions of development in a long-term and global perspective. The popularity of 'sustainability' stems also from a simple model used to facilitate the comprehension of the term: the triangle of environmental (conservation), economic (growth), and social (equity) dimensions. Mostly, sustainable development is modelled on these three pillars also referred to as tipple bottom line (ETH Zurich report, 2005)

All the developed and developing countries of the world should consider sustaining its welfare and resources to future generations through respecting sustainable development goals that comprise social progress, poverty reduction, equity, enhanced resilience, economic growth, and environmental sustainability (Parag, Y., Sovacool, B., 2016).
Sustainable development is increasingly becoming a goal, to which numerous countries throughout the world aspire (Montes, G M. *et. al.*, 2005; Rosen MA., 2009). Overall sustainability has been defined in many ways and is often considered to have three

distinct components: environmental sustainability, economic sustainability and social sustainability. Overall sustainable development in general requires the simultaneous achievement of environmental, economic and social sustainability. Achieving this balance is indeed a challenging. Environmental sustainability encompasses emission of greenhouse gases, environmental pollution (Drexhage and Murphy 2010). Social sustainability should be achieved by providing adequate basic facilities such as health, education and gender equity. Economic sustainability includes, empower the people economically through better job prospects and entrepreneurial opportunities.

Figure 1: Sector view of sustainable development



Source: Giddings et al. (2002. p. 189).

6. Harnessing solar energy for sustainable development

The fuel driving the engine of growth and sustainable development of any nation is the nation's access to reliable and adequate energy. Access to energy is a crucial enabling condition for achieving sustainable development.

The concept of sustainable development encompasses economic, social and environmental dimensions (Elkington, 1997; Stead et al., 2004). Sustainable development enhances standard of living economically and environmentally in the long term growth that has got to be supported by the economic structure of the country. To sustain energy convenience and keep atmosphere inhabitable for future generations, finding alternative sources of energy is crucial. In addition, growing awareness of society concerning environmental problems and the depletion of the fossil energy sources support renewable energy sources. These alternative sources of energy are the necessary and determinant policy areas for the countries, and will embody current and future energy policies. The economic growth and prosperity of any country or region in the world is related to the level of its consumption of energy (Parag, Y., Sovacool, B., 2016).

The term "Renewable energy" covers all forms of energy generated from natural resources such as sunlight, wind, water (or hydro power), tide, geothermal heat, biomass and biofuels. They are derived from natural processes that are constantly replenished and each of them has characteristics that determine where and how they are used (Duke, R, Williams, R and Payne, A. 2005).

Renewable energy is considered an important resource in many countries around the world (Alnatheer, O. , 2005; Huacuz, J M. 2005; Duke, R, Williams, R and Payne, A. 2005; Montes, G M. *et. al.*, 2005; Kaldellis, J K. *et. al.*, 2005; Cavaliero *et. al.*, 2005; El Sayed, M A H. ; 2005). It is considered that renewable energy is in a synergy with various aspects of sustainable development (Stigllitz, 2002). Therefore, thanks to renewable energy, sustainable growth and development are at the centre of policies all over the world. As stated by Bugaje (2006), the following considerations should be taken into account to make renewable energy consumption sustainable and acceptable for other socio-economic parameters of development (Inglesi- Lotz, 2015. p. 1, 2):

Sustainability of environment by means of appropriate resource management and protection of the environment. Economic sustainability is to develop infrastructure, services and empower the people economically. Social sustainability with helping the poor, rights of women, children's rights. (Parag, Y., Sovacool, B., 2016).

RE can accelerate access to energy, particularly for the 1.4 billion people without access to electricity.

Fig 2. Region wise electricity access across the world (2015 and 2030 projections)

Region	2009			2015	2030	2009	2015	2030
	Rural	Urban	Total	Total	Total	%	%	%
Africa	466	121	587	636	654	42	45	57
Sub-Saharan Africa	465	120	585	635	652	31	35	50
Developing Asia	716	82	799	725	545	78	81	88
China	8	0	8	5	0	99	100	100
India	380	23	404	389	293	66	70	80
Other Asia	328	59	387	331	252	65	72	82
Latin America	27	4	31	25	10	93	95	98
Developing country	1229	210	1438	1404	1213	73	75	81
World	**1232**	**210**	**1441**	**1406**	**1213**	**79**	**81**	**85**

Source. International Energy Agency World Energy Outlook (2010)

Solar energy, the best suitable for Indian geographical conditions has been recognized as an excellent alternative source for fossil fuels. It can be used at optimum level for villages and at places where there is no utility connectivity. At the same time, solar energy meets the three sustainable development challenges – social sustainability, economic sustainability and environmental sustainability – in rural areas. Solar prosumption has immense potential to meet the energy requirements in a sustainable manner. Solar prosumption plays a significant role in contributing to the social, economic and environmental benefits of small villages.

7. Solar prosumption for sustainable rural India

Sustainability is a critically important goal for human activity and development. Sustainability in the area of energy is of great important to any plans for overall sustainability given (i) the pervasiveness of energy use, (ii) its importance in economic development and living standards, and (iii) the significant impacts that energy processes and systems have had, and continue to have, on the environment (Montes, G M. *et. al.*, 2005).

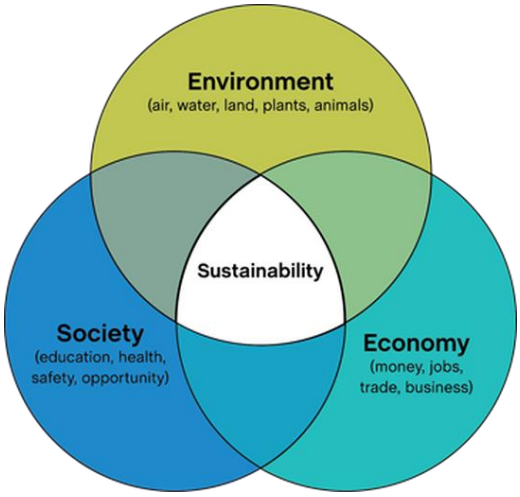
Sustainable development benefits include health improvement, local employment and reduced energy imports (IPCC, Intergovernmental panel on climate change, UNEP report, 2012).

Sustainable development is increasingly becoming a goal, to which numerous countries throughout the world aspire (Rosen MA., 2009).
Funds invested in renewable energy sources development could contribute to increased standards of living and income in less favoured, peripheral, island, remote or declining regions.

According to the Planning Commission of India, more than one third population of India live in off the grid areas and an equal number of people live in areas with unreliable grid electricity and frequent power cuts. Solar energy will enhance livelihood prospects, improve efficiency in rural households. The Ministry of New and Renewable Energy (MNRE) established the "Solar Energy Centre" in 1982 with the aim of promoting and developing solar energy technologies to meet the energy deficit faced by the country. As the Indian economy enjoys a sustained positive momentum, rural India continues to be the heart of the country, accounting for 67 per cent of the total population and 37 per cent of its GDP. Agriculture is the primary occupation of rural households and mainstay of their socio-economic structure. While the overall Indian economy is expected to grow in excess of 7 per cent – the fastest amongst large global economies – rural India still lags behind substantially.
The primary hindrance to growth in rural productivity and subsequent economic growth is the lack of basic infrastructure such as electricity, clean water and sanitation. As part of the government's vision of 'Electricity for all by 2019', the Centre has placed special emphasis on incentivising distributed solar power, having already sanctioned 4,604 distributed solar project in rural area to power 4,745 villages/hamlets.

Solar power offers an opportunity to bridge this massive infrastructure gap and improve the social, economic, environment and health indicators of India's rural population as discussed below.

Fig 2. The three dimensions for rural sustainability



7.1 Social dimension

7.1.a. Education

Education for all is one of the foremost requirements of our country today. So when a factor like lack of electricity in the remote corners of our country acts as a hindrance towards studying, something must be done. As on December 2011, nearly one third of India's rural population lacked electricity, a loss compensated by burning fossil fuels (kerosene lamps included) to give light. The kerosene lamps cause more harm than good. Most students with the will to study, due to lack of proper lighting or frequent power cuts, have to succumb to studying under street lights or under the dim lighting of the kerosene lamps, post sunset.

One of the innovative solutions was to address the problem of students facing difficulty while studying in either the light of street lights or under dim, polluting and dangerous oil based or kerosene lanterns, by providing them with highly efficient, solar chargeable lamps, LED Study Lights which are much cleaner, brighter, and safer to use.

Sri Aurobindo International Centre for Education in Puducherry has become the first fully solar-powered educational institute in India. According to reports, the institute generates thrice the electricity it consumes through solar power plants installed on the roofs of the dining room, primary school, library and high school in the campus. School authorities reported that they now save up to Rs 10,000 per month due to the almost-non-existent electricity and utility costs. Within the next ten years, they hope to recover the investment made on the solar panels (Rs 1 crore).

7.1..b Health care

In India, about 55 per cent of households depend on the public health system to meet their healthcare needs. But as of 2015 nearly 35 million people in rural areas relied on local health centres without an electricity supply, according to government data. One in every two primary health centres has no electricity or suffers from power outages. A 2016 report by the Council on Energy, Environment and Water, a non-profit research agency, said only a fifth of primary health centres meet Indian public health standards, which include having functional infrastructure for electricity.
A study of PHCs in Chhattisgarh has found that solar-powered PHCs could significantly improve in-patient services, out-patient services, emergency care, delivery services and laboratory services in rural India. Scaling solar systems across PHCs is in India's interest as it meets the targets of the National Solar Mission as well as the National Health Mission. Across several states, government health centres are gradually turning to solar energy for a reliable power supply to store their vaccines, operate infant warmers, sterilise equipment and cut the time spent caring for patients. Solar-powered healthcare centres can significantly improve in-patient services, shows study on role of electricity access on health outcomes in rural Chhattisgarh. The study is based on evaluation of 147 PHCs, including 83 having solar photovoltaic (PV) systems, across 15 districts in Chhattisgarh. During 2012-2016, the Chhattisgarh State Renewable Energy Development Agency (CREDA) installed off-grid solar PV (photovoltaic) rooftop systems across 570 PHCs in the state. The ability of solar-powered PHCs to operate cold chain, storing vaccines and drugs, and new-born care equipment was also better, said the study. The results of the study could be significant, especially for India, as a large number of PHCs have unreliable power supply or have no access to electricity at all, which affects diagnostic and treatment services, reduces hours of operation to daytime, and forces patients to travel more in search of better healthcare services.

Fig 3. Fully solarised PHC in Chhattisgarh

A boat offering healthcare services that operates on the Brahmaputra river in the northeast Indian state of Assam. The first of 15 Indian boat clinics to go solar, the S. B. Nahor has for the first time brought a dentist to the doorstep of tens of thousands of people who live on flood-prone river islands in Assam. Off-grid solar systems like that on the boat are a growing source of power in India, particularly in rural areas, but they still provide less than a tenth of the electricity generated by grid-connected solar plants, experts say.

Karuna Trust is working with SELCO to solar power 10 more PHCs in Karnataka, Arunachal Pradesh, and Meghalaya. Systems are designed after critically assessing current and future usage of the centres, the demographic and geographic context they are situated in, and the energy efficiency of medical equipment.

7.1.c Solar cookers

According to the World Health Organization, 400,000 of India's population dies prematurely every year due to effects of biomass fuel used in households for cooking. Exposure to smoke and poisonous fumes from burning biomass in poorly ventilated homes is a major cause of cardiovascular and respiratory diseases in women and children. As many as 4.3 million deaths worldwide were linked to indoor air pollution in 2012 in homes that depend on coal or biomass for cooking, out of a total of 7 million deaths caused by exposure to air pollution, according to estimates by the WHO. Cook stoves and lamps powered by sunlight help eliminate this hazard.

Nearly 300 million people in rural India lack access to grid-connected power, promoting use of archaic sources of energy such as kerosene, diesel, wood-fired *chulhas*, etc, which not only results in huge government subsidies, but also substantial health and environmental hazards. Hours spent gathering wood or biomass fuel robs families of time and energy needed for education and work. Deforestation degrades soil and destroys habitats. Typical energy use in Indian villages is extremely polluting. Cooking is fuelled mostly by wood and waste biomass and kerosene oil is used to light homes. Women and children spend hours seeking out fuel for cooking, while burning kerosene and wood cause lethal indoor air pollution and releases greenhouse gases that contribute to global warming. The Indian government, along with non-governmental institutions, has recognized the potential for using the sun as an energy source and, for the past 50 years, has been at the forefront of promoting solar cook stove programs.

In November 2003, The Barefoot College created the Society of Women Barefoot Solar Cooker Engineers in Tilonia, Rajasthan. It is the first association of illiterate and semi-literate women who fabricate, install and maintain parabolic solar cookers in their homes. The parabolic solar cooker is constructed from 300 mirrors that reflect the sun's rays onto the bottom of a cooking pot to cook food quickly and sustainably. Women who once spent long hours searching for firewood can spend their time on other productive activities. Communities with solar cookers can expand their livelihood opportunities and limit the negative effects of deforestation and pollution.

In order to reduce serious health hazards associated with cooking using fossil fuel and empowering women by protecting their health, India Post in collaboration with Western Union Money Transfer will be distributing solar cookers and lights in 16 villages of Agra region. The distribution will begin from next month. The idea is to empower women and protect their health by reducing serious health hazards associated with cooking based on fossil fuel. This will also reduce the number of deaths in villages due to unclean cooking fuel and prevent children from number of acute respiratory illnesses caused due to indoor air pollution by burning the fossil fuel.
Subsidies on solar cookers vary, depending on the program or type of cooker, but typically range up to 50 per cent. Government support is very important. Poor people cannot afford solar cookers, so subsidies help make this technology available to everyone who wants it.

7.1.d Drinking water

Clean water remains a big challenge in rural India, since water treatment requires power. Solar energy is finding important applications in this field. For example, Nagaland recently installed a solar powered water treatment plant in Tsiesma, a village near Kohima, which works on an advanced membrane filtration system producing pure drinking water. India's first ever solar powered reverse osmosis plant produces 3,600 litres of clean water daily and provides drinking water for over 1,000 villagers. The system provides potable water through reverse osmosis: brackish water flows at a high pressure through a thin membrane. The purified water is free of salts and contaminants, which are stored in tanks and collected from pipes in the evening. The plant reduces the salinity of locally available water, making it safe to drink and free of any salty taste. It is powered by a 2.5-kilowatt solar generator that creates an uninterrupted supply of water without relying on the standard electric grid.

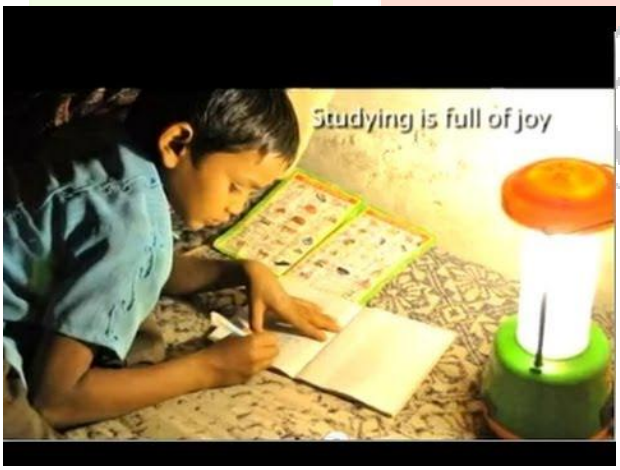
7.1.e Solar lighting enhances productivity

According to the Planning Commission of India, more than one third population of India live in off the grid areas or rural areas depend on These villages survive on petromax, kerosene lamps for home lighting which adversely affects their health. Kerosene lamps emit carbon monoxide that is harmful for the health and environment. According to the World Bank, breathing kerosene fumes is equivalent to smoking two packets of cigarettes a day. Besides, even the light emitted by them isn't sufficient, does not spread evenly and can be damaging for eyesight. Cost wise, every household in India spends Rs 900 annually on kerosene, the amount being subsidized by the Government. Kerosene lamps are not only dangerous to operate, but have also been known to cause fire accidents and burn injuries to children due to kerosene spill overs and explosions on a regular basis in rural areas. Kerosene or other fuels used for lighting are even costly and sometimes difficult to procure. The lack of proper light often led to loss of interest in studies among the children. The result was that many students either dropped out or were irregular or under-performing in their studies.

Solar lighting, for example, not only provides a high quality solution to improve rural productivity, but also substantially reduces health hazards by enabling replacement of kerosene lamps. Even 4-5 hours of additional lighting can improve productivity and income of rural household by nearly 30 per cent.

Launched in 2012, the Lighting Asia/India program aimed at bringing high-quality solar lighting solutions to 3 million people who live off the grid in rural India. By December 2015, it had already reached almost 8 million people.

Fig 4. Solar lighting for education



7.2 Economic dimension

7.2.a Agricultural water pumps

Another important application is solar powered agri pumps, which have the potential to substantially improve productivity of Indian farmers. Solar agri pumps are an economic and environmentally-friendly alternative to nearly 26 million agri pumps installed in India, of which 10 million are diesel-fired. Replacement of 1 million diesel pumps could, over its life, improve agricultural output by □ 30,000crore, mitigate usage of diesel by 9.4 billion litres — translating into a reduction of diesel subsidy by □ 84,000million and CO2 abatement of 25.3 million tonnes. While solar pumps cost nearly 10 times more upfront than the diesel variants, they have attractive payback period of 4 years vis-a-vis diesel pumps. Central and State governments have introduced multiple favourable schemes to promote usage of solar pumps, by providing subsidy for the upfront costs.

Fig 4. Solar water pump for irrigation

7.2.b Creation of Job opportunities

Renewable energy schemes can play an important role in regional development by injecting a valuable and sustainable source of income into rural areas. Solar energy will lead to significant new rural employment opportunities in rural areas.

India launched a massive push for renewable energy in 2014 — a move that could bring more electricity and jobs to rural communities. The government set ambitious targets to generate 160 gigawatts (GW) of wind and solar power over the next five years (2017-2022), a 400 per cent increase from previous targets. A study from the Council on Energy, Environment and Water and the Natural Resources Defence Council estimates that to achieve this goal, India must create 330,000 new jobs over the next five years. Many of these jobs can provide steady incomes, healthcare benefits and skill-building opportunities for semi-skilled and unskilled workers. For India's rural poor, especially women, these clean energy positions offer a lucrative alternative to subsistence farming. The job opportunities come with healthcare benefits, safety trainings and capacity-building programs that help workers secure promotions.

India's new clean energy jobs can be game-changers in these communities which can provide a reliable source of income that enables families to make smarter investments, save for unexpected expenses and plan for their children's futures.

Fig 5. Solar energy for employment

7.2.c Empowering women through entrepreneurship

Solar energy can create a difference to millions of poor people across the world especially rural women. These opportunities could be in the skilled, semi-skilled, and unskilled categories, spanning functions such as construction, project commissioning and design, business development, and operations and maintenance (World Resources Institute).
Solar energy empowers rural women with entrepreneurial opportunities. For instance, initiatives like Sakhi Unique Rural Enterprise (SURE) – a rural distribution and marketing company working with rural women entrepreneurs and markets clean green products like improved cook stove, solar lantern, biogas, solar water heaters etc. SURE was formed with an aim to improve the health and well-being of Indian rural households. SURE aims to make rural women entrepreneurs with excellent door-to-door selling techniques so that they can earn commission-based income and enjoy significant commission-based income too.

There are almost 1,010 women entrepreneurs in the villages of Maharashtra and Bihar who have empowered themselves by running successful businesses of selling solar appliances to rural households. This was made possible through the efforts of Swayam Shikshan Prayog (SSP), a non-profit based at Pune in Maharashtra that helps village women to become clean energy entrepreneurs. By 2015, SSP successfully established a network of more than 1,010 grassroots women entrepreneurs across eight districts of Bihar and Maharashtra. This initiative to create climate leaders has earned it a UN climate award this year.

Rural women of 'solar barefoot engineers' have brought light into their lives and their communities in Rajasthan. These women were trained to become solar engineers thereby helping light up houses in their communities. And the residential training programme has made it possible for women to overcome social barriers and secure steady employment.
Today, the clean energy sector in India employs an estimated 103,000 people in the solar power sector and around 48,000 in the wind sector (International Renewable Energy Agency).

7.3 Environmental dimension

7.3.a Generation of Solar energy is pollution-free

In our country electricity generation sector alone contributes 40 per cent of the total emission of CO2 from the use of the energy (Murthy et al., 1997)**.** Emission of pollutants like CO2, SO2, and NOx is highly reduced by installation of CPV systems, going solar is elimination of noise and air pollution. The MNRE planned to reduce carbon emissions (generated by burning the diesel of generators associated to cell phone towers) by using solar power (Naveen Kumar Sharma et. al., 2012).

7.3.b Helps to reduce deforestation

Majority of the rural people in India depend on twgis and branches for household cooking purpose. This fuel wood mainly collected from their own farmlands, wastelands, roadside trees and nearby forests. The villagers have to spend a minimum of 3 to 4 hours for this purpose and they have to travel a long distance too for which they have to loose valuable time and their energy. Solar cooking equipment not only saves time and energy but protects the forests thus saves the eco system.

Swayam Shikshan Prayog (SSP), a non-profit based at Pune in Maharashtra, the project has now reached more than 4 million people across four states in India. The project's women entrepreneurs make clean energy products accessible to people living in their communities, which helps cut greenhouse gas emissions. Their efforts have resulted in more than 100,000 women and households using clean cook stoves, which save almost 100 tonnes of firewood per day.

8. Conclusion

In a country where the fossil fuels are limited in nature, solar energy has enormous potential to meet the energy requirements of India's rural folk in a sustainable manner. And solar prosumers are emerging as an important segment in the energy sector to accomplish their own energy needs. The current study elaborately discussed the contribution of solar energy to meet the three important dimensions – social, economic and environmental – of sustainable development of rural areas. As the initial cost of installation of solar energy is high, the government need to take steps to reduce the high initial cost and also need to increase the subsidy for the rural poor. At the same time, support from the NGOs, social entrepreneurs and financial institutions is vital to make the solar energy affordable and accessible to rural India. And at the end, sustainability is the precious gift we can present to the next generations.

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