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Research Article

Solar Energy Policy for Commercial Buildings Sector: Recommendations for the Indian Scenario

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Abstract

India is a rapidly developing nation and is heavily dependent on fossil fuels. Renewable energy presents an attractive solution to the growing challenges concerning energy needs. Solar energy is abundant in India, and thus, its application and use are rapidly advancing. This study assesses various government initiatives for off-grid Solar Photovoltaic/Solar Water Heating systems for commercial establishments in India and elucidates the need for improvements in their implementation, highlighting the problems in availing the incentives. The study was conducted in six states/Union Territories (UTs) of India, which were selected based on their total installed solar capacity. Questionnaires and secondary sources were used as tools for data collection. Policy recommendations were proposed to improve the policy structure and address the problems reported by the stakeholders. A key feature of the recommended policy framework is the inclusion of stakeholders at every stage to make the process efficient. The findings and recommendations in the study might make the government initiatives for increasing the off-grid installations in the commercial buildings sector more acceptable and easier to implement.

Keywords

Solar energy; off-grid solar energy installations; policy recommendations; commercial buildings sector; renewable energy; India

1. Introduction

Energy is necessary for economic growth and increasing the developmental opportunities of a nation. A secure and accessible supply of energy is crucial for sustenance [1]. However, the availability of adequate and clean energy for everyone is a significant challenge faced by society. The increasing use of fossil fuels is a concern for energy security as well as the environment. The growing population and economic development have put immense pressure on the existing energy resources. Studies estimate a 50% increase in global energy consumption by the year 2050 [2]. Figure 1 illustrates the projected world energy consumption from different sources.

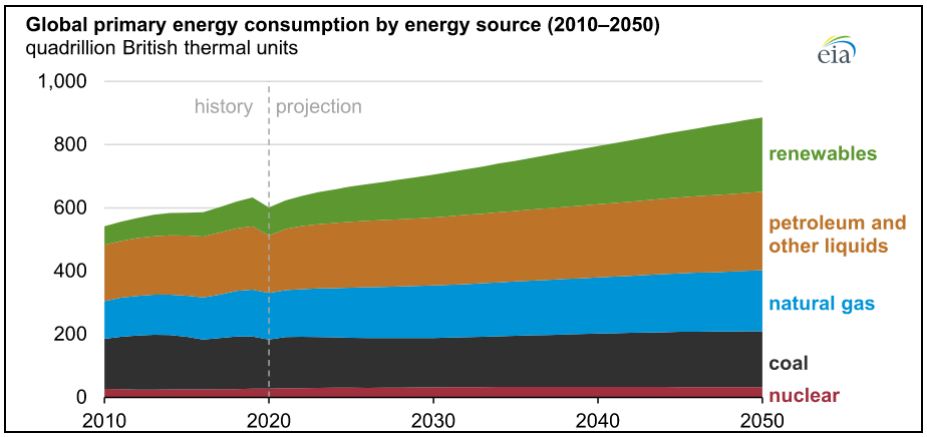

Figure 1 The projected increase in World Energy Consumption [2].

India can be categorized as an energy guzzler. Energy demands are increasing exponentially as India's GDP is rising rapidly [3]. India's total energy consumption is expected to increase from 35 quadrillion British thermal units (Btu) in 2018 to 120 quadrillion Btu in 2050, growing from a 6% share of the world's total consumption to 13% [4]. Despite the setback due to COVID-19, India's electricity demand is still projected to grow by almost 5% per year to 2040, which is nearly double the rate of the global average energy demand [5].

India is a rapidly developing nation, and energy is the key to developing its infrastructure and meeting the needs of the ever-growing population. Urbanization is also a key factor in increasing the country's energy demands, owing to an increase in the use of fuels, a rise in appliance and vehicle ownership, and an increase in the demand for construction materials. Also, there are great opportunities to carve a more sustainable and innovative way to develop the energy sector.

India has traditionally depended on fossil fuels for meeting most of its energy demands, which has been an area of concern [6]. Globally, fossil fuel reserves are shrinking at a fast pace. Moreover, climatic changes driven by fossil fuel combustion are leading to an increase in greenhouse gas emissions, which directly impact the environment. Currently, energy production and distribution are the major sources of fossil fuel combustion [7].

Renewable energy in India constitutes 21.95% of the country's total installed power generation capacity [8]. Accelerating the use of renewable energy is vital to meet India's growing energy demands while reducing the impact on the environment [9]. India has a wind potential of more than 300 GW, a solar potential of about 750 GW, a small hydro potential of about 20 GW, and bioenergy potential of 25 GW. The total installed capacity of renewable power in India has increased from about 28.07 GW in 2013 to 147.10 GW in 2021, indicating over 500% growth [10, 11].

Geographically, India lies between the Tropic of Cancer and the Equator, has an average annual temperature ranging between 25 °C and 27.5 °C, and averages 300–330 sunny days per year. Thus, it has a huge solar potential [12]. India's total installed solar energy capacity is more than 42 GW, and an additional capacity of around 14.04 GW is under installation [13].

Solar energy is a primary concern in India's National Action Plan on Climate Change, with the National Solar Mission (NSM) of 2010 as one of the key objectives. NSM is a major initiative of the Central Government of India with participation from the different states to promote the application of solar energy for addressing India's energy challenges. The Mission's objective is to create policy incentives for solar technology diffusion across the country as quickly as possible. The Mission is in line with India's target to achieve about 40% electric power from non-fossil fuel-based energy resources [14].

1.1 Research Focus

Solar energy can be utilized in two ways, including grid-connected and off-grid [15]. Off-grid systems have small-scale, decentralized applications but cannot be used for large-scale power production. Thus, an interesting feature of an off-grid solar system is that it can be used in a decentralized manner, where the energy is produced for an individual home or commercial building. An off-grid/decentralized solar collection scheme is more energy-efficient than a grid-connected/centralized one. It can supply power directly at the location without any transmission and distribution losses. The Off-grid Solar PV Applications Program is one of the oldest programs of the Ministry of New & Renewable Energy, Government of India, aimed at providing solar applications in areas where grid power is either not available or is unreliable. Hence, off-grid/decentralized solar energy systems can be used effectively for providing substantial levels of solar energy in India [16]. Currently, over 80% of all solar energy systems in India comprise off-grid systems [13].

Commercial buildings, which include various institutional and industrial establishments, consume high levels of energy. Based on the urbanizing trends of the country, it is estimated that 70% of the commercial sector is yet to be built. The commercial buildings sector in India consumes over 8% of the total electricity, and the consumption rate is growing faster than that in the other sectors [17]. The commercial buildings sector has the marketing motivation and the resources available to show its willingness to embrace off-grid solar energy solutions. Thus, it is important to focus on off-grid solar installations in the commercial buildings sector and to investigate the government initiatives to promote solar energy in this target sector to propose policy improvements.

1.2 Research Significance

Several researchers have studied renewable energy in India, in general, and solar energy initiatives in particular. A comprehensive review of the key studies can highlight the need to find different strategies for improving the policies of the Indian government to promote off-grid solar energy systems in the commercial buildings sector.

Meisen [18] conducted a study on sustainable renewable energy potential in India and suggested that there is a need for a policy framework for promoting the acceptance of solar energy in India. The study concluded that without political support, solar energy would remain underutilized. Developing solar energy-based systems would require strong political and economic support, especially through laws that guarantee stable tariffs. Similarly, according to Basu [20], several countries which have high levels of solar installations do not have as much potential as India, and thus, there is a huge investment opportunity in the solar energy sector in India. However, to promote this sector, India has to implement a conducive policy structure according to India's strategic vision and objectives.

For bringing solar energy into the mainstream, the Indian government has taken several initiatives in the past few decades. Currently, the central and state governments are working toward deploying solar power projects in India under various schemes. These schemes mainly include Feed-in-Tariff (FiT), Renewable Purchase Obligation (RPO), long term Power Purchase Agreements (PPAs), Renewable Energy Certificates (REC), Accelerated Depreciation (AD) benefit, and reverse bidding/auctions. Hence, the cost of solar power has decreased substantially. Jawaharlal Nehru National Solar Mission (JNNSM) is one of the several initiatives taken by the Government of India. The mission envisions a gradual shift from conventional energy sources to renewable energy sources. It is a concerted effort by the Government of India to achieve self-reliance and meet the growing energy demands. Electricity is a subject that needs to be addressed by both the center and the states, and thus, the objectives of JNNSM have to be achieved through the combined efforts of both the central and the state governments [16]. Basu [19] had, however, critiqued the emphasis of JNNSM on developing MW-size grid-connected SPV projects instead of focusing on off-grid solar applications. He emphasized that in the Indian context, the smaller off-grid applications were more appropriate, and financial support should be provided to them.

Similarly, Mishra and Sarangi [20] also emphasized that JNNSM was not designed adequately for the development of off-grid solar systems, and the off-grid component of JNNSM focuses only on setting up small-scale power plants in rural areas. The study illustrated a generic organizational framework regarding financial support for off-grid solar systems. However, only the rural application of off-grid solar technologies has been focused on. Mishra and Sarangi [20] stressed that despite a supportive policy environment, multiple challenges obstruct the use of off-grid solar systems. These challenges are related to several aspects like technology, economy, and community participation.

In another study conducted by Sarangi and Mishra [21], the authors concluded that despite several policy initiatives concerning the mainstream off-grid solar sector in India, the problem of energy access persists. The reasons for such a scenario, according to them, include inadequate and inconsistent policies, combined with the lack of an implementable integrated framework for the sector. The study proposed an integrated framework to prioritize economic linkages, policy support, and various technological options related to the sector.

Luthra, Kumar, Garg, and Haleem [22], in their study, showed the increasing energy demand and growing environmental concern in India. According to them, renewable energy technologies have faced several barriers that have affected their rate of adoption. Luthra et al. [22] identified 28 barriers and ranked the major barriers in the Indian context through an extensive literature review. They placed the barriers into seven categories, which included economic and financial, market, awareness and information, technical, ecological and geographical, cultural and behavioral, and political and governmental barriers. However, no solutions or suggestions were provided to overcome those barriers.

Singh [23] collated the responses of government officials and entrepreneurs working in the area of off-grid solar technologies. According to them, the procedure for availing capital subsidies for off-grid applications was very complicated and time-consuming. They mentioned that capital subsidy was good for large-scale grid-connected projects, but for small-scale projects, it was difficult. Some of the entrepreneurs opined that capital subsidies were useful in the beginning when consumers did not have much awareness about the technology, but since solar technology had significantly penetrated the market, subsidies were no longer needed. Some of them even reported delays in the release of capital subsidies by the government which led many of the market players to operate outside the subsidy environment. The study thus focused on the innovative business models for the penetration of off-grid solar systems and emphasized the barriers in the policy regime.

The above-noted review of the literature highlights the need for providing initiatives by the Indian government for off-grid solar technology and the barriers associated with them. The programs and policies initiated by the Indian government for promoting off-grid solar technologies can be more effective if the key barriers can be identified and recommendations can be developed to mitigate those barriers. The vast potential for off-grid SPV and SWH applications of solar energy in India remains largely untapped, and the uptake of these technologies is still limited. Thus, there is a need to analyze the existing policy scenario for off-grid SWH systems for possible improvements.

In this study, we compiled the initiatives of the central and selected state/UT governments regarding their framework and scope in promoting selected off-grid solar technologies in commercial establishments. We also collected information on the perspective of the stakeholders regarding the barriers associated with the implementation and adoption of these government initiatives. Based on the findings, we formulated a framework for better acceptance and implementation of such initiatives.

2. Methodology

The methodology included conducting surveys and interviews of key stakeholders from commercial buildings with off-grid solar installations in selected locations throughout India. This study was conducted in six states/Union Territories (UTs) of India. The states/UTs represented different categories of the total installed solar capacity. Gujarat and Rajasthan were under the high-performing category, Punjab and Haryana were under the medium-performing category, and Delhi and Chandigarh were under the low-performing category. In the commercial buildings sector, both public and private buildings were included. For each selected state/UT, the following stakeholders were identified:

- Government officials responsible for solar policy, both at the level of the Central government and the selected State/UT government
- Owners or managers of commercial buildings with off-grid solar installations
- Channel partners or implementation agencies who serve as a link between the above two groups

In each state/UT, the buildings were selected based on the criteria that the building had either Solar Photovoltaic (SPV) or Solar Water Heating (SWH) system installed under a government incentive. Additionally, these systems were functional for at least one year but less than five years. The minimum duration was selected as one year to make sure that the stakeholders had completed all documentation requirements and were in a position to share their experiences. The maximum period was selected as five years because solar energy policies change often, and the policy requirements for older buildings were different.

Survey questionnaires were used to collect primary data about the programs and incentives offered by the Central and State/UT governments to promote SPV or SWH installations. Separate questionnaires were formulated for each of the stakeholders. In most of the questions, the respondents were asked to rate their answers and give reasons for their responses. All the questionnaires had both open-ended and closed-ended questions. The questionnaires were first shared with experts working in the field of solar energy for their suggestions.

The questionnaire for government officials included questions on the ongoing programs and incentives for promoting SPV/SWH. It included questions related to the objectives of the policies and programs, initiatives offered, other accelerators provided, and impediments faced. They were also asked to provide suggestions to improve the programs.

The questionnaires for building owners/managers and channel partners focused on the awareness of the government initiatives and the available sources of information. It included questions on the accelerators encountered, the barriers faced by them, and their satisfaction level with the government initiatives. The questionnaire for the building owners/managers included additional questions about the role of channel partners in the process. They were also asked to provide suggestions to improve the process.

During the initial stages of data collection, several visits were made to the central government offices dealing with renewable energy to understand the national structure of policy and programs for solar energy, in general, and off-grid SPV and SWH installations, in particular. In these meetings, the secondary data were also collected in the form of government reports, brochures, policy documents, and booklets. Similar interviews were held online with officials of state/UT governments to collect state/UT level secondary data.

All survey questionnaires were administered through personal interviews. The interviews with building owners/managers were mostly held at the building site, and the researchers used this opportunity to also visit the installed SPV/SWH systems. The interviews with channel partners were mostly held in their offices. During these interviews, the channel partners also shared their experiences regarding other projects.

The primary and secondary data were analyzed to identify the barriers and formulate recommendations to overcome the barriers. The data were tabulated and subjected to quantitative analysis. Statistical measures such as the mean and standard deviation were computed. One-way Analysis of Variance (ANOVA) and the post hoc Tukey HSD tests were

conducted when required. The recommendations were provided for each category of stakeholders for executing the program effectively. These recommendations were developed by the researcher, based on the responses of the stakeholders, for overcoming the barriers mentioned, according to the various stages of policy formulation and implementation for off-grid solar technologies.

The permission to conduct the study was granted by the Institutional Ethics Committee, Lady Irwin College, University of Delhi. Confidentiality of information was assured by the researcher at every stage of data collection.

3. Results, Discussion, and Policy Recommendations

3.1 Structure of Government Initiatives for Solar Energy in India

Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India and is involved in research and development, framing national policies, and strengthening the institutional mechanism for new and renewable energy in the country. It has nodal agencies in every state/UT of India to cater to the renewable energy needs of that particular state/UT and implement the policies made by MNRE. Some state/UT governments have formulated policies and programs separate from those of MNRE to further incentivize the renewable energy sector. Figure 2 illustrates the policy framework for renewable energy in India.

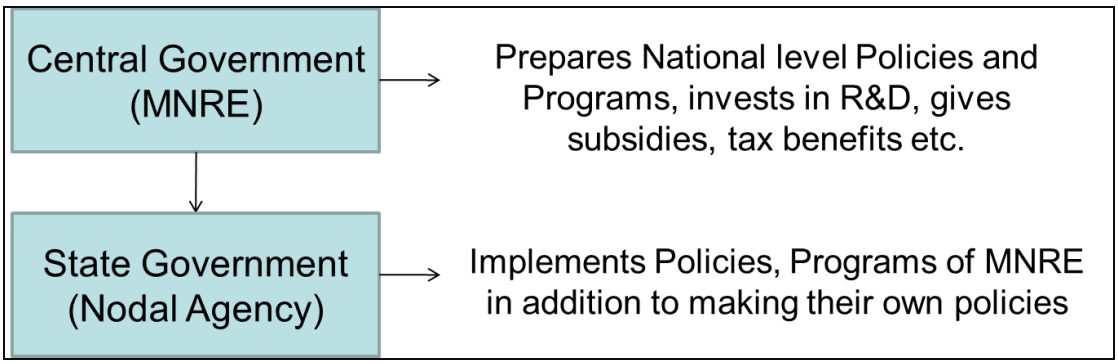

Figure 2 The policy framework for renewable energy in India.

The MNRE programs for off-grid SPV and SWH systems were implemented through several agencies, including the state nodal agencies, channel partners, Solar Energy Corporation of India (SECI), and financial institutions like Indian Renewable Energy Development Agency Limited (IREDA). The four major incentives offered by MNRE included capital subsidies, accelerated depreciation benefits, soft loans, and interest subsidies. Accelerated depreciation benefits of up to 80% were provided in the first year of the installation, leading to tax savings for the beneficiary in the first year. Soft loans were provided by commercial banks and non-banking financial institutions like IREDA. These loans normally had a lower rate of interest than the market, with flexible terms and conditions for repayment. Interest subsidy was another incentive offered by MNRE, wherein loans were given by commercial banks for installing SPV and SWH systems at a much lower rate of interest. Besides the MNRE incentives, a few states also provided additional capital subsidies for off-grid SPV/SWH installations.

3.2 Barriers Reported by Selected Stakeholders While Installing SPV/SWH Systems in the Buildings and Availing Government Incentives

We identified some of the barriers faced by stakeholders concerning the government initiatives for off-grid SPV/SWH in the commercial sector in India. When asked about barriers hindering the installation of SPV/SWH systems in commercial establishments, several barriers were reported by the three selected stakeholders. Government officials felt that the most important barrier was a change in the MNRE policies without consulting the stakeholders, causing undue hardships and delays. Channel partners gave the highest rating to the barrier regarding the delayed release of capital subsidy by MNRE. Building owners/managers stated that limited financial and fiscal incentives from the government were the major barriers and gave it the highest rating as a barrier. Additionally, the most common barrier reported by the selected stakeholders was limited sources of information with unclear, technical, and incomplete information. This implied that although various sources of information were reported by the stakeholders, these sources were not providing enough and easily understandable information regarding SPV/SWH systems and government initiatives for the same. The stakeholders also mentioned that detailed and intensive documentation was required while applying to the government for incentives, which acted as a barrier.

Another barrier closely associated with the abovementioned barrier was that the government websites were not updated regularly. The government officials also reported that although the government was promoting SPV/SWH installations, there was a lack of awareness regarding their benefits and government initiatives for the same. Another barrier reported by the government officials and building owners/managers was the availability of a limited number of channel partners. Building owners/managers also reported unreliable channel partners who failed to meet the timelines for finishing the work. The government officials and the building owners/managers also reported that there were delays in site inspection by the channel partners while preparing the Detailed Project Report (DPR). On the other hand, channel partners highlighted that their role was very important in completing the documentation, which was technical and time-consuming as no support was provided by the state nodal agencies to building owners/managers.

Furthermore, delays were reported in the installation and commissioning of the SPV/SWH systems by the channel partners. Government officials from the state nodal agencies reported that there was no timely release of capital subsidy by MNRE, while the government officials from MNRE stated that delays were made in site inspection by the state nodal agencies. Regarding the problems of soft loans, stakeholders reported that the soft loans were rejected by the banks because of collateral issues.

3.3 Development of a Framework to Improve Implementation and Acceptability of Government Initiatives for Off-grid SPV/SWH Systems in the Commercial Sector

The outcomes of the study were based on the perspectives of selected stakeholders based on the barriers faced in the implementation and adoption of government initiatives for off-grid SPV/SWH systems. The outcomes were used to develop a framework for improving the implementation and acceptability of government initiatives for off-grid SPV/SWH systems in the commercial sector. Figure 3 presents a recommended policy framework for the installation of off-grid SPV/SWH systems in India.

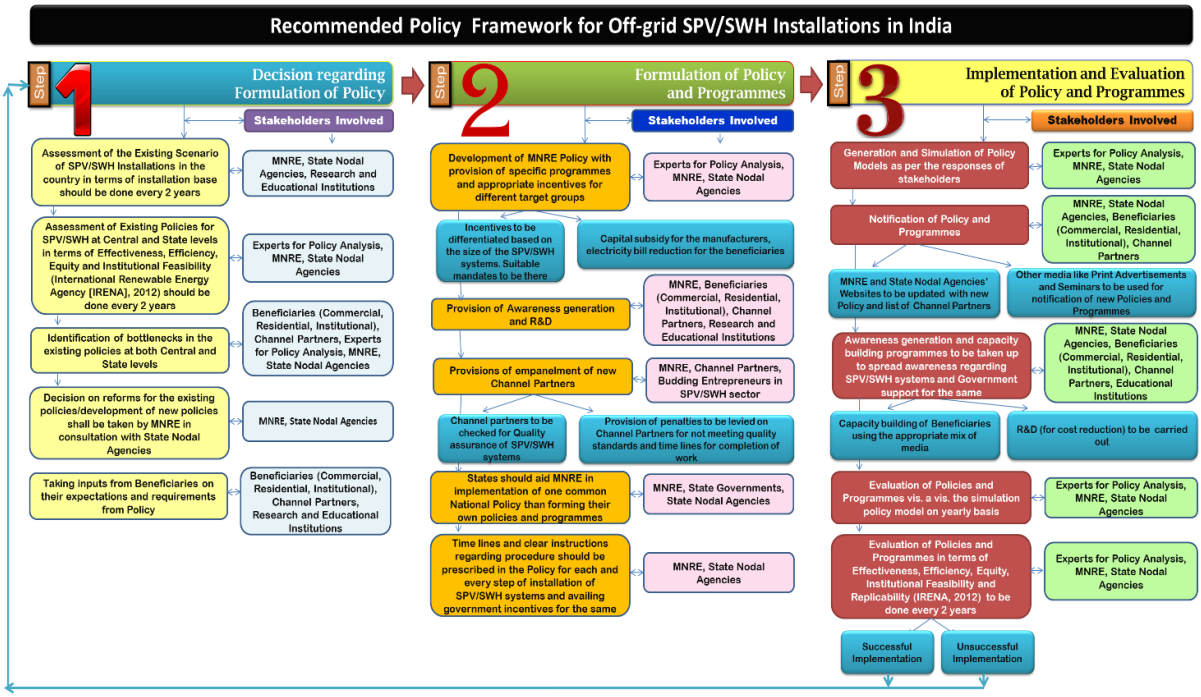

Figure 3 The recommended policy framework for off-grid SPV/SWH installations in the commercial sector in India.

The key feature of the recommended policy framework is the inclusion of stakeholders at every stage to make the process efficient and effective. Suggestions from all stakeholders, which include government officials from State Nodal Agencies, owners of commercial establishments, end-users, and channel partners, should be incorporated into the policy structure. The recommended policy framework has been divided into three steps as follows:

3.3.1 Step 1: Decision Regarding the Formulation of the Policy

First, the existing scenario of the installation base of off-grid SPV/SWH systems needs to be assessed by MNRE, State Nodal Agencies, and various research organizations for making decisions regarding the formulation of the new policy. After the scenario is assessed, the existing policy and programs for the same should be analyzed for any inefficiency. The assessment should be performed every two years to continuously evaluate the scenario. During the assessment, MNRE, State Nodal Agencies, and experts for policy analysis should be engaged.

In the existing policy scenario, bottlenecks have to be identified at the central and state levels. Besides MNRE, State Nodal Agencies, and policy experts, it is essential to consider the views of the beneficiaries to understand the barriers they face concerning the policies and programs. Subsequently, the decision should be taken jointly by MNRE and State Nodal Agencies to reform the current policies.

3.3.2 Step 2: Formulation of Policies and Programs

After assessing the expectations of the beneficiaries, MNRE should frame the central level policy with specific programs and incentives for different target groups. The government incentives like accelerated depreciation benefits, interest subsidies, and soft loans should be

differentiated based on the size of the SPV/SWH systems. Also, the commercial organizations should be given other long-term incentives like reduction in electricity bills through the removal of cross-subsidy surcharge.

Suitable mandatory provisions should be made in the policy. For the mandates, bigger commercial establishments should be targeted first as they have most of the resources like space and money. The SPV/SWH systems should not only be installed but should also be functional. There should be a provision in the policy for penalties to be levied in case the mandatory requirements are not met.

There should be a provision for generating awareness as part of the policy. Separate funds should be allocated for this by MNRE and State Nodal Agencies. Educational and research organizations should be engaged for these purposes. Furthermore, research and development should be included as part of the policy. Separate funds should be allocated for these purposes to reduce the cost of the SPV/SWH systems through technological advancements.

There should be a provision for the empanelment of new channel partners to motivate entrepreneurs to invest in this sector. Moreover, strict monitoring should be performed during installation to assure the quality of the SPV/SWH systems by channel partners, and penalties should be levied on them for not meeting the timelines for completion of the work.

Instead of having separate state-level policies and programs, the states should aid MNRE in the implementation of the common National Policy. The states should assure better governance and efficient submission of the applications to MNRE. Such steps might prevent interstate differences regarding policies and programs and, thus, might help in increasing the installation base of the SPV/SWH systems in all the states. Furthermore, the policy should have clear instructions for the beneficiaries regarding every stage of installation of the SPV/SWH systems and availing government incentives for the same. The policy should also include a timeline to be followed for each step.

3.3.3 Step 3: Implementation and Evaluation of Policies and Programs

Once the policy and programs have been formulated, they have to be notified by MNRE and State Nodal Agencies, using a combination of effective media. The websites of MNRE and State Nodal Agencies should be updated with the new policy and programs, along with the latest list of channel partners. Besides the websites, other media like print media and seminars should be used to spread information about the new policy.

Additionally, programs to generate awareness and build capacity should be conducted by MNRE and State Nodal Agencies to spread large-scale awareness among the beneficiaries regarding the SPV/SWH systems and the policy structure. The government should facilitate an increase in demand through awareness generation campaigns. For this, using the correct set of media is important. Social media needs to be used extensively. The awareness campaigns should be general, discussing the benefits of solar energy, and targeted, discussing specific technical details of off-grid SPV/SWH systems and government support for the same. Need-based training programs should be designed and implemented for different stakeholders such as commercial, residential, agricultural, and industrial.

The policy should be evaluated based on the simulation model every year. Moreover, every two years, the effectiveness, efficiency, institutional feasibility, and replicability of the policy should be evaluated. In case of discrepancies, suitable amendments should be made to the policy structure.

4. Conclusions

With the ambitious target of deploying 100 GW of solar energy by 2022, solar energy has become one of the most important renewable energy sources for India to meet its ever-increasing demand while being responsive to environmental concerns. The country has focused on promoting off-grid solar energy installations as an effective way to achieve the new targets regarding solar energy.

The application of the policy structure was studied at the central and state/UT levels. Several barriers emerged, which the stakeholders faced while availing of government incentives. These barriers need to be addressed to have a better policy regime and a favorable environment for the SPV/SWH installations to flourish. In this study, we identified the bottlenecks in the existing policy structure at the central and state/UT levels. Key policy recommendations were made to improve the policy structure and reduce the barriers faced by the stakeholders.

The findings and recommendations made in the study might make the government initiatives for increasing the off-grid solar installations in the commercial buildings sector more acceptable and easier to implement. The study might be replicated in other sectors to overcome the barriers related to the specific sector. Through concerted efforts, combined with high targets for deploying solar energy, India might become a key player in solar power installations.

Author Contributions

The corresponding author was the PhD scholar, and the second and third authors were the supervisors. Dr. Jain was involved in developing the research design, data collection and analysis, under the supervision of Prof. Mital and Prof. Syal. All the three authors worked on developing the manuscript and its revisions thereof.

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Competing Interests

The authors have declared that no competing interests exist.

References

1. Bureau of Energy Efficiency. ECBC user guide [Internet]. New Delhi: Bureau of Energy Efficiency; 2012. Available from: http://www.emt-india.net/ECBC/ECBC-UserGuide/ECBC-UserGuide.pdf.
2. U.S. Energy Information Administration. EIA projects nearly 50% increase in world energy use by 2050, led by growth in renewables [Internet]. Washington: U.S. Energy Information

Administration; 2021. Available from: https://www.eia.gov/todayinenergy/detail.php?id=49876.
3. Ministry of Statistics and Programme Implementation, Government of India. India GDP annual growth rate [Internet]. New York: Trading Economics; 2020. Available from: http://www.tradingeconomics.com/india/gdp-growth-annual.
4. U.S. Energy Information Administration. EIA analysis explores India's projected energy consumption [Internet]. Washington: U.S. Energy Information Administration; 2019. Available from: https://www.eia.gov/todayinenergy/detail.php?id=42295.
5. International Energy Agency. India energy outlook 2021 [Internet]. Paris: International Energy Agency; 2021. Available from: https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf.
6. International Energy Agency. World Energy Outlook [Internet]. Paris: International Energy Agency; 2019. Available from: https://www.iea.org/reports/world-energy-outlook-2019.
7. Sargsyan G, Bhatia M, Banerjee SG, Raghunathan K, Soni R. Unleashing the potential of renewable energy in India. Washington: The World Bank; 2011.
8. Ministry of New and Renewable Energy, Government of India. Annual report 2018-19 [Internet]. New Delhi: Ministry of New and Renewable Energy; 2019. Available from: https://mnre.gov.in/img/documents/uploads/0ce0bba7b9f24b32aed4d89265d6b067.pdf.
9. Kaur R. Renewable energy-an alternative energy source for India [Internet]. New Delhi: MapsofIndia; 2014. Available from: http://www.mapsofindia.com/my-india/india/use-of-renewable-energy-to-meet-the-energy-shortage-in-india.
10. Ministry of Power, Government of India. Power sector at a glance all India [Internet]. New Delhi: Ministry of Power, Government of India; 2022. Available from: https://powermin.gov.in/en/content/power-sector-glance-all-india.
11. Ministry of Statistics and Programme Implementation, Government of India. Energy statistics India 2022 [Internet]. New Delhi: Ministry of Statistics and Programme Implementation, Government of India; 2022. Available from: https://mospi.gov.in/web/mospi/reports-publications/-/reports/view/templateFive/27201?q=RPCAT.
12. Energy Efficiency & Renewable Energy Management Centre, Government of NCT of Delhi. Solar energy [Internet]. New Delhi: Energy Efficiency & Renewable Energy Management Centre, Government of NCT of Delhi; 2017. Available from: http://web.delhi.gov.in/wps/wcm/connect/doit_eerem/EEREM/Home/Renewable+Energy/.
13. Ministry of New and Renewable Energy, Government of India. Initiatives & achievements [Internet]. New Delhi: Ministry of New and Renewable Energy; 2021. Available from: https://mnre.gov.in/.
14. Ministry of New and Renewable Energy, Government of India. Overview [Internet]. New Delhi: Ministry of New and Renewable Energy; 2022. Available from: https://mnre.gov.in/solar/current-status/#:~:text=India%20is%20endowed%20with%20vast,providing%20huge%20scalability%20in%20India.
15. Silicon Solar. What is the difference between on-grid and off-grid solar power [Internet]? Melbourne: Silicon Solar; 2015. Available from: http://www.siliconsolar.com/on-grid-vs-off-grid/.

16. Ministry of New and Renewable Energy, Government of India. Jawaharlal Nehru national solar mission: Towards building solar India [Internet]. New Delhi: Ministry of New and Renewable Energy. Available from: https://mnre.gov.in/solar/schemes.
17. Central Statistics Office, National Statistical Organisation, Ministry of Statistics and Programme Implementation, Government of India. Energy statistics 2019. New Delhi: Central Statistics Office, National Statistical Organisation, Ministry of Statistics and Programme Implementation, Government of India; 2019. Available from: http://www.indiaenvironmentportal.org.in/files/file/Energy%20Statistics%202019.pdf.
18. Meisen P. Overview of sustainable renewable energy potential of India [Internet]. San Diego: Global Energy Network Institute; 2010. Available from: http://www.geni.org/globalenergy/research/renewable-energy-potential-of-india/Renewable%20Energy%20Potential%20for%20India.pdf.
19. Basu S. India solar policy: Elements casting shadow on harnessing the potential [Internet]. New Delhi: IDFC Policy Group; 2011. Available from: www.idfc.com/pdf/publications/India-Solar-Policy-Element-Casting-Shadow-on-Harnessing-the-Potential.pdf.
20. Mishra A, Sarangi GK. Off-grid energy development in India: An approach towards sustainability. Leicester: Institute of Energy and Sustainable Development, De Montfort University; 2011; Working paper 12.
21. Sarangi GK, Mishra A. Mainstreaming off-grid renewable energy systems in India: An integrated approach. Proceedings of the National Seminar on Energy Security and Management Strategies for Rural Areas, National Institute of Rural Development; 2012 August 27th-28th; Hyderabad, India. Leicester: De Montfort University.
22. Luthra S, Kumar S, Garg D, Haleem A. Barriers to renewable/sustainable energy technologies adoption: Indian perspective. Renew Sust Energ Rev. 2015; 41: 762-776.
23. Singh K. Business innovation and diffusion of off-grid solar technologies in India. Energy Sustain Dev. 2016; 30: 1-13.