Scientific Research Publishing

Energy and Power Engineering, 2023, 15, 191-203
https://www.scirp.org/journal/epe
ISSN Online: 1947-3818
ISSN Print: 1949-243X

Indian Solar Panel Initiatives in Reducing Carbon Dioxide Emissions

Manoj K. Khanna, Sarika Malik, Hemant Kumar, Suruchi*

Ramjas College, University of Delhi, Delhi, India
Email: *suruchi@ramjas.du.ac.in

How to cite this paper: Khanna, M.K., Malik, S., Kumar, H. and Suruchi (2023) Indian Solar Panel Initiatives in Reducing Carbon Dioxide Emissions. *Energy and Power Engineering*, **15**, 191-203.
https://doi.org/10.4236/epe.2023.154009

Received: March 11, 2023
Accepted: April 14, 2023
Published: April 17, 2023

Abstract

Environmental degradation and the emission of greenhouse gases particularly carbon dioxide have expanded problems to human wellness and to the atmosphere. The second-most populated country in the globe, India, is among the primary users of conventional resources, which leads to global warming. The growth rate is anticipated to raise more before 2050, which will cause the brisk industrial expansion and rising energy demand to both increases. In order to reduce carbon emissions and meet energy requirements, many countries use alternate usage of renewable energy particularly solar energy. In this review we aim to study solar panel schemes initiated by India, mainly focusing on National Solar Mission. This study also reviews the present solar installed capacity, solar panel scheme 2022, and initiatives and outcomes of solar panels in residences and offices. This study reviewed that by using solar panel resources, the (MNRE) Ministry of New and Renewable Energy hopes to help the Indian Government reach its purpose of 100 GW solar installed capacity by end of 2022. Despite having an amazing 40 GW of solar power installed capacity till December 2021, India is still far from reaching its own goal of 100 GW by March 2023 as per NSM. In essence, this means that India will need to change a few of its ongoing plans further.

Keywords

Renewable Energy, Solar Panel, Carbon Dioxide Emission, Schemes of the Indian Government, Initiatives

1. Introduction

Energy is crucial to the growth of both businesses and the human community. The requirement for energy is increasing as numerous technological fields develop over time. According to current predictions, the need for fundamental en-

ergy supplies is expected to triple globally in the following decades [1]. While the troubling greenhouse scenario requires that this increasing energy usage be satisfied by pollution-free renewable sources rather than fossil fuels [2] and other resources that presently control the energy sector, these possess two primary problems: they will eventually run out of fuel and emit large amounts of carbon dioxide CO_2 and other harmful greenhouse gases (GHG) [3]. The enormous rise in the usage of conventional resources (such as coal, oil, and natural gas) to fulfil the speed of the rapidly increasing energy requirement is primarily too responsible for the rise in CO_2 emissions in emerging nations like India [4]. Therefore, fossil-fuelled power stations emit a lot of chemicals that are bad for the atmosphere, like sulphur dioxide (SO_2), nitrogen oxides, and carbon dioxide (CO_2). On average, the world's power-producing industry now emits close to 530 g of CO_2 per kWh (gCO_2/kWh) [5]. In terms of energy-related CO_2 emissions, the electricity and heat industries stand for the largest share (42% of global emissions) [6].

According to International Energy Agency (IEA) reports, India's projected rise in net energy consumption can be linked to population growth, which would make India the most inhabited nation by 2050 [7]. According to these estimates, the need for oil and natural gas will rise over the following years. It is predicted that the nation's energy infrastructure would have to treble in scale to meet this sharp increase in energy requirements [8]. In order to attain the aim of having net-zero carbon emissions by 2050, several nations throughout the world are currently concentrating their efforts on the development of renewable energy (RE) by ceasing to utilize conventional energy sources [9]. It is imperative that the effectiveness of sustainable energy processing equipment be strengthened by reducing its downsides in order to meet these objectives [10]. According to the Greenpeace analysis, PV plants will rise nationwide, making up 20% to 40% of all existing renewable power sources in India [11].

India has also turned to renewable resources to suit its energy needs, following the trend seen around the world. There is currently a seismic movement away from traditional resources of power and toward non-conventional ones, such as bioenergy, hydropower, nuclear, wind, and solar energy, in order to tackle the issues of energy deprivation and the negative atmospheric consequences of traditional energy sources. Additionally, there is a rise in the usage of gasoline in a number of industries and residential, commercial, and transportation areas [12].

Sun is the only consistent and dependable power source on Planet. India, a tropical nation, has a lot of solar power obtainable. To meet the growing requirement for energy, solar energy can indeed be used. Research is concentrating extensively on this area because solar power is a non-vanishing, less GHG and CO_2 emission, and a noise-free power source [13] [14]. Solar panels use silicon-oriented technologies to capture sunlight and convert it into electricity. Solar panels are made up of several PV cells. When sunlight strikes the top of a solar panel, it absorbs photons, which are packages of the sun's energy. This excites

the cells and enables them to vibrate, producing green electricity. This is characterized by the Photovoltaic effect, which has been developed by Edmond Becquerel in 1839 [15].

In this study, researchers aim to review different types of solar panels, India's solar installed capacity, and population usage. This study mainly focuses to review Indian schemes introduced for Solar panels like the National Solar Mission, also initiatives and outcomes of Solar panels in residences and offices, and the government solar panel scheme 2022.

2. Types of Solar Panels

Solar energy plant technologies [16] can be widely categorized into

- Solar Photovoltaic (SPV) cell Panels
- Solar Thermal Power Panels

Solar Photovoltaic (SPV) cell Panels works on the principle of photovoltaic effect, through which a photon inhibiting a surface made up of a specific material brings about the liberation of an electron. However, Solar Thermal Power Panel uses the sun's energy to heat a fluid (can be water or other fluid, depending on the particular operation).

The effectiveness of every PV panel varies. Therefore, some types and perhaps especially brand of solar panels are more efficient in terms of converting sunlight into electricity. This is due to the fact that panels' silicon cell types and counts might differ. The price, size, and mass of a solar panel are frequently influenced by its cell count. SPV panel cells are also divided into mono-crystalline silicon (c-Si), poly (or) multi crystalline silicon (c-Si), and thin film [15].

Mono (c-Si) panels are the most established and ancient sort of solar panel. Mono (c-Si) Solar Panels, as the term implies, are composed of on (c-Si) solar cells. Pure silicon is made into bars and sliced into wafers to create these solar cells. The Czochralski methodology is used to make the majority of mono (c-Si) cells [17]. Poly (c-Si) panels are additional c-Si-based technology. When comparing it to mono (c-Si) innovation, the performance rates are reduced. They do not produce as much energy from the sun as Mono (c-Si) panels and do not last a longer period. Since there are several crystalline in each cell, electrons have less flexibility to migrate. However, the manufacturing expenses and silicon wastes created are minimized [18]. For a thin film solar panel, a thin layer of (PV) substance is applied to a glass surface. Thin film panels are thus less expensive yet less productive than c-Si panels. To balance their reduced performance, thin film panels operate superior in low-irradiance circumstances, have more aesthetic alternatives, are more flexible, and are lighter in mass [19]. The solar thermal panel is typically utilized to raise the temperature of the water. It's a basic innovation: solar panels are used on the rooftop to seize sunlight and convert it to heat energy, the energy was then preserved and transformed into solar power [20].

Every solar panel includes advantages and disadvantages; however, PV is vital to decarbonizing power generation. This is crucial in the Indian power envi-

ronment because India is presently the third greatest CO_2 emission contributor (after China and USA). According to research, the CO_2 generated by SPVs over the lifespan of the unit is significantly lower than the generated by conventional energy sources, such as coal. This could also be ascribed to the notion that the majority of emissions of CO_2 comparable from solar panels originate through the production process. Comparing the lifetime emissions of different energy resources in tones of CO_2 equivalence per GWh is evident in **Figure 1**.

In India, significant schemes have been developed over the period as a result of factors like the richness of solar irradiance, the requirement for countryside electrification, the advantages of solar power, and the growth of the solar industry.

3. Indian Solar Panel Scheme-National Solar Mission

The National Solar Mission (NSM) is a project of the Indian administration and state administrations to advance solar energy. Among the numerous initiatives included in the National Action Plan on Climate Change (NAPCC) is the purpose. The NSM aims to make India as a powerhouse in solar power by launching the policy structure for its rapid adoption throughout the nation [21]. This mission was launched by Ex PM Manmohan Singh on January 11, 2010, as the Jawaharlal Nehru National Solar Mission (JNNSM) to meet 20 GW by 2022 [22]. Present PM Narendra Modi later raised this to 100 GW in the Indian Union budget for 2015. In 2018, 4 years before the 2022 timeframe, the initial goal of 20 GW was exceeded (including solely built grid potential) [12].

The NSM is largely responsible for India's large solar energy construction, but various State-level programs also actively encourage the solar installation and the expansion of solar energy capacity. There are three stages to the implementation of India's solar mission:

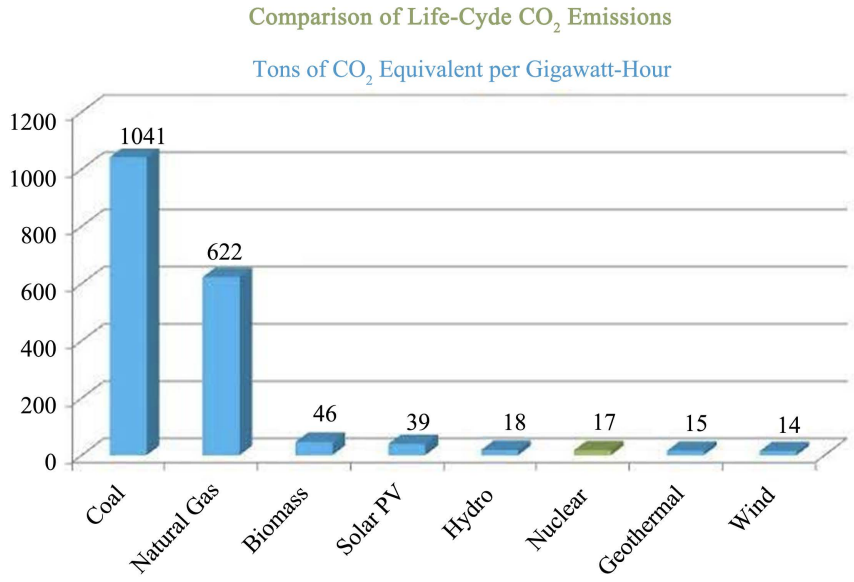

Figure 1. Comparison of emissions.

3.1. Phase-1 NSM

The inaugural stage (Phase-1) of Indian NSM, which covered the years 2010 to 2013, had as its goal the installation of 1000 MW of solar energy capacity. It did this by gathering up producers, financiers, Engineering, Procurement and Commissioning (EPC), and Operational and Maintenance (O&M) contractors to develop a breakthrough solar energy sector. Project funding for solar PV and thermal energy was distributed equally in NSM Phase-1 (50:50). Backward bidding was used to assign Solar Power Project (SPPs) for NSM Phase-Batch-1 and Batch-2 commissioning phases. Phase-1 in batch-1 has seen the commissioning of 26 140 MW PV initiatives and 3200 MW Concentrating Solar Power (CSP) initiatives. The permanent plant power for PV in Batch-2 was 5 - 20 MW. 350 MW of power overall 28 PV initiatives were chosen. In Batch-2, the PV plant tariff ranged from 7.49 to 9.44 Indian rupees per kWh. Within Batch-1, 26 PV initiatives with a total power of 330 MW have indeed been put into operation. The Mumbai and Delhi Industrial Corridor Development Corporation Ltd. have established a 5 MW PV facility as part of the NSM Phase-1 packaging scheme. Due to the packaging plan, 523 MW of PV initiatives and 202.5 MW of CSP initiatives have indeed been launched within Phase 1 [23].

3.2. Migration Scheme

This program was launched in Feb 2010 to permit the transfer of these kinds of initiatives to NSM with the goal of enabling both the swift start-up to NSM and indeed the fast execution of current projects within established stages of execution in various States. Overall, 16 projects overall 84 MW in potential have been sanctioned underneath this plan for prolonged energy contracting by NTPC Vidyut Vitran Nigam (NVVN) at Central Electricity Regulatory Commission (CERC) alerted tax for 2010-2011, *i.e.*, INR 17.91/kWh for SPV and INR 15.31/kWh for CSP. These schemes included 13 PV projects with a potential of 54 MW and 3 CSP schemes with a potential of 30 MW. Underneath this program, 11 SPV projects overall 48 MW and a single CSP project overall 2.5 MW have indeed been put into service [24].

3.3. Rooftop Solar PV Scheme

The Rooftop SPV and Small Solar Power Generation Programme (RPSSGP) standards for SPPs linked to delivery networks below 33 kV were generated by the Ministry of New and Renewable Energy (MNRE), India in June 2010. Encouraging every state of India to proclaim their Solar Energy Policies for grid-based schemes focused on the distributing system and enhancing the tail-end of the network was one of the main goals of RPSSGP. The proposals were submitted to Indian Renewable Energy Development Agency (IREDA) via an internet registration procedure. To establish 98 MW potential initiatives in 12 States, 78 initiatives were chosen. 71 initiatives with a combined potential of 90.8 MW have indeed been linked to the grid in response to this [25].

To safeguard domestic production, NSM Phase-1 also required a domestic product criterion. This regulation required PVs built of c-Si to be purchased regionally by builders; however, Thin Films (TF) innovation did not use this policy because there were not sufficient producers. Researchers claim that this policy was ineffectual because it steered developers toward less expensive TF imports from China, and the US [26].

3.4. Phase 2-NSM

To enable a significant expansion in on-grid solar installation capacity, NSM Phase-2 began in 2013 and lasted until 2017. In NSM Phase-2, PV received more emphasis than CSP (70%) because CSP was not backed among developers throughout Phase-1. In Phase 2, the State Administrations also took over 60 percent of the installed capacity. For phase 2, MNRE has released three draught plans. The initiative seeks to procure 750 MW of on-grid solar power with Viability Gap Funding (VGF) in Batch 1 through a fair backward tendering procedure for SPP builders (no Feed-in Tariff). The VGF, the Solar Energy Corporation of India (SECI) additionally provided a long-term commitment to both acquire produced power from suppliers at a defined amount and distribute it to distributors at a defined amount. The MNRE has suggested a State-based packaging plan for the establishment of 3000 MW SPPs, carried out by NVVN, for Batch 2. Phase-2 proposals included a state-based VGF plan for the construction of 2000 MW SPPs having a 25-year Power Purchase Agreement (PPA) run by SECI [27] [28].

Phase 3 would have represented the thirteenth 5-year scheme (2017-2022).

4. Initiatives and Outcomes of Solar Panel Usages in Residences and Firms

According to an IEA estimate, the energy supplied to residential structures accounts for 10% of global energy consumption and is growing at a pace of 1.5% annually. The residential building market in India, which accounts for 79.9% of all existing homes, uses around 21.98% of all energy (170,034 GWh), making it the 2nd highest energy consumer in the country following the business market [29]. The household sector's average annual energy usage is 0.63 MWh, which results in the 3rd highest CO_2 emissions after China and the United States at 1710.3 million metric tonnes [30].

Today, solar power panels are widely obtainable for use in both homes and offices, with the extra bonus of requiring minimal maintenance. MNRE, the Indian government's key organization for the development of novel RE sources, is promoting the usage of RE in homes and offices through the accompanying initiatives. Solar power might well be made commercially viable through government tax breaks and incentives [31].

The initiative promotes the construction of power-efficient buildings for both residences and offices with passive solar aspects, which take into account the

utilization of solar power for day illumination, and temperature control through optimum orientations, the utilization of suitable resources, entrance, and window dimensions, and layout, shading systems, etc [32]. Although many states have built display buildings, little has changed. But Himachal Pradesh is the initial state in the nation to mandate passive architecture elements in the development of all upcoming buildings, and it has also built a lot of passive solar-designed structures. The Solar House Action Plan of the Himachal Pradesh government, India was managed by the SS Chandel between 1993 and 2009, resulting in the development of a far greater than 200 residence population under this initiative. The functionality and energy-saving capacity of a solar passive structure as demonstrated by the functioning of a solar bank office building in Shimla, India improves energy performance, economic competitiveness, and conservation significantly [33].

A further attempt by MNRE to boost sustainable buildings for both households and offices in India is the 12th 5-Year scheme (2013-2018)'s Green Assessment Integrated Habitat Assessment (GRIHA) rating scale, which offers subsidies for the development of eco-friendly structures. Along with providing subsidies to banking firms to facilitate the implementation of solar plants, MNRE also offers funding aid for the deployment of rooftop solar PV energy supply frameworks, for solar lights, solar cookers, and solar water heaters [34]. As per research by consultancy Bridge to India, residential rooftop solar in India is gradually improving after nearly static yearly development of 100 - 200 MW through the fiscal year 2020 [35].

Indian Government Solar Panel Scheme 2022

By December 2022, the MNRE's grid-linked rooftop solar panel initiative hopes to have installed 4 GW of solar power in homes. The scheme, which is currently in phase 2, gives a 40% incentive for the initial 3 kW of rooftop plant production capacity and a 20% discount up to a 10 kW cap. Electricity supply corporations are responsible for implementing the scheme by the state government [36].

A solar incentive scheme has indeed been in place for a long time under the administration of the Indian government. To motivate households to switch to solar power, a solar panel subsidy is mostly offered. The state-by-state solar subsidy scheme was first created to help the nation reach its goal of implementing 4 GW of solar panels at residential locations by the end of 2022. The COVID-19 emergence caused a pause in events. The home installation deadline has now been raised to December 2024. In addition, PM Narendra Modi has unveiled a national subsidy scheme. On July 30, 2022, a national rooftop solar portal scheme was introduced [37].

The other solar schemes introduced by the Indian government in 2022 include, Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) for agricultural solar and RE usage, the Atal Jyoti Yojana (AJAY) phase 2 scheme was started by the MNRE to create solar-powered street lights in gloomy areas. It is a sub-program of the MNRE, the Government of India's

off-grid and decentralized solar use plan, phase 1 was gone from 2016-2018, while phase 2 started in 2018 and will go till 2022. Likewise, there are many other schemes introduced by the Indian government for solar panels [38].

5. India's Solar Installation Capacity and Population Usage

From Jan to Nov 2021, India's solar installation capacity increased by around 11.1 GW. As per JMK research analysis, this is almost 249% more than the installations made in 2020 [39].

As per information provided by the MNRE, India's overall RE installed capacity as of November 2021 was 104 GW (Shown in **Figure 2**). The major contribution in the RE sector right presently, solar energy accounts for over 47% of the market, trailed by wind power (38%), biopower (10%), and hydropower (5%) [40] [41].

The research states that between January and November 2021, an additional 748 GW solar utility-scale was deployed. Rajasthan installed the most utility-scale solar capacity overall roughly 3615 MW. Rajasthan was trailed by Gujarat (1538 MW), and then UP (674 MW) [42] [43].

From January to November 2021, a total of around 2605 MW of additional capacity was installed in the rooftop solar industry. Gujarat tops the list of regions with an installed capacity of 660 MW, which represents over 25% of all rooftop panel deployments over the course of the investigation (Shown in **Figure 3**). Besides Gujarat, the largest increases in rooftop panel installed capacity include Maharashtra (597 MW), Haryana (266 MW), and Rajasthan (225 MW).

Although installed solar capacity has increased significantly, solar power's share of the nation's electricity supply has not kept up. For example, just 3.6% (50 billion units) of India's overall energy production of 1390 BU in 2019-2020 came from solar energy. Only Gujarat has indeed managed to get through the barriers that are as follows [44]:

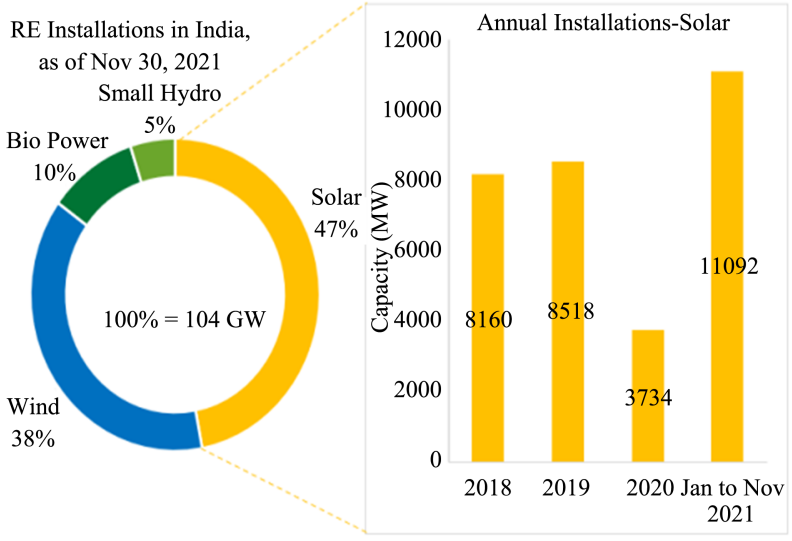

Figure 2. India's solar installation capacity.

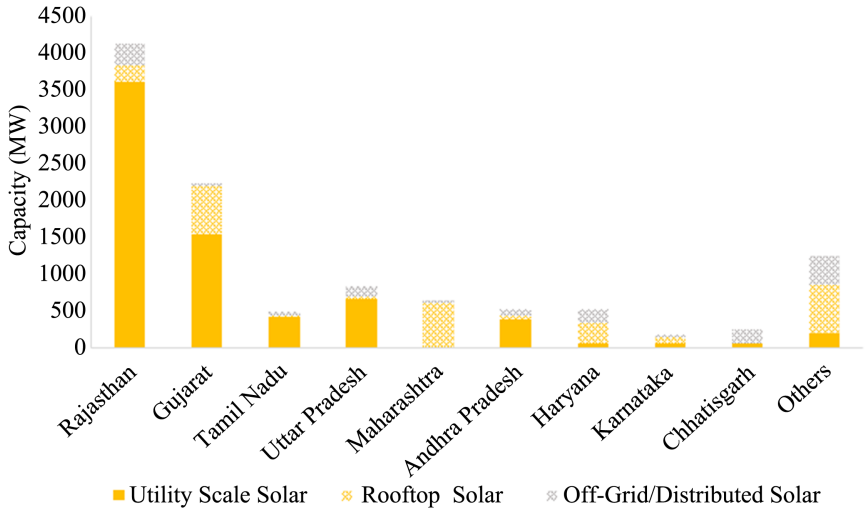

Figure 3. State-wise solar installation capacity.

1) Financial Banner
2) Political and Policy Barriers
3) Institutional and Industrial Barriers
4) Land Availability
5) Research and Development Cost Barriers

This makes solar energy widespread amongst households from all of the governments that provide a government incentive on solar panels. Currently, more than 3 lakh population residences were installed solar and benefited from the incentive.

6. Conclusions

The past few generations have seen a rise in demand globally for alternate, greener methods like a solar panel for instance of producing electricity due to factors such as carbon dioxide emissions, energy prices, and the energy dilemma. India's solar installed capacity is estimated by the National Institute of Solar Energy at 748 GW, presuming that SPV panels will occupy 3% of the unused land region. With NSM as among the main scheme, solar power has assumed a vital position in India's NAPCC. On January 11th, 2010, the NSM was initiated. The Indian government launched the NSM as a significant project to enhance environmental integrity and clear up India's power dearth issues. Also, India will make a significant contribution to the worldwide endeavour to address the concerns of global warming. The project's aim is to make India a powerhouse in solar power by establishing the regulatory framework for its rapid dissemination across the nation. By 2022, the Mission hopes to have 100 GW worth of solar grid energy units installed. This is in line with India's Intended Nationally Determined Contributions (INDCs) to contribute about 40% of total installed capacity for electrical energy from renewable energy like solar energy by 2030 and to decrease the CO_2 emission rate by 33% to 35% from 2005 levels.

The Indian administration has launched a number of initiatives to promote the production of solar energy in the nation, like the Solar Rooftop Initiative, bundling (or) packaging Initiative, and Passive Solar Initiative which have been explained in this review with its outcome. This study examined the growth of solar power in India, in addition to the possibilities and development of present initiatives of solar panels in residences and firms in India to encourage its incorporation into the energy supply. India's solar energy has been thoroughly examined in this report, providing information on its potential, installed capacity, and schemes. Despite having an amazing 40 GW of solar power installed capacity till December 2021, India is still far from reaching its own goal of 100 GW by March 2023 as per NSM. In essence, this means that India will need to change a few of its ongoing plans further.

This review assessment will serve as a helpful roadmap for the government, businesspeople, regional and international funders, stakeholders, regulators, and scientists as they develop and engage in renewable energy initiatives in India and elsewhere in the globe.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Shahsavari, A. and Akbari, M. (2018) Potential of Solar Energy in Developing Countries for Reducing Energy-Related Emissions. *Renewable and Sustainable Energy Reviews*, **90**, 275-291. https://doi.org/10.1016/j.rser.2018.03.065

[2] Lu, Y., Khan, Z.A., Alvarez-Alvarado, M.S., Zhang, Y., Huang, Z. and Imran, M. (2020) A Critical Review of Sustainable Energy Policies for the Promotion of Renewable Energy Sources. *Sustainability*, **12**, Article 5078. https://doi.org/10.3390/su12125078

[3] Koohi-Fayegh, S. and Rosen, M.A. (2020) A Review of Renewable Energy Options, Applications, Facilitating Technologies and Recent Developments. *European Journal of Sustainable Development Research*, **4**, Article No: em0138. https://doi.org/10.29333/ejosdr/8432

[4] Birol, F. (2021) India Energy Outlook 2021. https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf

[5] Heubaum, H. and Biermann, F. (2015) Integrating Global Energy and Climate Governance: The Changing Role of the International Energy Agency. *Energy Policy*, **87**, 229-239. https://doi.org/10.1016/j.enpol.2015.09.009

[6] Rutovitz, J., Dominish, E. and Downes, J. (2015) Calculating Global Energy Sector Jobs. https://opus.lib.uts.edu.au/bitstream/10453/43718/1/Rutovitzetal2015Calculatingglobalenergysectorjobsmethodology.pdf

[7] IEA, I. (2015) India Energy Outlook. US Energy Information. https://www.iea.org/reports/india-energy-outlook-2015

[8] Hussain, A., Arif, S.M. and Aslam, M. (2017) Emerging Renewable and Sustainable

Energy Technologies: State of the Art. *Renewable and Sustainable Energy Reviews*, **71**, 12-28. https://doi.org/10.1016/j.rser.2016.12.033

[9] Owusu, P.A. and Asumadu-Sarkodie, S. (2016) A Review of Renewable Energy Sources, Sustainability Issues and Climate Change Mitigation. *Cogent Engineering*, **3**, Article 1167990. https://doi.org/10.1080/23311916.2016.1167990

[10] Teske, S., Pregger, T., Simon, S. and Naegler, T. (2015) Energy [R]Evolution—A Sustainable World Energy Outlook. https://www.greenpeace.org/static/planet4-canada-stateless/2018/06/Energy-Revolution-2015-Full.pdf

[11] Gulagi, A., Bogdanov, D. and Breyer, C. (2018) The Role of Storage Technologies in Energy Transition Pathways towards Achieving a Fully Sustainable Energy System for India. *Journal of Energy Storage*, **17**, 525-539. https://doi.org/10.1016/j.est.2017.11.012

[12] Hairat, M.K. and Ghosh, S. (2017) 100 GW Solar Power in India by 2022—A Critical Review. *Renewable and Sustainable Energy Reviews*, **73**, 1041-1050. https://doi.org/10.1016/j.rser.2017.02.012

[13] Qazi, A., Hussain, F., Rahim, N.A., Hardaker, G., Alghazzawi, D., Shaban, K. and Haruna, K. (2019) Towards Sustainable Energy: A Systematic Review of Renewable Energy Sources, Technologies, and Public Opinions. *IEEE Access*, **7**, 63837-63851. https://doi.org/10.1109/ACCESS.2019.2906402

[14] Sharma, S., Jain, K.K. and Sharma, A. (2015) Solar Cells: In Research and Applications—A Review. *Materials Sciences and Applications*, **6**, 1145-1155. https://doi.org/10.4236/msa.2015.612113

[15] Degree Solar (2022) The Different Types of Solar Panels. https://www.deegesolar.co.uk/types_of_solar_panels/

[16] Raina, G. and Sinha, S. (2019) Outlook on the Indian Scenario of Solar Energy Strategies: Policies and Challenges. *Energy Strategy Reviews*, **24**, 331-341. https://doi.org/10.1016/j.esr.2019.04.005

[17] Friedrich, J., von Ammon, W. and Müller, G. (2015) 2—Czochralski Growth of Silicon Crystals. In: *Handbook of Crystal Growth*, 2nd Edition, Elsevier, Amsterdam, 45-104. https://doi.org/10.1016/B978-0-444-63303-3.00002-X

[18] Green, M., Hishikawa, Y., Dunlop, E., Levi, D., Hohl-Ebinger, J., Yoshita, M. and Ho-Baillie, A.W.Y. (2018) Solar Cell Efficiency Tables. *Progress in Photovoltaics*, **27**, 3-12. https://doi.org/10.1002/pip.3102

[19] Mesquita, D.D.B., Silva, J.L.D.S., Moreira, H.S., Kitayama, M. and Villalva, M.G. (2019) A Review and Analysis of Technologies Applied in PV Modules. 2019 *IEEE PES Innovative Smart Grid Technologies Conference—Latin America* (*ISGT Latin America*), Gramado, 15-18 September 2019, 1-6. https://doi.org/10.1109/ISGT-LA.2019.8895369

[20] Kuravi, S., Trahan, J., Goswami, D.Y., Rahman, M.M. and Stefanakos, E.K. (2013) Thermal Energy Storage Technologies and Systems for Concentrating Solar Power Plants. *Progress in Energy and Combustion Science*, **39**, 285-319. https://doi.org/10.1016/j.pecs.2013.02.001

[21] Quitzow, R. (2015) Assessing Policy Strategies for the Promotion of Environmental Technologies: A Review of India's National Solar Mission. *Research Policy*, **44**, 233-243. https://doi.org/10.1016/j.respol.2014.09.003

[22] Solangi, K.H., Islam, M.R., Saidur, R., Rahim, N.A. and Fayaz, H. (2011) A Review on Global Solar Energy Policy. *Renewable and Sustainable Energy Reviews*, **15**, 2149-2163. https://doi.org/10.1016/j.rser.2011.01.007

[23] Purohit, I. and Purohit, P. (2018) Performance Assessment of Grid-Interactive Solar Photovoltaic Projects under India's National Solar Mission. *Applied Energy*, **222**, 25-41. https://doi.org/10.1016/j.apenergy.2018.03.135

[24] Kulkarni, T., Hingne, A., Agarwal, V. and Altamirano, J.C. (2022) Sustainable Development Impacts of Renewable Power: Insights from Three Indian States. World Resources Institute, 1-46. https://doi.org/10.46830/wriwp.20.00109

[25] MNRE (2016) Annual Report 2016-17. Ministry of New and Renewable Energy, New Delhi. https://mnre.gov.in/img/documents/uploads/file_f-1608050046985.pdf

[26] Goel, M. (2016) Solar Rooftop in India: Policies, Challenges and Outlook. *Green Energy & Environment*, **1**, 129-137. https://doi.org/10.1016/j.gee.2016.08.003

[27] Yenneti, K. (2016) The Grid-Connected Solar Energy in India: Structures and Challenges. *Energy Strategy Reviews*, **11**, 41-51. https://doi.org/10.1016/j.esr.2016.06.002

[28] Moallemi, E.A., Aye, L., Webb, J.M., de Haan, F.J. and George, B.A. (2017) India's On-Grid Solar Power Development: Historical Transitions, Present Status and Future Driving Forces. *Renewable and Sustainable Energy Reviews*, **69**, 239-247. https://doi.org/10.1016/j.rser.2016.11.032

[29] Franco, S., Mandla, V.R. and Rao, K.R.M. (2017) Urbanization, Energy Consumption and Emissions in the Indian Context a Review. *Renewable and Sustainable Energy Reviews*, **71**, 898-907. https://doi.org/10.1016/j.rser.2016.12.117

[30] Satheedevi, A.G., Sharma, A. and Dhar, M. (2022) How Do the Anthropogenic Factors Affect the Environment in India? Evidence from the Urban Provinces. *Technological Forecasting and Social Change*, **183**, Article 121950. https://doi.org/10.1016/j.techfore.2022.121950

[31] Goswami, A., Phukan, A., Borah, A. and Hazarika, M. (2017) Solar Energy Utilization in Raj Bhawan and Bijulee Bhawan, Guwahati: A Case Study. *ADBU Journal of Engineering Technology*, **6**, Article 6031201. https://journals.dbuniversity.ac.in/ojs/index.php/AJET/article/view/404

[32] Chandel, S.S. and Sarkar, A. (2015) Performance Assessment of a Passive Solar Building for Thermal Comfort and Energy Saving in a Hilly Terrain of India. *Energy and Buildings*, **86**, 873-885. https://doi.org/10.1016/j.enbuild.2014.10.035

[33] Chandel, S.S., Sharma, A. and Marwaha, B.M. (2016) Review of Energy Efficiency Initiatives and Regulations for Residential Buildings in India. *Renewable and Sustainable Energy Reviews*, **54**, 1443-1458. https://doi.org/10.1016/j.rser.2015.10.060

[34] Kochhar, P., Mahal, N., Seth, S. and Singh, M. (2022) Green Rating for Integrated Habitat Assessment—A Green-Building Rating System for Catalysing Climate-Change Mitigation/Adaptation in India. *F*1000*Research*, **11**, 153-182. https://doi.org/10.12688/f1000research.108826.1

[35] Makol, N., Gupta, P., Mital, M. and Syal, M. (2020) Government Initiatives for Solar Home Systems for Rural Electrification in India: Outlook and Challenges. *International Journal of Home Science*, **6**, 32-38. https://www.homesciencejournal.com/archives/2020/vol6issue3/PartA/6-3-10-717.pdf

[36] The Outlook for Residential Rooftop Solar in India (2021) PV Magazine India. https://www.pv-magazine.com/2021/11/30/the-outlook-for-residential-rooftop-solar-in-india/

[37] Rohankar, N., Jain, A.K., Nangia, O.P. and Dwivedi, P. (2016) A Study of Existing Solar Power Policy Framework in India for Viability of the Solar Projects Perspective. *Renewable and Sustainable Energy Reviews*, **56**, 510-518.

https://doi.org/10.1016/j.rser.2015.11.062

[38] Jain, M., Mital, M. and Syal, M. (2022) Solar Energy Policy for Commercial Buildings Sector: Recommendations for the Indian Scenario. *Journal of Energy and Power Technology*, **4**, Article 14. https://doi.org/10.21926/jept.2202014

[39] Gandhi, H.H., Hoex, B. and Hallam, B.J. (2022) Strategic Investment Risks Threatening India's Renewable Energy Ambition. *Energy Strategy Reviews*, **43**, Article 100921. https://doi.org/10.1016/j.esr.2022.100921

[40] Majid, M.A. (2020) Renewable Energy for Sustainable Development in India: Current Status, Future Prospects, Challenges, Employment, and Investment Opportunities. *Energy, Sustainability and Society*, **10**, Article No. 2. https://doi.org/10.1186/s13705-019-0232-1

[41] Gielen, D., Boshell, F., Saygin, D., Bazilian, M.D., Wagner, N. and Gorini, R. (2019) The Role of Renewable Energy in the Global Energy Transformation. *Energy Strategy Reviews*, **24**, 38-50. https://doi.org/10.1016/j.esr.2019.01.006

[42] Singh, U., Rizwan, M., Malik, H. and García Márquez, F.P. (2022) Wind Energy Scenario, Success and Initiatives towards Renewable Energy in India—A Review. *Energies*, **15**, Article 2291. https://doi.org/10.3390/en15062291

[43] Rynska, E. (2022) Review of PV Solar Energy Development 2011-2021 in Central European Countries. *Energies*, **15**, Article 8307. https://doi.org/10.3390/en15218307

[44] Elavarasan, R.M., Shafiullah, G.M., Kumar, N.M. and Padmanaban, S. (2020) A State-of-the-Art Review on the Drive of Renewables in Gujarat, State of India: Present Situation, Barriers and Future Initiatives. *Energies*, **13**, Article 40. https://doi.org/10.3390/en13010040