



E-ISSN: 2664-603X
P-ISSN: 2664-6021
IJPSG 2025; 7(3): 129-135
www.journalofpoliticalscience.com
Received: 20-01-2025
Accepted: 22-02-2025

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India's net-zero targets: Accessing the role of solar energy in its renewable energy mix

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DOI: <https://www.doi.org/10.33545/26646021.2025.v7.i3b.472>

Abstract

India's ambition to gradually lessen its fossil fuel dependency and to accelerate its non-fossil fuel installed capacity to 500 GWs by 2030, and to become net zero by 2070 would not be possible without the development and deployment of the renewable energy resources. To boost its renewable energy sector, the Government of India has been initiating a series of policies and programmes encompassing Solar, Wind, Hydro and Bio-fuels to achieve the above-mentioned targets. India's multi-layered approach to increase renewables in its energy mix and to reduce carbon emissions would be largely met through the wind and solar energy. However, considering the versatility and decentralized output of the solar energy, sizable contribution can be expected from the solar energy in its renewable energy mix. This paper would initially discuss about the role of renewables in India's energy landscape. Further, it would be detailing the transformative steps, and the policies initiated by the Ministry of New and Renewable Energy to develop, deploy and generate solar energy in India. Finally, it would lay a stress on the reforms to be initiated as far as the solar energy policies are concerned to meet its net zero targets.

Keywords: Renewable energy, wind energy, solar energy, energy mix

Introduction

The foundation stone for the progress of new and renewable energy was driven amidst the twin oil shocks in the 1970's. Due to the sudden disruption in the oil supply and the consequent price shocks, made India to realize the importance of self-sufficiency through the alternative energy resources. Furthering its ambitions towards Energy Independent India, Commission for Additional Sources of Energy was established in March 1981, as a constituent unit of the Department of Science and Technology. The newly created Commission for Additional Sources of Energy was endowed with Progressing the research and development in New and Renewable energy technologies along with the formulation and implementation of policies related to the alternative energy sources. However, the commission for Additional Sources of Energy was upgraded into an autonomous and a new independent department under the name of Department of Non-Conventional Energy Sources (DNES) in 1982 to make progressive steps in building the renewable energy infrastructure, apart from accelerating the development of non-conventional energy sources [1].

Added to supply chain disruptions and inflated oil prices in the International Market prices, the progressive consensus over the causes of the climate change and on the possible consequences that the nations would incur over the accelerated usage of Conventional Energy Sources. Realizing the significance of the transition towards non-conventional energy Sources a separate ministry was established in 1992, which was later renamed as the Ministry of New and Renewable Energy in 2006. The ministry of New and Renewable energy has increasingly emphasized the role of non-conventional energy sources in its mission of transition with its five-point formulae:

1. Energy security with the development & deployment of alternative fuels.
2. Increase the share of Renewable and Clean power.
3. Energy Availability and Access: Supplementing the energy needs with alternative fuels.
4. Energy Affordability: through renewable.
5. Energy Equity: Increasing per-capita energy consumption with the global average by 2050 through a sustained and diverse fuel-mix [2].

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In consonance with the efforts of the newly established Ministry, Planning commission in its report in 2006, stressed the need to develop maximum domestic supply options and to also the need to diversify energy destinations. The report also highlighted need to accelerate the renewable energy in the fuel-mix of the country^[3].

The Ministry of New and Renewable Energy in an order to manifest its mission of accelerating the renewable energy, it has established specialized institutions like solar energy centre (SEC) (to serve as a focal point in the development of solar energy) at Gawal Pahari, Haryana and Centre for wind Energy Technology (C-WET) (as a nodal agency for Wind Power) at Chennai, Tamil Nadu. Apart from the specified Centre's focused on solar and wind energy, the ministry also laid a specific emphasis on Bio and synthetic fuels by establishing Sardar Swaran Singh National Institute of Renewable energy (SSS-NIRE) in Kapurthala, Punjab. To make the finances available to the renewable energy sector, the Ministry has also established a Non-Banking financial entity called Indian Renewable Energy Development Agency (IREDA) for providing loans to renewable energy and energy efficiency projects. Apart from this, the Government of India has initiated 100% Foreign Direct Investments in the renewable energy sector under the Build-Own and Operate to make India a global destiny of Clean Development Mechanism^[4].

Further, the Government of India has initiated a number of initiatives to meet its emission targets, including the creation of Solar Energy Parks, RE-Invest 2015, a summit of Global Investors, a huge grid-connected solar Roof-Top programme, allocating Thirty Eight Thousand crores for the Corridor of Green Energy, and increasing cess on clean environment from Rs 50 per tonne to Rs 400 per tonne by an eightfold factor. All of these actions have significantly aided in the Progress of renewable energy sources in the country^[5].

India made it clear to the UNFCCC regarding its Intended Nationally Determined Contribution (INDC), outlining the country's plan of climate action post-2020, in accordance with the set targets to be attained by 2022. In addition to the stated goal of producing 175 GW of renewable energy by 2022, India also set an aim of producing 40% of its installed electric capacity from non-fossil sources by 2030^[6]. In addition, India pledged in its INDC to produce around 2.5 to 3 billion tonnes of carbon sinks and to cut its GDP's greenhouse gas emissions by 32 to 33% below 2005 levels by 2030^[7].

The Ministry of New and Renewable Energy has been actively advancing its new policies and reformulating existing ones in order to meet these goals, such as the Purchase Obligation, the creation of Smart Cities with a minimum of 10% renewable energy, the purchase of solar and wind energy through a tariff-based competitive bidding process, the expansion of tax-free solar bonds, the provision of long-term loans, etc. In order to encourage and support research in the renewable energy targets and ultimately pave the way for achieving intended nationally determined contribution, in 2019 the Ministry of New and Renewable Energy allocated 228 crores for the development of the RE-RTD (Renewable Energy Research and Technology Development) programme^[8].

India due to its concrete efforts made since 1970s has produced 172488.40 Mega Units⁹ of renewable energy until December 2023, with a solar energy contributing nearly 84319.58 Mega Units. India with a set target of achieving

50 per cent of its energy needs by 2030 from the non-fossil fuel resources and its plan towards achieving net-zero targets by 2070 is proceeding slowly but steadily towards the projected targets. This paper will be specifically exploring the programmes and policies for the development and deployment of the solar energy rather than dealing with the wide variety of alternative energy sources. At the end it will access the role that the solar energy would contribute for India's net-zero targets.

Solar Energy

India has a significant potential for Solar energy electricity production because of its location. Depending on location, the average daily solar energy incident over India ranges from 4 to 7 kwh/m², while the annual sunshine hours range from 2300 to 3200^[10]. In February 2023, India's production of renewable energy hit 174.53 GW. With a total contribution of 63.3 GW, solar energy is the main source of this 174.5 GW^[11]. India's energy objectives to meet 50% of its energy needs through renewable energy by 2030 and to reach net negative by 2070 rely heavily on solar energy¹². This section deals with solar policies initiatives, development and deployment in India.

Off-Grid Solar Photovoltaic

On the recommendation of the Indian Institute of Bombay (IITB), the Ministry of New and Renewable Energy approved the purchase of 70 lakh solar-powered study lamps, which will be distributed to students in conjunction with Energy Efficiency Services Limited (EESL) to reduce energy consumption, provide clean energy, and increase public confidence in solar energy. Assam, Bihar, Jharkhand, Odisha, and Uttar Pradesh are the initial five states chosen for the implementation of this plan where the electrification is less than 50%. A total of 1495 blocks are chosen in order to increase the reach of this strategy based on the following factors, such as: 1) Block where the primary source of lighting is kerosene at the household level, and 2) Population that is marginalised. The mission mode of this plan's implementation will last for two years, from January 2017 to December 2018. The following goals has been established for this scheme and are being worked towards:

1. To give students in remote places without electricity sources solar study lamps.
2. To strengthen local communities by deploying solar energy technology.
3. Raise awareness of and trust in the use of solar products in rural areas^[13].

Women are permitted to participate in solar study lamp assembly, distribution, repair, and maintenance in order to address issues with after-distribution services. A total of nearly 1900 entrepreneurs were trained, and solar products shops have been opened. Nearly 7436 women were trained as technicians, and 1769 repair centres were constructed.¹⁴ The Ministry of New and Renewable Energy expanded the scope of this programme in August 2018 under the off-grid and localised solar PV applications programme, addressing local electricity needs by deploying solar street lights, solar study lamps, and solar power packs in rural areas. Additionally, under the PM-KUSUM Scheme, solar-powered agricultural pumps and 2 MW solar power plants are deployed. Up till December 31, 2021, 217 MW of solar PV off-grid power packs/plants have been installed.

The following are some significant Off Grid Solar PV

projects that will be implemented in FY 2021-2022.

- a) In North Eastern States and LWE impacted districts, more than four lakh Solar Powered study lamps are supplied to enrolled students.
- b) Over seventy-nine thousand solar street lights, particularly in the Hill States/UTs and North Eastern States, have been erected.
- c) As part of the Atal Jyoti Yojana: Phase-II, 1.2 lakhs solar street lights are installed by December 31, 2021.
- d) At public service institutions in Kerala, 190 kWp solar off-grid power plants have been installed.
- e) In the state of Odisha, 130 kWp solar off-grid power plants have been erected at public service institutions.
- f) Public service institutions in the state of Bihar now have 105 kWp solar off-grid power plants installed.¹⁵

National Solar Mission

In order to make use of the abundant solar energy resources, the Government of India had initiated a National Solar Mission programme. On January 11, 2010, National Solar Mission was launched to promote environmentally friendly development, while solving India's energy security issues. The National Solar Mission's main goal is to position India as a leader in solar energy by establishing the political framework for its rapid spread throughout the country. By 2022, the Mission targeted 100 GW of grid-connected and off-grid solar power plants in place. Government of India has launched a number of other programmes to promote the production of solar electricity in the country to meet the laid targets, including the Solar Park Scheme, VGF Schemes, CPSU Scheme, Defence Scheme, Canal bank & Canal top Scheme, Bundling Scheme, Grid Connected Solar Rooftop Scheme, etc. As a result of all these efforts, India now ranks fourth globally in terms of the deployment of solar photovoltaic (PV) energy. The overall solar power installation could only reach 61.97 GW by November 2022, falling short of the projected Installation of 38.03 GW despite the government's constant and clear attempts to enhance solar energy Installations.¹⁶

Solar Parks and Ultra Mega Solar Power Projects development Scheme

In 2014, the Ministry of New and Renewable Energy has begun a programme for the Development of Ultra Mega Solar Power Projects to boost the output of solar energy with a preliminary objective of producing 20,000 MW. This programme was upgraded in 2017 with the goal of creating 50 solar parks by 2021-2022, which would produce at least 40,000 MW. Each solar park is expected to have a capacity of at least 500 MW, however if no non-agricultural land is available, this limit is lowered to 20 MW¹⁷. In order to boost this program, the central government began financial support of 25 lakhs for the creation of the detailed project report. In addition, the government will contribute twenty lakhs per megawatt, or Thirty percent of the project's cost. The total sanctioned disbursements up to 2022 under this Scheme is 8100.00 crore rupees¹⁸.

This plan has been successful in hastening the installation of solar power. After receiving bids from 12 states, the ministry has approved 50 solar parks with a total capacity of 37,990 MW. Out of the 50 Solar parks, 11Solar Parks with an aggregate capacity of 8521 MW were already operational and 7 Solar Parks are yet to be completed, which will add more 3985 MW. The Solar Parks and Ultra Mega Solar Power Projects Development scheme has been anticipated to

add more to the existing capacity as it has a timeline up to March 2026¹⁹.

Grid-connected solar power projects by government agencies and CPSUs

The Ministry of New and Renewable Energy established a policy in 2015 to create 1000 MW Solar PV Power projects with Grid integration in order to engage the Central Public Sector Units and other Government Organisations in the production of clean energy. With a budget of 1 billion rupees approved, twelve different public sector units have joined this initiative to manufacture solar energy. The Scheme has been updated for 2019 with a 12,000 MW production objective; the output can be employed internally or sold to interested parties. 8,580 crores are allocated for the Viability Gap Funding throughout the course of four years, from 2019-20 to 2022-2023²⁰.

Setting up of 300 MW Solar PV Power Projects with Grid-integration by Defence Establishments under NSM

The Ministry of New and Renewable Energy agency, with the assistance and support of the Defence Ministry, had instituted a policy in 2015, to install Solar Energy in Defence and Para Military bases, in order to address the issue of transportation and availability of fossil fuels, especially in the hilly and remote regions. Military stations and cantonments have a solar energy potential of roughly 5000 MW and 950 MW in Ordnance Factory Boards. The Ministry of New and Renewable Energy has issued a comprehensive policy guideline in an effort to end this opportunity. The following are the scheme's policy guidelines:

1. A minimum size of 1 MW will be installed in various Ministry of Defence establishments, including paramilitary forces, with a magnitude of 300 MW. The government has also given developers selected by the defence establishments, permission to use the land for their projects, including the construction of their own solar power plants and the sale of any extra energy to distribution firms through leases or other agreements.
2. The projects funded by this scheme must use domestically produced solar cells and modules.
3. The aforementioned Establishments would periodically identify border regions as well as other spots within the nation for the development of solar projects.
4. The following two methods of tendering are acceptable. A) Developer method: In this method, the project is given to the developer, who invests in, owns, and provides energy to the defence establishments. B) EPC Mode: This is used when a project is built by an EPC contractor and the Defence establishment or Paramilitary Forces invest.
5. The Defence organizations/Establishments would be free to own the power projects, which would allow them to either employ an EPC contractor to execute the project on their behalf or a developer to put up the cash and supply power at a set tariff of Rs.5.50 per unit for 25 years (or Rs.4.75 with AD). EPC has been suggested by the MHA, Planning Commission, and MoD.
6. According to the bid, VGF will be given to the solar power project developers. The bidders will be chosen based on their pledge to provide solar energy at the project's minimum VGF rate of Rs. 5.51/KWh for a period of 25-year.

The VGF's top bounds, however, are as follows: Category-I projects are priced at rupees two and half crores per megawatt (MW), or thirty percent of the project cost, whichever is lower; Category-II projects are priced at two crore per megawatt (MW), or 30% of the project cost, whichever is lower; and Category-III projects are priced at Rs. 1.5 crore per megawatt (MW), or 30% of the project cost, whichever is lower. This plan has 241 MW of in-principle approval 181.4 MW of the total capacity, which is to be installed at various defence installations, has already been installed, with the remaining capacity still in the implementation stage ^[21].

Canal Bank and Canal Top Solar Installation

The development of solar PV power plants that are grid-connected is one of the objectives of the National Solar Mission. To this end, the Government of India has suggested a plan to install solar PVs on canal banks and canal tops. This plan's initial goal was to produce 50 MW or more in solar PV installations for canal banks and tops. According to requests from seven states, installation of 44 MW of canal top and 50 MW of canal-bank is in principle approved. The Central Financial Assistance for solar systems was authorised at Rs. 69.0 crores. The Ministry of New and Renewable Energy has given SECI the authority to distribute funds to the organisations running Canal Bank and Canal Top Solar Power generating²². This Scheme although has been closed for new Sanctions in 2019, the commissioning of the total approved capacity of 94 MW had been completed in 2021-22 ^[23].

Energy Efficient Solar/ Green Building Scheme

The issue of energy security can be solved in two ways: switching to renewable energy sources and energy conservation. Since 2009, a programme to develop energy-efficient Solar/Green Buildings has been launched by the Ministry of New and Renewable Energy in order to promote energy conservation. To rate the buildings as part of this project, the Ministry created the "GRIHA rating system" in association with The Energy and Resource Institute (TERI) (Energy M. o., Annual Report, 2016-2017). The total green building percentage is very less that is 5%, compared to other countries. But it is projected that annual growth rate of 20% may be registered between 2021 and 2026 ^[24].

Grid Integrated Solar Roof-top Scheme & Small-Scale SPV Power Plants Programme

Grid Connected Solar Power Programme was launched in 2014 to boost the percentage of renewable energy by utilising wastelands and building rooftops. Through rooftop solar photovoltaic projects, the Ministry hopes to reach a target of 40,000 MW by 2022, ^[25] nonetheless, the timeframe was extended to 2026 ^[26] there are two types of solar rooftop systems. 1) A solar rooftop system with a battery storage facility; and 2) A solar rooftop system that is connected to the grid. In a rooftop or small SPV system that is connected to the grid, the DC power produced by the SPV panel is converted to AC power using a power conditioning unit and fed to the grid via 33 kV/11 kV three phase lines or 440/220 Volt three/single phase lines, depending on the system's capacity and the regulatory framework established for the relevant States ^[27]. Consumers and Discoms in various states have received financial support from the central government. For the special category states, which include the North-eastern states of Sikkim, Uttarakhand,

Himachal Pradesh, Jammu & Kashmir, and Lakshadweep as well as the Andaman & Nicobar Islands, the subsidy under this programme is up to 70%; for the remaining states, it is up to 30% of benchmark cost. Central financial assistance has been extended to the consumers and to the Discoms of various states. The subsidy provided under this scheme is upto 70% to special category states, i.e North-eastern states, Sikkim, Uttarakhand, Himachal Pradesh, Jammu & Kashmir and Lakshadweep, Andaman & Nicobar Islands and to the other states the subsidy has been provided up to 30% of benchmark cost. In the second phase, the amount of financial aid given to states in the general category was lowered to 40% of the benchmark price. According to reports, 1.18 GW of the 3.34 GW total that has been allocated to different states and UTs has already been installed. A total of Rs 1134.47 crores (i.e. Rs 1009.87 crore as CFA and Rs 124.60 as incentives) has been issued to various State and UT DISCOMs for the financial year 2021-22 ^[28].

Atal Jyoti Yojana (AJAY)

This scheme was launched in September 2016 to supply Solar Street Lights (SSLs) in rural, semi-urban, and urban areas in the states of Bihar, Assam, Jharkhand, Uttar Pradesh, and Odisha, where electrification of households is less than fifty percent. By 2018, each of the legislative districts in the aforementioned states had been installed with 2000 SSLs. Ministry of New and Renewable Energy along with the MPLADS fund of the Member of Parliament will split the cost 75:25. Energy Efficiency Services Limited (EESL) was designated as the nodal organisation responsible for carrying out this goal. By the end of March 2018, 96 constituencies in these five states had nearly 1.45 lakh solar street lights installed. The second phase of the project was launched in December 2018 with the goal of extending the use of the Solar Street Lights to other hilly states like Jammu & Kashmir, Himachal Pradesh, Uttarakhand, North-eastern States, and Islands. The targeted SSLs to be deployed were 3, 04,500 over the course of a year.²⁹ However, this programme was ended in April 2020 when the government decided to halt MPLADS for the following two years. However, up until March 31, 2020, the district administration placed orders for the installation of 1.48 lakh solar street lights, however by December 2021, 1,23,050 SSLs had been erected in total ^[30].

Green Energy Corridor

Government of India has launched a project to create a green energy corridor to lower the cost of renewable energy and use the abundant renewable resources present in the states of Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, and Tamil Nadu. These states are the focus of the Green Energy Corridor's development as they will be hosting large-scale renewable energy projects with expected investments of 10,141.68 crores. The Cabinet Committee on Economic Affairs (CCEA) has approved an estimated budget of 4056.67 crores from the National Clean Energy Fund (NCEF) in order to establish Intra-State Transmission systems to advance the ambitious targets and to facilitate the flow of clean energy during the Financial Year 2015-16 ^[31].

With an installation of over 9700 circuit and a transformation capacity of approximately 22600 Mega Volt Ampere throughout the aforementioned states, this plan proposes to create grid sub-stations at various voltage levels.

The transmission of the renewable energy generated in these states to load centres will be aided by the ISTS system. The first phase of the Green Energy Corridor was successfully completed by June 2022. At the end of the first phase about Rs 2,151 crores have been distributed to various states, which has an overall capacity of about 15268 MVA and a length of about 8468 ckm. The Green Energy Corridor's second phase, which was initiated in January 2022, aims to evacuate 20 GW of renewable energy from load centres as well as double the capacity of production and transmission lines. The estimated cost of the second phase is 12,031.33 crores, and it is anticipated to be finished by March 2026 [32].

Grid Connected Solar Power

Solar electricity is one of the fastest growing renewable energy industries in India. The establishment of 280 GW of solar energy by 2030 is the target production that the Indian government is pushing for. The Ministry of New and Renewable Energy launched the numerous programmes described above in order to meet these goals, and as a result, it has reached its overall goal of 61.97 GW, which comprises 52 GW from ground-mounted solar projects, 7.82 GW from rooftop solar projects, and 2.09 GW from off-grid solar projects. India ranks fourth in the world for its deployment capacity as a result of its various initiatives. In this section, a thorough examination of India's annual growth in grid-connected solar power was reported to be 11.35 MW overall in 2010 after being increased by 8.54 MW during the fiscal year. However, the next fiscal year the amount of solar energy that was connected to the grid had tripled, reaching to 24.58 MW, bringing the total contribution to 35.93 MW. With 896.37 MW, grid-interactive solar power had a significant increase during the 2011-12 fiscal year, bringing the total capacity to 932.30 MW. However, the capacity added in the following fiscal year (i.e., 2012-2013) decreased somewhat to 752.16 MW. By 2012-2013, this boosted total grid-interactive solar power production to 1684.46 MW. The entire installed capacity is estimated to be 947.46 MW in the following fiscal year, 2013-2014, bringing the total Grid-interactive solar power production to 2631.93 MW. Up until the fiscal year 2017-18, there was a general trend of rising grid-connected solar power generation. The cumulative grid-connected solar power capacity increased to 21651.48 MW for the fiscal year 2017-18, thanks to an addition of 9362.63 MW. However, the installed Grid linked Solar Power fell to 6529.20 MW, 6447.13 MW, and 5457.54 MW during the following three fiscal years from 2018 to 2021. When compared to 2017-18, the 2018-19 fiscal years had registered a decline in its capacity addition, which is measured at 2833.43 MW. The decline for the following fiscal year (2019-20) is 82.07 MW less than it was in 2018-19. Due to the pandemic, the same pattern has persisted for the upcoming fiscal year that is 2020-2021, with a recorded Grid-connected solar power of 5457.54 MW [33].

Generation based Incentive Scheme

The Ministry of New and Renewable Energy had put forth a plan to encourage the production of high efficiency Solar PV modules in order to further its National Ambitions. The "National Programme on High Efficiency Solar PV Modules" is the name of this programme. The budget for this programme, which was started on April 28, 2021, was

Rs. 4500 crores. This effort seeks to manufacture Solar PV modules at a scale of Giga Watts (GW).

The basic objectives of this programme are

1. To create solar PV modules with a high level of efficiency.
2. Creating advanced technology by producing high-efficiency modules.
3. To create integrated plants for greater quality assurance and competitiveness.
4. Establishing a method for obtaining resources locally to make solar PV modules.
5. Increasing employment opportunities and ensuring technological self-sufficiency.

Implementing agency IREDA chose three candidates with a PLI of 4455 crores for the establishment of 8,738 MW of fully connected solar module manufacturing units in accordance with the Ministry's directives. PLI are given to the chosen manufacturers for at least five years following the date of commissioning, and they are expected to begin production within three years [34].

Conclusion

India being one of the fastest developing countries in the world needs an uninterrupted and continuous flow of energy either through conventional or non-conventional sources. Globally, as the conventional sources of energy are shrinking fast and the import dependency has been accelerating day by day. This problem needs a multi-layered policy approach to overcome wide variety of problems faced by the accelerated utilization of fossil-fuels. The Government of India has initiated the process of transition from the mid-1970s. Since then India has been making slow but steady progress in the development and the deployment of the solar energy resources across the country to become the third largest producer of solar energy in the world. Introducing various policies like National Solar Mission, Production linked incentives, Atal Jyoti Yojana etc had pushed India to produce nearly 12.78 GW of Solar energy by the end of March 2023. In order to boost its solar investments, the Government of India has opened the gates for the 100-% Foreign Direct Investment in 2007, on the model of Build-Own and Operate, further, to boost research and technology related to the renewable energy sources, an initiative was taken in the last financial year with a budgetary allocation of 228 crores. Though the Government has been working for the reduction of its energy dependency, there are certain problems faced by the solar energy sector in India, they are grid-integration problems, to produce reliable and affordable solar energy to provide it to its people and at the same time to make it's profitable to the DISCOMs, severe regulatory procedures, red tapism etc. Overcoming these problems should be the top priority of the government to make her as the global leader in the renewable energy sector. Despite these problems India today stands as a self-sufficient producer of solar panels, further it has exported the solar panels worth of \$1.03 billion in 2022-23. This proves that India can not only lead in the generation of solar energy but it may in the near future be able to emerge as one of the major exporters of solar modules. If this pace of solar energy production is continued, India would reach its stipulated targets of net-zero. In reaching its stipulated targets, solar energy is going to play a major role.

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