Volume 15 • Issue 3 • April 2025

नवीन एवं
नवीकरणीय ऊर्जा मंत्रालय
MINISTRY OF
NEW AND
RENEWABLE ENERGY

सत्यमेव जयते

Renewable Energy Akshay Urja

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PM Surya Ghar Muft Bijli Yojana

"The scheme will lead to more income, lesser power bills and employment generation for people."
- Narendra Modi, Prime Minister

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- Up to ₹78000 subsidy
- Loan at lower interest rates
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Akshay Urja
Renewable Energy

Volume 15 | Issue 3 | April 2025

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EDITORIAL OFFICE
Ministry of New and Renewable Energy
Atal Akshaya Urja Bhawan
Pragati Vihar, New Delhi 110 003
Tel. 011-20849145

PRODUCED BY
TERI, Darbari Seth Block
India Habitat Centre
Lodhi Road, New Delhi – 110 003
Email: tpsankar@teri.res.in

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Ministry of New and Renewable Energy
Atal Akshaya Urja Bhawan
Pragati Vihar, New Delhi 110 003
Tel. 011-20849145 | Email: akshayurja@nic.in

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From the Editor's Desk...

Dear readers,

Welcome to the April 2025 issue of Akshay Urja! This marks the first issue of the new financial year, 2025/26. While the numbers for the month of March 2025 are trickling in, we are quietly confident about surpassing the previous financial year's RE achievement. As of February 2025, the country's renewable energy installed capacity has reached approximately 223 GW, nearly half of the 500 GW target set for 2030.

Geothermal energy has long been recognized as a promising renewable resource. With an estimated potential of 10 GW from around 350 hot springs across the country, it is gaining increasing attention. The successful demonstration of the first indigenous geothermal power plant of 5-kW capacity seems to have ignited a lot of interest among RE stakeholders and investors. The cover story of this issue opens it up for you to an extent.

Artificial intelligence (AI) is the talk of the town and is sneaking into the RE sector also. The story on how AI can potentially benefit the biomass energy sector is a must-read.

Tapping the potential of Agri-PV is gaining traction in the country. There is a story that discusses the nitty-gritty of the White Paper being published on Agri-PV, including the advantages and challenges in the implementation of Agri-PV. The article on this topic outlines the current state of ocean energy technologies, their potential, and the initiatives by MNRE to tap this energy source.

India has been investing in the R&D of fuel cells for some time now. Among fuel cells, the low temperature polymer electrolyte membrane fuel cell (LTPEM-FC) technology is the leading one when it comes to deployment in light and heavy duty vehicles. The Centre for Fuel Cell Technology (Advanced Research Centre International) of IITM, with support from the R&D scheme of MNRE, has set up a pilot line for manufacturing automated components of PEMFC/stack fabrication. This is a significant development towards self-reliance in PEMFC and the story on it captures it well.

As we know, the PM Surya Ghar Yojna has been a successful scheme, poised to transform energy production and consumption in the residential sector. To give the scheme even more momentum, the Council on Energy, Environment, and Water (CEEW) has proposed ways to enhance the financial support system. Hope the RE financing ecosystem pays attention to this story.

The establishment of a state-of-the-art facility at CSIR-NPL under the R&D scheme of MNRE for calibrating solar PV cells is going to be a gamechanger for the development of India's PV market. This in-house world-class facility is expected to save time and foreign exchange reserves considerably in the coming days.

Hope you like the stories of this issue. I invite readers of Akshay Urja to share your stories on technology and innovations, along with your insights on future developments in the renewable energy sector.

Best wishes

Arun K Tripathi

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RENEWABLE ENERGY NEWS

PM Surya Ghar: Muft Bijli Yojana Crosses Milestone of 10 Lakh Installations

Ministry of New and Renewable Energ, 11 March 2025

PM Surya Ghar: Muft Bijli Yojana (PMSGMBY), the world's largest domestic rooftop solar initiative, has achieved a significant milestone by completing 10.09 lakh installations across the country as of 10th March 2025. This ambitious scheme, launched by Prime Minister Shri Narendra Modi on 13th February 2024, aims to provide free electricity through rooftop solar systems to 1 crore residential households and reduce dependence on conventional power sources while enabling citizens to become energy producers. The scheme enables every household to contribute to climate change mitigation by reducing carbon emissions equivalent to planting 100 trees.

Empowering Households with Subsidies and Incentives

The scheme, implemented by the Ministry of New and Renewable Energy (MNRE) has received 47.3 lakh applications. 6.13 lakh beneficiaries have successfully received subsidies, amounting to ₹ 4,770 crore. With a fully automated application, vendor selection and subsidy redeem process through www.pmsuryaghar.gov.in subsidies get credited to applicants' bank accounts within 15 days.

Under Prime Minister Shri Narendra Modi's leadership, a key feature of the PM Surya Ghar: Muft Bijli Yojana is the provision of collateral-free loans through 12 Public Sector Banks (PSBs) at a subsidized interest rate of 6.75% for loans up to Rs. 2 lakhs, making rooftop solar installations more accessible to the masses. With the easy loan facility, a 3 KW rooftop solar system could be installed with an investment as low as ₹15,000/- giving returns up to ₹15 lakh in 25 years. Loan application process is also fully automated and online. So far, 3.10 lakh loan applications have been received, with 1.58 lakh loans sanctioned and 1.28 lakh disbursed, ensuring wider accessibility for potential beneficiaries. Beneficiaries receive subsidy of upto ₹78000 for upto 3KW rooftop solar system, significantly reducing installation costs.

Remarkable Progress Across Several States

The scheme has seen remarkable progress across several states. Notably, Chandigarh and Daman & Diu have achieved 100% of their government building rooftop solar targets, leading the nation in clean energy adoption. States like Rajasthan, Maharashtra, Gujarat, and Tamil Nadu are also performing exceptionally well, contributing significantly to the overall installation figures. The Government is actively monitoring the progress across all states to ensure the smooth and timely execution of the scheme, with the goal of reaching 1 crore households by 2026-27.

https://mnre.gov.in

Rajasthan's new land registration law to increase costs and delay renewable energy projects, experts warn

The Economic Times, 24 March 2025

Renewable energy projects in Rajasthan, India's leading solar state, are expected to become more expensive and face delays due to a recent amendment to the state's land registration laws, industry experts said. The Rajasthan government has made it compulsory for companies to pay stamp duty when signing an agreement for sale or leasing land for solar projects, as both types of agreements must now be registered. New renewable energy projects in Rajasthan would see at least 8%-10% increase in land expenses due to registration charges and stamp duties. Land expenses account for nearly one-fifth of overall project costs.

https://economictimes.indiatimes.com/industry/renewables/rajasthans-new-land-registration-law-to-increase-costs-and-delay-renewable-energy-projects-experts-warn/articleshow/119429222.cms

RECORD-BREAKING ANNUAL GROWTH IN RENEWABLE POWER CAPACITY

IRENA, 26 March 2025

International Renewable Energy Agency (IRENA) has issued the Renewable Capacity Statistics 2025, indicating a significant rise in renewable power capacity in 2024, totaling 4,448 gigawatts (GW). The 585 GW increase last year is a 92.5% proportion of the overall capacity expansion, marking a record annual growth rate of 15.1%. Despite 2024 representing a significant milestone in renewable energy capacity and expansion, advancements remain inadequate to meet the 11.2 terawatts required to achieve the global objective of tripling installed renewable energy capacity by 2030. To achieve this objective, renewable capacity must increase by 16.6% each year until 2030. Furthermore, advancements once more indicate considerable spatial differences. Similar to prior years, the majority of the increase transpired in Asia, with China accounting for about 64% of the global new capacity, whereas Central America and the Caribbean contributed a mere 3.2%. In 2024, the G7 and G20 nations represented 14.3% and 90.3% of newly installed capacity, respectively.

Solar: The number of solar photovoltaics increased by 451.9 GW last year. 278 GW of the total expansion was contributed by China alone, with India following at 24.5 GW.

The capacity of **hydropower** (excluding pumped storage hydropower) reached 1,283 GW, indicating a significant increase from 2023, primarily due to China's contributions. Nepal, Indonesia, and Ethiopia Pakistan, Tanzania, and Vietnam each contributed over 0.5 GW.

Wind: The expansion of wind energy experienced a minor decline, resulting in a total capacity of 1,133 GW by the conclusion of 2024. China and the United States (US) once again dominated expansion.

Bioenergy: expansion resumed in 2024, with a 4.6 GW increase in capacity, as opposed to a 3.0 GW increase in 2023. China and France were the primary drivers of growth, each contributing 1.3 GW of new capacity.

Geothermal energy increased by 0.4 GW in total, with New Zealand taking the lead, followed by Indonesia, Turkey, and the United States.

In the **off-grid electricity sector** (excluding Eurasia, Europe, and North America), the capacity expansion nearly tripled, increasing by 1.7 GW to reach 14.3 GW. Off-grid solar energy was the primary driver of growth, with a total of 6.3 GW by 2024.

https://www.irena.org/News/pressreleases/2025/Mar/Record-Breaking-Annual-Growth-in-Renewable-Power-Capacity

PILOT PROJECTS ON HYDROGEN FUELLED BUSES AND TRUCKS LAUNCHED UNDER THE NATIONAL GREEN HYDROGEN MISSION

Ministry of New and Renewable Energy, 3 March 2025

As part of the National Green Hydrogen Mission, the Government has initiated five pilot projects for using Hydrogen in buses and trucks. Earlier the Ministry of New and Renewable Energy had issued guidelines for implementing Pilot projects in the Transport Sector under this Mission.

Accordingly, the proposals were invited for different types of hydrogen-based vehicles, routes, and hydrogen refueling stations. After detailed scrutiny, the Ministry of New and Renewable Energy has sanctioned five pilot projects consisting total of 37 vehicles (buses and trucks), and 9 hydrogen refueling stations. The vehicles that will be deployed for the trial include 15 hydrogen fuel cell-based vehicles and 22 hydrogen internal combustion engine-based vehicles. These vehicles will run on 10 different routes across the country viz., Greater Noida – Delhi – Agra, Bhubaneshwar – Konark – Puri, Ahmedabad – Vadodara – Surat, Sahibabad – Faridabad – Delhi, Pune – Mumbai, Jamshedpur – Kalinga Nagar, Thiruvananthapuram – Kochi, Kochi – Edappally, Jamnagar – Ahmedabad, and NH-16 Visakhapatnam – Bayyavaram. The above projects are awarded to major companies like TATA Motors Ltd, Reliance Industries Limited, NTPC, ANERT, Ashok Leyland, HPCL, BPCL, and IOCL.

The total financial support for selected projects made available will be around Rs. 208 Crore from the Government of India. These pilot projects are likely to be commissioned in the next 18-24 months, paving the way to the scaleup of such technologies in India.

https://mnre.gov.in

MERC GIVES APPROVAL FOR MSEDCL TO PROCURE OVER 7000 MW SOLAR ENERGY FOR FARM LANDS

The Times of India, 16 March 2025

The Maharashtra Electricity Regulatory Commission (MERC) has accorded its approval for MSEDCL to procure over 7000 MW electricity on long term basis at low tariff of Rs 2.82 to Rs 3.10 per unit from solar generators. This is being done as part of Mukhyamantri Saur Krushi Vahini Yojana 2.0 (MSKVY 2.0), under which agricultural feeders are proposed to be solarised by December-2025. MSEDC sources said the state power utility will be signing power purchase agreements with successful bidders for the solar projects soon. MSEDCL managing director Mr Lokesh Chandra said Maharashtra is first state to shift agriculture to solar and this is world's largest distributed RE project for farm lands. With the 7000 MW procurement, the state will totally procure 16000 MW, with the permissions for 9000 MW procurement given in the past.

https://timesofindia.indiatimes.com/city/mumbai/merc-gives-approval-for-msedcl-to-procure-over-7000-mw-solar-energy-for-farm-lands/articleshowprint/119084151.cms

INDO-GERMAN PROJECT TO MAKE SIRCILLA A SOLAR POWER HUB

Deccan Herald, 20 March 2025

In a groundbreaking development, Germany's International Agriculture Cooperation (IAK) Agrar Consulting GmbH has partnered with Telangana's Cooperative Electric Supply Society (CESS) to transform Sircilla into a hub for renewable energy in Rajanna Sircilla district. During a meeting with agriculture and cooperation minister Tummala Nageswara Rao, IAK chief Mr Sven Gelhaar outlined ambitious plans to transition CESS into a solar power centre. The initiative will decentralise energy production by establishing Renewable Energy Cooperatives (RECs), enabling local citizens to actively participate in generating solar energy. The project aims to convert over 2,53,500 existing consumers into solar power producers, targeting an 80 per cent energy self-sufficiency for CESS. This strategic shift is expected to significantly reduce reliance on traditional power sources and lower Carbon Dioxide (CO_2) emissions by approximately 7,05,000 tons annually.

https://www.deccanchronicle.com/southern-states/telangana/indo-german-project-to-make-sircilla-a-solar-power-hub-1868054

UNION MINISTER SHRI PRALHAD JOSHI INAUGURATES A 5.4 GW HIGH-TECH PLANT AT CHIKHLI IN GUJARAT

Ministry of New and Renewable Energy, 29 March 2025

Shri Pralhad Joshi, the Union Minister of New and Renewable Energy, inaugurated the state-of-the-art 5.4 GW solar cell gigafactory/manufacturing facility of Warree Energy at Chikhali in Gujarat. As India's largest advanced solar cell manufacturing plant, this milestone marks a significant move towards bolstering the domestic solar supply chain and reducing reliance on imports. Additionally, it positions India at the forefront of the global solar energy value chain, advancing the country's role as a net exporter and key enabler in the ecosystem.

RBI REVISES PRIORITY SECTOR LENDING GUIDELINES, INCREASES LOAN LIMITS FOR HOUSING, RENEWABLE ENERGY

The Reserve Bank of India (RBI) issued revised guidelines for Priority Sector Lending (PSL) aimed at improving the targeting of bank credit to key sectors of the economy. The updated norms will come into effect from April 1, 2025. The RBI stated that the revised guidelines are designed to better direct bank credit to priority sectors, enhancing the coverage and effectiveness of PSL. Key changes in the revised norms include higher loan limits for housing loans, expanding eligibility for renewable energy-related loans, and adjusting the overall PSL target for urban cooperative banks (UCBs) to 60% of Adjusted Net Bank Credit (ANBC) or Credit Equivalent of Off-Balance Sheet Exposures (CEOBSE), whichever is higher. On renewable energy, bank loans for renewable energy-based power generators and public utilities up to Rs 35 crore will be eligible for PSL classification. Additionally, loans up to Rs 10 lakh per borrower for individual households related to renewable energy projects will also be eligible.

MNRE ANNOUNCES

GUIDELINES

FOR "DESIGN SPECIFICATIONS, PERFORMANCE GUIDELINES AND TESTING PROCEDURE FOR SOLAR COLD STORAGE WITH THERMAL ENERGY STORAGE BACKUP"

FEBRUARY 2025

This document provides comprehensive guidelines on the design, performance, and testing standards for Solar Cold Storage systems equipped with Thermal Energy Storage (TES) backup. These systems operate primarily on solar photovoltaic (PV) energy, offering a sustainable solution for preserving agricultural, fish, dairy, and pharmaceutical products. By ensuring consistent cold storage and reducing reliance on grid electricity or diesel generators, they address critical challenges in post-harvest management. The systems use solar energy to power refrigeration during sunshine hours while TES stores cooling energy to maintain operations during non-solar periods. Designed for off-grid applications, they include provisions for grid connectivity during extended cloudy conditions. The guidelines cover systems in capacities of 2 MT, 5 MT, 10 MT, and 20 MT, with temperature ranges from -5°C to 4°C. Cold rooms are insulated with polyurethane foam (PUF) for efficiency and equipped with essential safety features and remote monitoring systems. TES utilizes phase change materials (PCMs), which reduce long-term costs through efficient energy storage and extended operational life.

Performance requirements specify that systems must support daily precooling of 10% of the total storage capacity for two days, ensuring cold storage autonomy. Solar PV panels and TES deliver high efficiency, reinforced by robust design standards for durability and safety. Testing procedures outlined in the document provide clear protocols for measuring cold storage performance, TES capacity, and solar system efficiency, including autonomy tests to evaluate temperature maintenance and system performance under varying conditions.

The adoption of these systems significantly reduces post-harvest losses, enhances the incomes of small-scale farmers, and supports sustainability by minimizing greenhouse gas emissions. To ensure effective operation, comprehensive manuals are provided, detailing system components, safety precautions, troubleshooting, and maintenance procedures. Additionally, a five-year maintenance guarantee ensures long-term reliability and system performance. These guidelines form a crucial step in promoting renewable energy applications in the cold storage sector, combining sustainability, efficiency, and economic benefits.

Over 1400 solar cold storage systems have been installed in the country, so far. These guidelines will act as guidance to Ministry of Agriculture and concerned state government departments who are installing solar cold storage. It will help in preparing bid documents for solar cold storage.

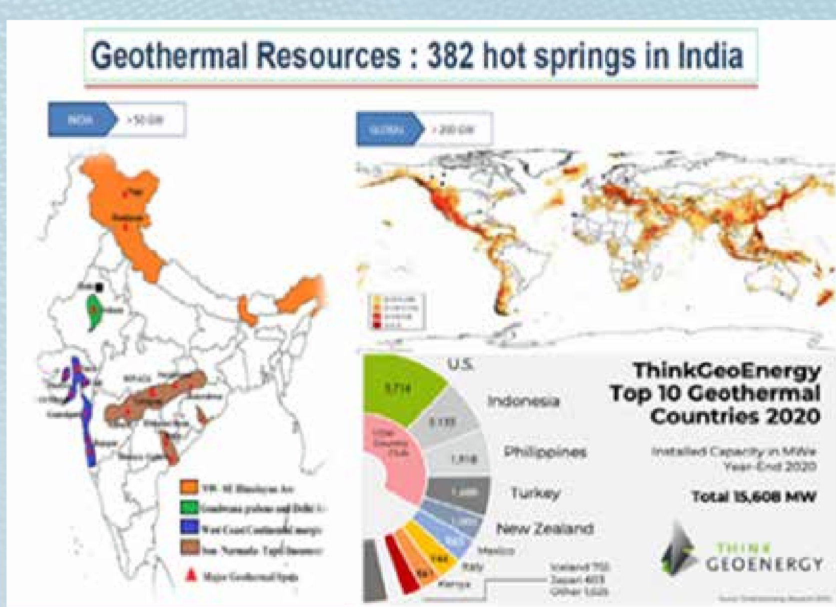
Guidelines can be accessed from:

https://mnre.gov.in/en/notice/guidelines-on-design-specifications-performance-guidelines-and-testing-procedure-for-solar-cold-storage-with-thermal-energy-storage-backup/

HARNESSING GEOTHERMAL ENERGY: THE POTENTIAL UNFOLDS

Geothermal energy is gaining traction as a serious alternative to other energy resources. The first indigenous geothermal power plant of 20-kW capacity has been developed and demonstrated in field by the Shriram Institute for Industrial Research (SRI) and Renergizr Industries Pvt. Ltd. The project was sponsored by the Ministry of Coal, Government of India, and supported by the Ministry of New and Renewable Energy (MNRE). With an identified potential of 10 GW from about 350 hot springs in the country, geothermal energy can become a gamechanger of sorts in the coming days.

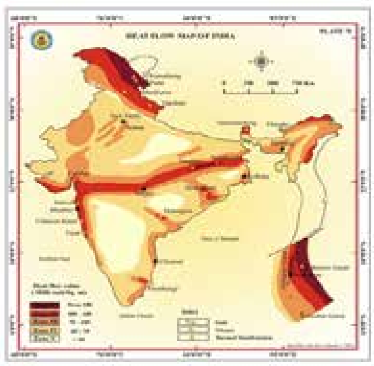
India is a country with vast and varied renewable energy (RE) resources. Geothermal energy is a promising RE resource that has not been explored much, unlike many other RE resources. Geothermal energy is derived from the Earth's internal heat, is available round-the-clock, unaffected by weather conditions, and offers a high capacity utilization factor (CUF) throughout the year. This makes geothermal a particularly attractive alternative to other intermittent renewable sources such as wind and solar.



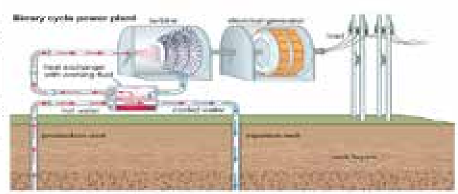
Geothermal Potential of India

Geothermal energy is generated

Geothermal energy has the lowest operational cost and carbon footprint among all the renewable sources of energy and its performance is independent of time of day or weather conditions.



Heat Flow Map of India
(Source: GSI Geothermal Atlas, 2022)



from the natural decay of radioactive elements like uranium and potassium in the Earth's crust, producing heat that can be harnessed for electricity generation and heating applications. This heat manifests in the form of hot springs, geysers, and underground reservoirs, which are the key sources of geothermal energy.

The countries that lead in geothermal energy production are the US, the Philippines, Indonesia, Turkey, and New Zealand. While geothermal energy capacity in India is still in its nascent stages, the country's potential for geothermal power generation is immense. The Geological Survey of India (GSI) estimates that India's theoretical geothermal power potential stands at over **10,000 MW (10 GW),** which is equivalent to the global geothermal capacity. By **2030**, India aims to tap into this potential and generate 10 GW of geothermal energy, marking a significant milestone in the nation's RE journey.

As part of its transition away from fossil fuels to more sustainable sources of energy, India has identified approximately 382 hot springs across the country, making geothermal energy a viable and clean alternative. Currently, geothermal resources are primarily categorized into three zones:

1. Geopressurized Zones,
2. Hot-Rock Zones, and
3. Hydrothermal Convection Zones.

While only hydrothermal convection zones are commercially exploited worldwide, India's geothermal potential is largely tied to these three zones.

Geothermal Energy: Benefits and Applications

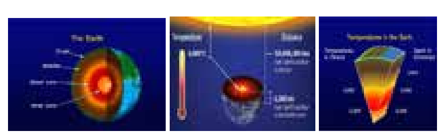
Geothermal energy offers several key advantages:

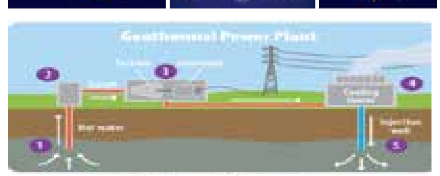
- Continuous Supply: Unlike solar or wind, geothermal energy is available 24/7, ensuring a reliable power supply.
- Minimal Environmental Footprint: The carbon emissions from geothermal power plants are very low compared to fossil fuel-based power generation.
- Long Lifespan: Geothermal plants have a lifespan exceeding 100 years.
- Low Operational Costs: Once operational, geothermal plants have relatively low maintenance and operational costs.
- Diverse Applications: Geothermal energy can be used for power generation, heating and cooling, water desalination, greenhouse cultivation, refrigeration, and even the extraction of rare metals and gases.

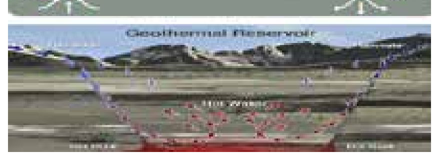
India's First Indigenous Geothermal Power Plant

One of the significant steps in India's geothermal energy journey is the development of its first indigenous geothermal power plant, which is a collaborative effort between the Shriram Institute for Industrial Research (SRI) and Renergizr Industries Pvt. Ltd. (RIPL)

This project, sponsored by the Ministry of Coal, Government of India, and supported by the Ministry of New and Renewable Energy (MNRE), has successfully demonstrated a 5-kW geothermal pilot power plant. The plant generates electricity using a hot water source at 65 °C, simulating geothermal energy, marking a significant achievement for India.







Technological Advantages

Core Technology:
- Harnesses geothermal renewable energy using organic refrigerants
- Reuses waste heat for electricity generation, green hydrogen production, and more

Key Equipment:
- Fully indigenous, designed and manufactured in India to international quality standards
- Long operational lifespan (>100 years) based on advanced borewell design

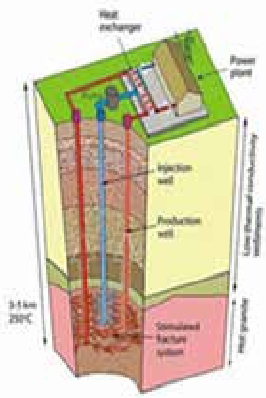
Performance Metrics:
- Energy Savings: Achieved 16 GJ savings during a pilot project in Telangana

Capacity Factor:
- Operates at over 98%, ensuring continuous and reliable energy generation

Power Density:
- Delivers 5 times higher power density compared to solar energy

Comparison of renewable energy sources

S. No.	Factors	Geothermal	Fossil Fuels	Solar	Wind	Hydro
1	OPEX cost	Low	High	High	High	High
2	Land footprint	Low	High	High	High	High
3	Carbon footprint	8 gCO2/KW	980g CO2/KW	48 gCO2/KW	12 gCO2/KW	24 gCO2/KW
4	Capacity	>99%	58%	25%	35%	32%
5	Power density	> 5times solar	> 50 times solar	< (1/5) geothermal	< (1/3) times geothermal	< (1/4) times geothermal
6	Life cycle	>100 yrs	>30 yrs	>10yrs	>7 yrs	>30 yrs
7	Weather impact	None	None	High	High	High



This breakthrough is credited to the dedicated efforts of scientists, including , Dr Bhupesh Sharma, Mr Himanshu Gupta, Dr Manmohan Kumar and Dr. Mukul Das, who developed this indigenously designed process including turbine for low-boiling fluids. The extension of this innovation has also been established for the first time on actual geothermal resources, with a 20 kW capacity. This facility has been commissioned in Manuguru, Telangana, since February 2023. Developed with local support of Singareni Collieries Company Limited (SCCL) and sponsored by the Ministry of Coal, Government of India, the site in the Godavari Basin utilizes hot water discharges at 65–68 °C for power generation. Indigenous developed process is protected with IPR, Patent No. 548040.

"Among 381 geothermal locations in India, Manuguru stands out with a promising potential of 122 MW!

Environmental Impact

GHG emissions performance:

- Decreases CO_2 emissions by 99% compared to fossil fuel-based plants, with a reduction of 600 metric tonnes of CO_2
- Lowest greenhouse gas emissions and land footprint among RE technologies

Promotion of Circular Economy:

- Utilizes waste heat from oil & gas operations, contributing to waste minimization and energy efficiency

Green power:

- Provides baseload energy for stable grid operation, ensuring 24/7 clean energy

All-weather operations:

- Operates independently of weather conditions, ensuring consistent energy supply

Working Model Details

5 KW Prototype in Delhi

20 KW Pilot Field Demonstration in ManuGuru, Telangana State

- Indigenous and Patented Process technology utilizing Geothermal Renewable Energy
- Patent No. 548040

20KW Geothermal Power Plant Social Impact : Village people in Pagaderu village, Manuguru on 14.06.2024

Binary Organic Rankine Cycle (ORC) Technology

The Binary Organic Rankine Cycle (ORC) technology is the key to making geothermal energy a viable power source at lower temperatures. This technology uses organic fluids with low boiling points, such as Butane, Isobutane, Pentane, and R245fa, to convert the heat from geothermal sources into electricity. In collaboration with SRF Ltd., a custom organic fluid has also been developed, tailored to the specific geothermal resource potential and local environmental conditions.

The ORC system works in a closed-loop cycle, where the geothermal heat is used to vapourize an organic working fluid in an evaporator. The resulting vapour expands in a turbine, generating electricity as it drives the rotor connected to a generator. The vapour is then condensed back into liquid form in a condenser, and the process repeats itself.

This closed-loop system not only ensures that no harmful emissions are released into the atmosphere but also enables the reuse of excess heat for other thermal applications. Furthermore, the modular nature of ORC systems makes them ideal for decentralized power generation, particularly in remote locations.

Working Model Details

The Way Forward: Scaling Up Geothermal Power in India

The pilot projects and ongoing research mark significant progress, but to achieve the ambitious target of 10 GW of geothermal energy by 2030, India must focus on scaling up geothermal power production.

- **Repurposing Existing Infrastructure:** One way to scale up geothermal energy generation is by repurposing existing borewells. Indian key players like Geological Survey of India (GSI), ONGC, and Oil India Limited (OIL) have already drilled several borewells for exploratory purposes. These could be adapted for geothermal energy generation, potentially lowering costs and speeding up the development process.
- **Policy Interventions and Financial Support:** To accelerate the growth of geothermal energy, experts have called for targeted policy interventions and financial assistance. One proposed solution is viability gap funding, which would cover 50% to 70% of both capital and operational costs. This would help encourage private sector involvement in geothermal energy projects.
- **Geothermal Projects in Remote Regions:** In Ladakh, a 1-MW geothermal power plant is being planned in collaboration with ONGC, MNRE, SRI, and GSI. The region's geothermal potential, particularly in areas like Puga and Chumathang, is expected to play a key role in India's RE strategy.

A Sustainable Path Forward

India's geothermal journey is gaining momentum, and with continued innovation and collaboration, the country is poised to unlock its vast geothermal potential. By scaling up pilot projects, repurposing existing infrastructure, and supporting stakeholders with financial and technical assistance, geothermal power could become an integral part of India's RE mix. This aligns with the country's ambitious goal of achieving 500 GW of RE capacity by 2030 and achieving net-zero emissions by 2070.

The successful deployment of geothermal technology could also help diversify India's energy portfolio, reduce dependence on fossil fuels, and provide sustainable power for generations to come. With the right policies and investments, geothermal energy can be a game-changer for India's clean energy future.

Bhupesh Sharma
Shriram Institute for Industrial Research
Delhi
bhupeshsharma@shriraminstitute.org

Anil Kumar
Ministry of New and Renewable Energy,
Government of India

AgriPV for Achieving Energy Security

Becoming a Net Zero Emissions country by 2070 is a commitment given by India to the world. In that journey, the role of every potential avenue for reducing carbon emissions is being explored. Among such avenues, AgriPV holds immense potential.Dr D K Singh and Dr C Viswanathan of the Centre of Excellence for AgriPV, an ICMR and MNRE initiative, discuss the nitty-gritty of the White Paper on AgriPV, including its advantages and challenges in its implementation.

Background

Agri-photo-voltaic (AgriPV) also referred to as Agrovoltaic is simultaneous use of cultivable land for agriculture and electricity production through photovoltaic cells. An AgriPV system enhances the land productivity through production of agriculture commodities and electricity from the same land and helps in reducing carbon emission. India has committed to achieve the net zero emissions by 2070 and has set target of 500 GW from non-fossil energy sources by 2030. In line with this target, the Ministry of New and Renewable Energy (MNRE) has set a target of achieving 292 GW from solar PV by 2030.

As of December 2024, India's total renewable energy installed capacity was 209.44 GW. To achieve the target of 292 GW from solar PV in the remaining 6 years concerted efforts are required. The AgriPV system offers several advantages along with several challenges too. A White Paper has been prepared by the Centre of Excellence - ICAR - Indian Agricultural Research Institute, New Delhi, titled 'AgriPV for Achieving Net Zero Emission Targets, Energy Security and Enhancing Farmer Income in India'. White Paperpublished by Centre of Excellence for AgriPV provides insights on AgriPV solution, its advantages and challenges in its implementation. It also looks at AgriPV from the perspectives of energy security and enhancing farmers' income. This article captures the gist of this White Paper.

1. Introduction

The global adoption of AgriPV is expanding rapidly. The global installed capacity of AgriPVsurged from5.0 MW in 2012 to 2.9 GW in 2018 and exceeded 14 GW by 2021. As perthe Fraunhofer Institute for Solar Energy Systems (ISE), majority of this 14 GW installations come from China, Japan, Korea in Asia and France, Italy, Germany, and the Netherlands inEurope.

Definitions of AgriPV vary across different countries. However, the one published in the report 'AgriPV in India',of Deutsche GesellschaftfürInternationale Zusammenarbeit (GIZ) GmbH finds resonance. It says that AgriPV systems should have at least 66% of agricultural reference yield keeping land losses due to mounting structures below 10% for Category I (Overhead PV) and 15% for Category II (Interspace PV).Having states that, there is a need to define and develop standards for AgriPV in India. Also, there is a need to develop a policy on how much agricultural land in different agro-climatic zones can be under AgriPV.

Advantages of AgriPV

The main advantages of AgriPV include the following:

- Enhanced land-use productivity through simultaneous land use for producing electricity and crops.
- Increased revenue generation from the same land parcel.
- Reduced financial risk through diversified source of income.
- Opportunities for rural youths to set up solar energy plant, job creation and income from diverse and multiple activities.
- Enhanced panel efficiency due to cooling from underneath crop.

2. AgriPV in India

As perland use statistics for the year 2021/22 published by the Department of Agriculture & Farmers Welfare, the total geographical area of India is 328.75 million ha, of which 141.01 million ha is net sown area and 219.16 million hectares is the gross cropped area. The theoretical potential of AgriPV in India is high with agricultural land accounting for over 59%. Integrating AgriPV with rainwater harvesting systems and on-site use of energy for agricultural operations further enhances its potential to support sustainable agriculture practices.

3. Challenges in Adoption of AgriPV in India

While AgriPVoffers numerous benefits, there are several challengessuch as system complexity and potential risks. It is essential to addresschallenges to ensure the long-term success and implementation ofAgriPV systems over conventional solar installations.

Some of the main challenges and possible solutions are presented in Table 1.

Table 1. Main challenges and possible solutions in the implementation of AgriPV in India

Challenges	Possible solutions
Land-use change	▪ Change in the policy of agricultural land use ▪ Address the issue of taxation due to income from sales of electricity ▪ Introduce a policy to lease agricultural land for AgriPV ▪ Address issues of risk to life, including animals
Mechanisation	Develop specialized machinery tailored for use beneath PV panels Customise PV panel designs for certain crops
Loss of yield and area	▪ Conduct systematic study on the impact of PAR (photosynthetically active radiation), LSP (light saturation point), LCP (light compensation point) on photosynthesis and yield under AgriPV system through AgriPV pilot projects in different agroclimatic zones to develop a crop suitability matrix
Crop suitability	▪ Conduct studies to quantify yield loss of crops under different agro-climatic zones of India ▪ Study key characteristics of crops such as light intensity adaptability, photosynthetic efficiency, stomatal regulation water use efficiency, temperature tolerance, change in the dynamics of insects, pests, and diseases, ease of agricultural operations, etc.
High initial costs	▪ Develop a clear policy and an incentive scheme to promote AgriPV ▪ Support investment by farmers and developers through subsidies, tax benefits, higher feed-in tariffs, and loans at lower interest ▪ Convergence of the PM-KUSUM Component-A with Agri Infra Fund (AIF) is a major initiative to boost AgriPV system in India. There is need to make Stakeholders aware about this initiative
Evacuation of electricity	▪ There is need to develop sufficient evacuation capacity closer to substations to minimize losses ▪ Develop a policy for captive use of electricity generated ▪ Cluster schemes for evacuation and use may be tried

Crop- Cabbage, SunMaster, Najafgarh, Delhi

Crop-Turmeric, GIPCL, Amrol, Gujarat

Other challenges include the availability of skilled manpower and their safety to operate and maintain the AgriPV systems. Engaging scientists and students from universities, institutions, and research centers is crucial for the success of AgriPV projects.

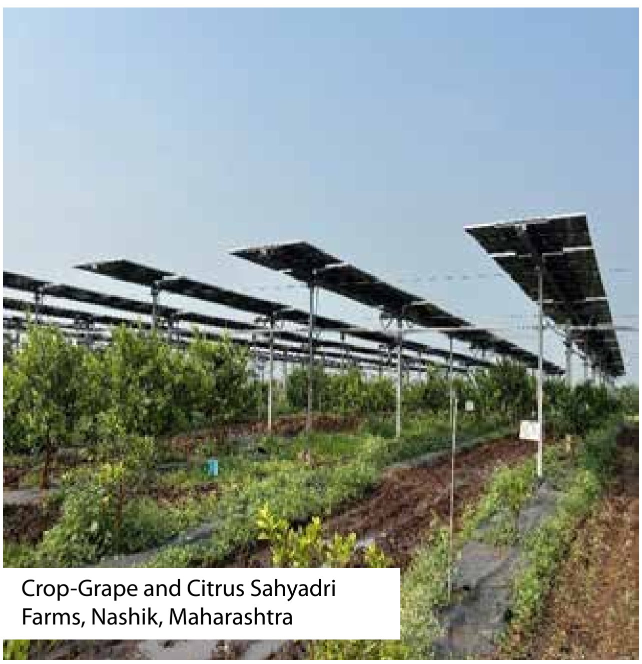
Crop- Banana, Manwath, Maharashtra

Capacity Building

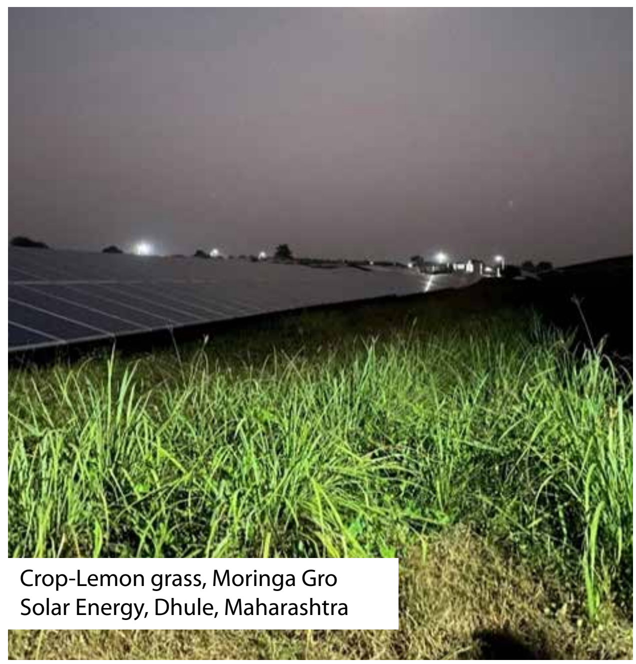
Farmers and stakeholders play a crucial role in the successful implementation of any such systems across India. Their perceptions and concerns must be addressed to ensure widespread adoption and long-term sustainability of solar-powered agriculture.

Conclusion

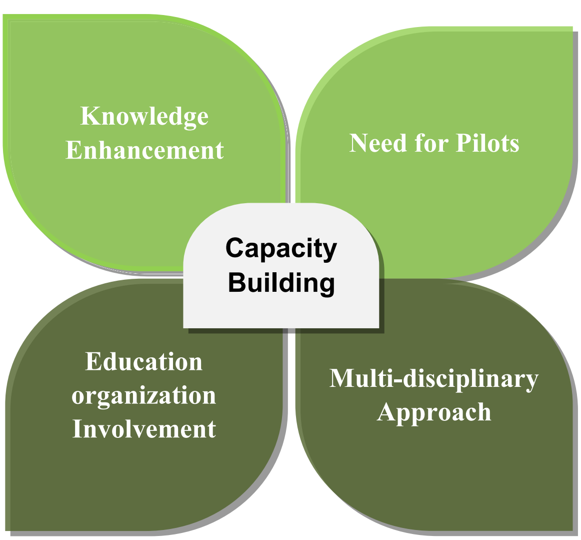
AgriPVis a promising solution to address the solar energy production from agricultural land. It offers several benefits including additional revenue from sell of energy,reduced greenhouse gas emissions, enhanced solar energy production along with crop production. Solar panels on agricultural land are must to achieve net zero emission level by 2070. The global adoption of AgriPV is expanding rapidly.



Crop-Grape and Citrus Sahyadri Farms, Nashik, Maharashtra



Crop-Lemon grass, Moringa Gro Solar Energy, Dhule, Maharashtra



Countries like India, where extensive agricultural land is available provides an ideal situation for installation of AgriPV. However, despite its numerous advantages, there are severalchallenges also.

Addressing challenges requires concerted efforts from various stakeholders, including policymakers, researchers, farmers, and industry. Establishing standardized definitions and guidelines, providing financial incentives and support, developing specialized machinery, pilot projects, enhancing knowledge through education and research, and fostering community engagement are essential steps towards realizing the full potential of AgriPV.

D K Singh and C Viswanathan
Centre of Excellence
ICAR Indian Agricultural Research Institute, New Delhi
dksingh.wtc@gmail.com | dksingh@iari.res.in

HARNESSING OCEAN ENERGY IN INDIA

Introduction

As the Ministry of New and Renewable Energy (MNRE) continues to expand India's renewable energy (RE) portfolio, ocean energy offers a sustainable solution to meet India's growing energy demands while reducing carbon emissions. This article outlines the current state of ocean energy technologies, their potential in India, and the current initiatives undertaken by MNRE to further the development of ocean energy in India.

Technologies in Ocean Energy

Tidal Energy

Tidal energy harnesses the gravitational forces of the moon and the sun, along with Earth's rotation, to generate electricity. Most conventional tidal range schemes utilize bulb turbines, which function similarly to hydropower turbines used in run-of-river plants. Tidal range technology offers three primary methods for power generation:

- **Ebb Tide Generation:** Reservoir fills at high tide; power is generated when water is released during low tide.
- **Flood Tide Generation:** Reservoir is emptied at low tide; power is generated when rising tide flows in through turbines.
- Two-Way Generation: Power is produced during both incoming and outgoing tides using specialized reversible turbines.

Wave Energy

Wave energy can be harnessed through various technologies that convert the energy of ocean waves into electricity. Each technology has its advantages, and the choice depends on factors like wave conditions, location (onshore, nearshore, or offshore), and energy requirements. The primary types include the ones listed below.

- **Attenuators:** These are long, floating structures aligned parallel to the direction of waves. These devices flex as waves pass, and the motion is converted into electricity using hydraulic systems.
- **Point Absorbers:** These are floating devices that move up and down with the waves. The relative motion is used to drive hydraulic pumps or generators. Point absorbers are compact and can be deployed in arrays offshore.
- **Submerged Pressure Differential Devices:** Installed on the seabed, these devices use the pressure difference caused by passing waves to generate energy.
- **Oscillating Wave Surge Converters:** These devices harness the horizontal movement of waves to drive pistons or hydraulic systems for electricity generation. They are usually mounted on the seabed nearshore.
- **Oscillating Water Columns (OWC):** These devices use the movement of waves to compress air in a chamber. The compressed air drives a turbine to generate electricity. OWCs are often installed onshore or nearshore.

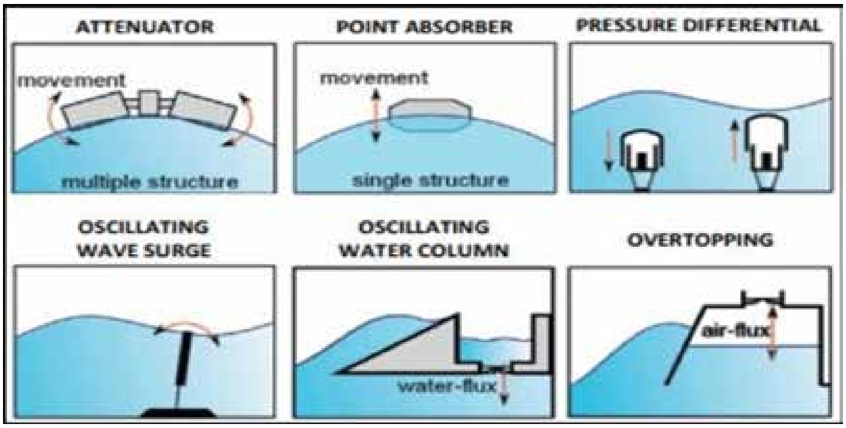


Figure 1. Kinds of wave energy systems (WES)

Source: Memon, S., Lawal, O. M., Tariq, S. A., & Khalid, B. (2020). Wave energy in the UK: Current scope, challenges and prognostications. International Journal of Solar Thermal Vacuum Engineering, 2(1), 59-78.

- **Overtopping Devices:** These structures capture water from waves in a reservoir. The water is then released back to the ocean through turbines, generating electricity.

Ocean Thermal Energy Conversion (OTEC)

Ocean Thermal Energy Conversion (OTEC) is a renewable energy technology that harnesses the temperature difference between the warm surface water of the ocean and the cold deep water to generate electricity. There are three main types of OTEC.

- **Open-cycle:** Warmer surface water is introduced through a valve in a low-pressure compartment and flash evaporated. The vapour drives a generator and is condensed by the cold seawater pumped up from below. The condensed water can be collected and because it is fresh water, used for various purposes (Figure 2a). Additionally, the cold seawater pumped up from below, after being used to facilitate condensation, can be introduced in an air-conditioning system. As such, systems can produce power, fresh water and air-conditioning.
- **Closed-cycle:** Surface water, with higher temperatures, is used to provide heat to a working fluid with a low boiling temperature, hence providing higher vapour pressure (Figure 2b). Most commonly ammonia is used as a working fluid, although propylene and refrigerants have also been studied. The vapour drives a generator that produces electricity; the working fluid vapour is then condensed by the cold water from the deep ocean and pumped back in a closed system.
- **Hybrid systems:** Hybrid systems combine both the open and closed cycles where the steam generated by flash evaporation is then used as heat to drive a closed cycle.

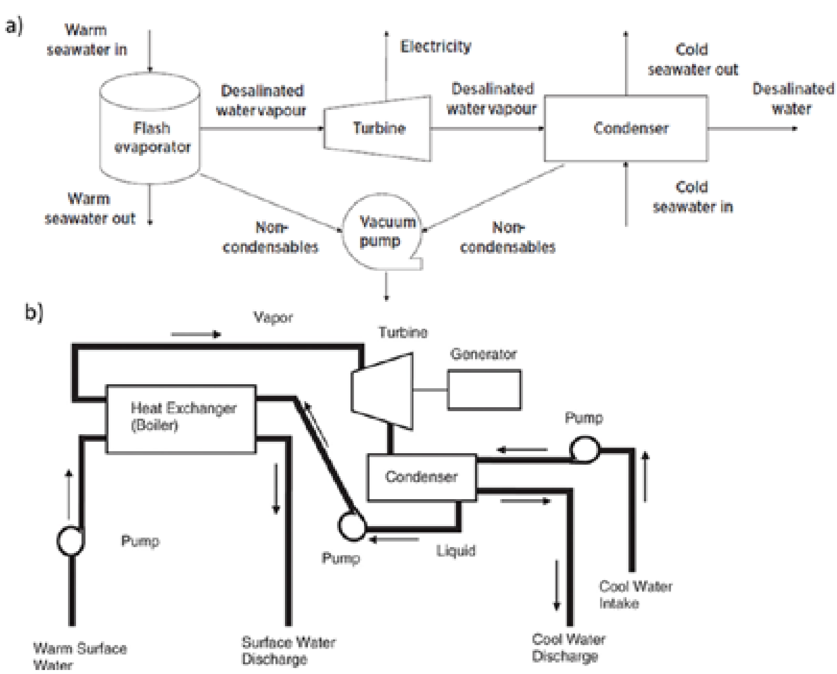


Figure 2. (a) Open cycle OTEC, (b) Closed cycle OTEC

Source (Fig. 2b): *Ocean thermal energy conversion technology brief, June 2014.*

Potential and Opportunities in India

Resource Assessment

The global installed capacity of ocean energy remains small compared to other renewables but is growing. The International Renewable Energy Agency (IRENA) estimates around 550 MW of tidal energy and 16 MW of wave energy projects globally.

India has significant potential for harnessing tidal energy due to its long coastline, particularly in regions like the Gulf of Khambhat, Gulf of Kutch, and the Sundarbans in West Bengal. As per the report from IREDA, India's theoretical potential for tidal power is estimated at 12,455 MW, with the highest concentrations in Gujarat and West Bengal. The Gulf of Khambhat alone accounts for 7000 MW, followed by 1200 MW in the Gulf of Kutch and approximately 100 MW in the Sundarbans region.

The country's wave power potential is estimated at 41.3 GW, according to CRISIL, making it a promising addition to India's renewable energy portfolio. India's southern coasts, particularly Tamil Nadu, Kerala, and Karnataka, are identified as suitable regions for harnessing wave energy.

Ocean Thermal Energy Conversion (OTEC) in India holds significant potential due to the country's tropical coastline, where the temperature difference between warm surface water and cold deep water is ideal for this technology. The National Institute of Ocean Technology (NIOT) has been at the forefront of OTEC development in India. A notable initiative includes a 1 MW demonstration plant planned near Kavaratti in the Lakshadweep Islands to harness this renewable energy source.

Technology	Total Potential	Location	Project/Regional Potential
Tidal Energy	12,455 MW	Gulf of Khambhat	7000 MW
		Gulf of Kutch	1200 MW
		Sundarbans	100 MW
Wave Energy	41.3 GW	Southern Coast (Tamil Nadu, Kerala, Karnataka)	41.3 GW
OTEC	1 MW	Lakshadweep Islands (Kavaratti)	1 MW (Demonstration Plant)

Geographical Advantages

- **Extensive Coastline**
- 7,500 km of coastline providing diverse marine energy opportunities
- Strategic location in the Indian Ocean with consistent wave patterns
- Numerous islands and coastal regions suitable for various ocean energy technologies
- **Favourable Ocean Conditions**
- Strong tidal ranges in specific regions (Gulf of Khambhat, Gulf of Kutch)
- Consistent wave activity along the southern coastline
- Suitable temperature gradients for OTEC in tropical waters

Technical and Infrastructure Support

- **Research and Development**
- Established institutions like NIOT focusing on ocean energy technologies
- Existing marine research infrastructure and expertise
- Growing experience in offshore engineering and marine operations
- **Supporting Infrastructure**
- Well-developed coastal infrastructure including ports
- Existing power grid connections near coastal areas
- Maritime facilities supporting offshore operations

Policy and Economic Framework

- **Regulatory Support**
- Ocean energy classified as renewable energy by Ministry of New and Renewable Energy
- Policy framework supporting renewable energy development
- Government initiatives promoting clean energy technologies
- **Economic Potential**
- Large coastal population creating local demand
- Potential for integrated applications (power generation, desalination)
- Opportunities for industrial and economic development in coastal regions

Environmental and Social Benefits

- Environmental Impact
- Contribution to renewable energy goals
- Reduced carbon emissions
- Sustainable coastal development
- **Social Development**
- Employment generation in coastal communities
- Energy security for remote coastal and inland areas
- Development of skilled workforce in marine technology sector

Strategic Advantages

India offers unique strategic advantages for harnessing ocean energy. The following advantages position India favourably for developing ocean energy as a significant component of its renewable energy portfolio.

MNRE's Current Initiatives

MNRE's strategic initiatives in RE development align with India's Nationally Determined Contributions (NDCs) under the Paris Agreement, supporting both emissions reduction and clean energy transition goals. Through targeted research investments, technology demonstrations, and collaborative partnerships, the Ministry is working to establish RE as a reliable component of India's sustainable energy future.

The Ministry is implementing the Renewable Energy Research and Technology Development (RE-RTD) Programme, which aims at scaling up the R&D effort for promoting indigenous technology development for widespread deployment of new and renewable energy in an efficient and cost-effective manner across the country. MNRE has included ocean energy development under the RE-RTD Programme.

Anil Kumar, *Scientist 'E', Ministry of New and Renewable Energy, Govt of India*

Pipasa Layak, *Consultant, Centre for Study of Science, Technology and Policy (CSTEP)*
pipasa.layak@ctep.in

Development of Automated PEM Fuel Cell Components/Stack Assembly Line

India is investing heavily in the R&D of hydrogen energy. Fuel cell (FC) is the device that converts chemical energy into electrical energy. Researchers at IITMRP-ARCI have been working on polymer electrolyte membrane fuel cells (PEMFCs) and the technology is going through the process of demonstrations and field trials in the country. As a logical next step, the ARCI has developed a pilot-scale manufacturing facility automated PEMFC components/stack fabrication. The researchers involved in this operation gives a brief overview of the development process. Read on.

Hydrogen fuel cell is an energy conversion device that converts chemical energy of a gaseous hydrogen fuel into electrical energy by electro-chemical reaction. They are classified primarily by the kind of electrolyte they employ in the cell. Among these, the polymer electrolyte membrane (PEM) fuel cells have been considered for the deployment for both stationary and transport applications. Low temperature PEM (LT-PEM) fuel cells operate at around 80 °C. These can easily be started up and stopped and respond well to dynamic loads. Amongst fuel cells, LT-PEM fuel cells technology is currently the leading technology for deployment in the light duty vehicles like two, three, and four wheelers, small boats, heavy duty vehicles like buses, trucks, trains, trams, ferries and materials handling vehicles like forklift trucks, as well as for stationary applications in the telecom sector.

Presently, the fuel cell demonstrations, and field trials taking place in our country, predominantly have imported LT-PEM fuel cell stacks. The major share of the cost of the fuel cell system is presently dominated by the stack. Fuel cell stack composed of several single cells (number depends on the desired power to be delivered). A fuel cell system comprises of fuel tank (with or without reformer), source of oxidant (air or oxygen), power conditioner (DC/AC convertor), waste heat exchanger, exhaust system etc. These are known as Balance of Systems (BoS) or Balance of Plant (BoP), constituting a major cost component. The deployment of PEM fuel cell (PEMFC) system for various applications and its cost reduction depends majorly on its manufacturing capability within India. Hence, Advanced Research Centre International (ARCI) initiated the development of such capability by the setting up of a pilot line for automated PEMFC components/stack fabrication sponsored by the Ministry of New and Renewable Energy (MNRE), Government of India.

A PEMFC stack comprises a number of components with a varied material property. The various steps involved in PEMFC components as well as stack development for automation process were identified. Accordingly, ARCI collaborated with Advanced Manufacturing Technology Development Centre (AMTDC), Chennai, as a partner in setting up the PEMFC stack/component assembly line at Centre for Fuel Cell Technology (CFCT). PEMFC is an assembly of several components as shown in Figure 1. The key elements in a PEMFC system are gas-diffusion electrodes, catalyst-coated membrane, and graphite bipolar plates. Figure 2 presents the sequence involved in the fabrication of each of the key elements of PEMFC. As presented in Figure 2, the sequence of operations is as follows:

- Gas diffusion layer (GDL);
- Fabrication of catalyst-coated membrane (catalyst on membrane);
- Fabrication of membrane electrode assembly (MEA);
- Assembly of MEAs, insulating gaskets, graphite plates, and end plates (PEMFC stack); and

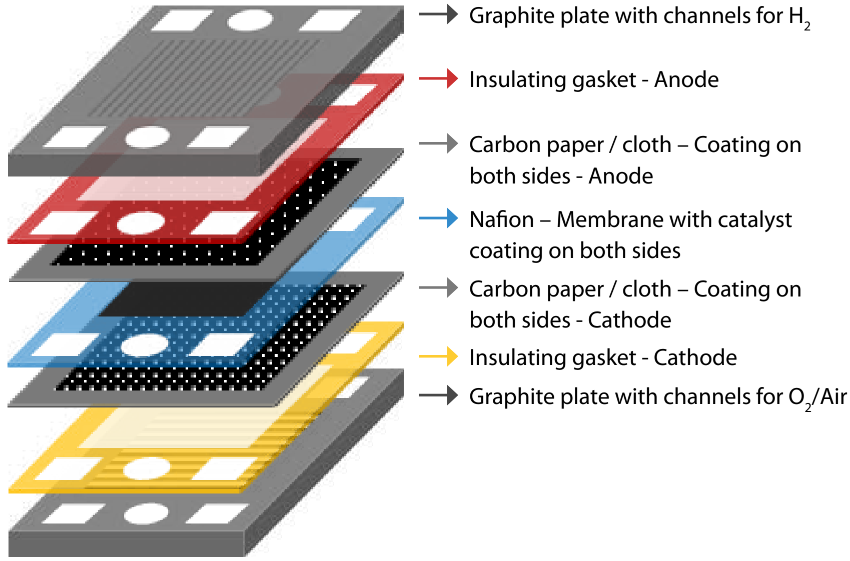


Figure 1. Schematic of PEMFC assembly components

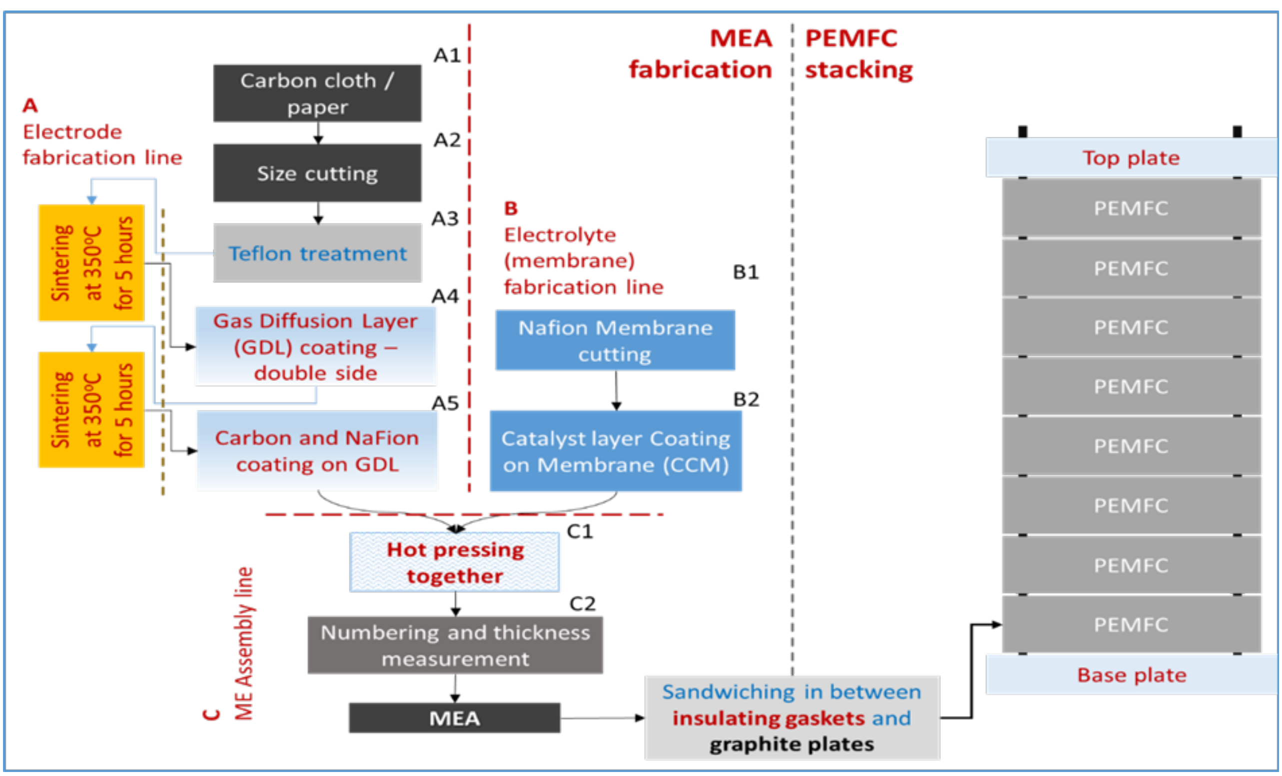


Figure 2. Process sequence for PEMFC stack fabrication

Figure 3. Established PEMFC components/stack assembly pilot line at ARCI-CFCT, Chennai

- Stacking of several single PEMFC for required power rating.

However, automation of the entire fabrication sequence poses several challenges as follows:

1. Controlled coating of carbon slurry on electrodes (by weight and thickness);
2. Controlled coating of catalyst on proton exchange membrane (by weight and thickness);
3. Proper alignment of coated areas during assembly of membrane electrode; and
4. Leak-proof sealing with gaskets.

In addition to the above requirements, handling of different materials during assembly needs additional care owing to their delicate nature. These components range from graphite plates measuring several millimetre thicknesses to catalyst-coated membrane measuring only 60 micrometres. The above-said operations and components have been handled using proper automation solution such as roll cutter, conveyor, sscreen printing, pneumatic handling, robotic arm for pick-and-place process.

In addition, gluing station for binding of MEA and gasket, and torquing station for clamping the final stack in assembly table have been developed. The entire process parameters and steps are controlled through supervisory control and data acquisition (SCADA) system. These automation facilities enable the realization of mass manufacturing of PEMFC components/stack development with reduced time and improved reliability of the process. PEMFC stack/ components of capacity about 100 kW/year have been targeted using this infrastructure.

Conclusion

In conclusion, the automated fuel cell assembly line will be the first of its kind in India, marking a significant step towards self-reliance in PEM fuel cell manufacturing. The primary objective is to establish a domestic model for fuel cell assembly, aligning with the vision of Atmanirbhar Bharat. This setup will be a cost-effective solution, utilizing materials sourced predominantly from within the country. Additionally, the automated assembly line will enable feasibility studies to fabricate customized fuel cells and further advancing India's clean energy ecosystem.

R Balaji, Raman Vedarajan and K Ramya
Centre for Fuel Cell Technology-ARCI
IITM Research Park, Chennai
rbalaji.arci@nic.in

ROLE OF ARTIFICIAL INTELLIGENCE IN BIOGAS SECTOR

Biogas technology holds significant potential for addressing the energy needs of rural India, while simultaneously solving waste management challenges and contributing to sustainable agriculture. With rapid advancements in artificial intelligence (AI), there is an opportunity to revolutionize the biogas sector, making it more efficient, economically viable, and scalable. This article explores the role of AI in the biogas industry, particularly for farmers and entrepreneurs in India, by examining its applications, economic potential, government support, and innovations in the sector.

Understanding Biogas Technology

Biogas is produced through the anaerobic digestion of organic materials like animal manure, agricultural residues, and food waste. The primary components of biogas are methane (CH_4) and carbon dioxide (CO_2), with methane being the key energy source. In rural India, biogas offers an eco-friendly alternative to conventional cooking fuels like firewood, kerosene, and LPG, while also producing organic fertilizer as a by-product.

In recent years, there has been a concerted effort to promote biogas plants at the grassroots level, especially in rural areas where farmers and small entrepreneurs can benefit from affordable and sustainable energy solutions. However, the sector faces challenges such as inefficient operations, lack of real-time monitoring, and suboptimal performance of biogas plants. This is where AI can play a transformative role.

Applications of AI in Biogas Technology

1. **Optimizing Biogas Production**

   AI can improve the efficiency of biogas plants by optimizing the fermentation process. Machine learning algorithms can analyze data from sensors installed in biogas digesters to monitor parameters such as temperature, pH, gas composition, and feedstock quality.

Based on this data, AI models can predict the optimal operating conditions for maximizing methane yield. For farmers and entrepreneurs managing decentralized biogas plants, this means less trial-and-error, better resource utilization, and consistent output.

2. **Predictive Maintenance and Fault Detection**

   Biogas plants require regular maintenance, and equipment failures can lead to costly downtime. AI-powered predictive maintenance systems use historical data from sensors and maintenance records to predict when equipment (e.g., pumps, compressors, or digesters) is likely to fail. This allows for proactive maintenance, reducing the risk of unexpected breakdowns and improving plant reliability.

3. **Waste-to-Energy Feedstock Optimization**

   AI can assist in identifying the most suitable waste feed-stocks for biogas production. Using data analytics, AI models can analyze the nutritional content of various organic materials (e.g., cow dung, crop residues, food waste) and predict which combination would yield the highest biogas output. For farmers, this means they can use locally available waste more efficiently, reducing the cost of inputs and improving the overall productivity of the biogas plant.

4. **Supply Chain and Logistics Management**

   AI can help optimize the logistics of collecting, storing, and transporting waste materials to biogas plants. AI-powered tools can forecast waste availability based on seasonal cycles or local agricultural activities, ensuring that biogas plants always have a steady supply of feedstock. This is especially crucial in rural areas where access to transport and logistics infrastructure can be limited.

» Futuristic Smart Biogas Plant: Integrating Renewable Energy with Digital Agriculture for a Sustainable Future

5. **Energy and By-product Utilization**

   AI can optimize the usage of the energy produced by biogas plants. For example, AI algorithms can control the distribution of biogas between electricity generation, cooking, and heating based on real-time demand. Similarly, AI can be used to optimize the use of digestate, the nutrient-rich slurry by-product, ensuring that it is converted into high-quality organic fertilizer for agriculture.

Reasons for adoption AI in Biogas Sector

The adoption of AI in biogas technology brings several advantages, especially in the Indian context.

- **Increased Efficiency**

  AI ensures more efficient use of resources, which is crucial in rural areas where access to resources can be limited. By optimizing the production process and reducing waste, AI helps farmers and entrepreneurs maximize their returns on biogas investments.

- **Sustainability and Environmental Impact**
  AI can help biogas plants minimize their environmental footprint. By optimizing methane production and reducing leaks or inefficiencies, AI systems ensure that biogas plants operate in a more sustainable manner, contributing to India's goals for reducing greenhouse gas emissions.
- **Cost-effectiveness**
  AI-driven biogas plants require less manual intervention, reducing labour costs and the need for constant monitoring. Additionally, by minimizing downtime through predictive maintenance and ensuring optimal resource usage, AI helps lower the overall operating costs of biogas plants, making them more economically viable for farmers and entrepreneurs.
- **Access to New Markets**
  AI can enable biogas producers to better manage their production, allowing them to scale operations and enter new markets for both energy and organic fertilizers. This opens up opportunities for small farmers and entrepreneurs to generate additional income streams.
- **Improved Decision-Making**
  AI-powered data analytics can help farmers and entrepreneurs make better decisions regarding the management of biogas plants. Real-time data collection and analysis provide insights that can lead to better strategies for feedstock management, maintenance schedules, and product distribution.

Government Support and Schemes for Biogas

The Government of India has recognized the importance of biogas

» AI Integration in Biogas Sector

technology in promoting sustainable development, especially in rural areas. Several initiatives have been introduced to encourage the adoption of biogas plants, particularly for farmers and small entrepreneurs. The 'National Biogas Program', launched by the Ministry of New and Renewable Energy (MNRE), provides financial assistance for setting up biogas plants in rural households and institutions. The scheme aims to promote biogas for cooking purposes, providing subsidies for the installation of biogas units.

Biogas Development and Training Centres (BDTCs) play a crucial role in training farmers and entrepreneurs in the installation, operation, and maintenance of biogas plants. These centres also promote the latest technological advancements in biogas, including AI, to ensure that biogas plants are operating at their full potential. BDTCs can serve as a vital resource for spreading knowledge about AI's role in biogas technology.

Challenges

While AI offers significant potential for the biogas sector, there are challenges to overcome. One challenge is the availability of high-quality data for training AI models. Biogas plants need to invest in robust data acquisition systems and ensure data accuracy.

Another challenge is the need for skilled personnel to develop, implement, and maintain AI solutions. The biogas industry needs to invest in training and development to bridge this skills gap.

Innovations and Future of AI in Biogas

Despite these challenges, the future of AI in the biogas sector is bright. As AI technology continues to evolve and mature, we can expect even more innovative applications that will further optimize biogas production, enhance efficiency, and contribute to a more sustainable energy future. Several cutting-edge innovations are emerging in the biogas sector in India, driven by the integration of AI and machine learning.

AI-Powered Smart Biogas Plants

A number of start-ups are developing AI-driven smart biogas plants that can automatically adjust parameters for optimal performance. These plants using AI to monitor real-time data from sensors and adjust the system's operations based on the available feedstock and environmental conditions.

- **Block chain and AI for Transparent Supply Chains**

  The integration of block chain with AI is also gaining attention, allowing farmers and entrepreneurs to create transparent and secure supply chains for feedstock collection and biogas production. This could help in increasing trust and facilitating easier access to financial resources or credit.

- AI in Biogas Grid Integration

  AI is also being used to integrate biogas-generated electricity into the national grid. By using machine learning algorithms to predict energy demand and supply, AI can help biogas plants manage their energy output more efficiently, ensuring a steady and reliable energy supply.

Conclusion

In conclusion, AI has the potential to revolutionize the biogas sector by optimizing production processes, improving efficiency, and enhancing sustainability. AI can control key factors like temperature and pH, predict equipment failures, and optimize feedstock mixtures to increase biogas yield. It also helps reduce energy consumption and manage digestate effectively. Although challenges such as data availability and skill gaps exist, AI's ongoing development promises smarter, more sustainable biogas plants.

For India, AI can boost the economic viability of biogas projects, supporting farmers, energy independence, and rural development through government initiatives like the National Biogas Program.

Kapil Kumar Samar
Maharana Pratap University of Agriculture and Technology
Udaipur
kapilsamar@gmail.com

Making Rooftop Solar Bankable: Strengthening the financial support system

The residential rooftop solar sector holds immense potential, not only as a pathway to sustainable energy transition but also as a lucrative investment opportunity. Financial institutions must recognise this dual benefit and actively participate in accelerating sectoral growth. Researchers from the Council on Energy, Environment and Water (CEEW) identify the challenges, explore the market potential, and suggest ways and means to strengthen the financial support system.

Introduction

To achieve India's net-zero targets and keep our homes sustainably powered, decarbonising residential electricity remains critical. In 2024, the launch of *PM Surya Ghar: Muft Bijli Yojana* renewed the push for rooftop solar (RTS) in the residential sector. It aims to solarise one crore households by 2026/27. This presents a promising investment prospect for the financial sector as the residential rooftop market is gaining momentum. Over the past year, there have been over 10 lakh installations; however, deployment is still far from matching up to its potential. According to estimates by the Council on Energy, Environment and Water (CEEW), India has the economic potential to deploy 118 GW of residential RTS, but high upfront costs, low consumer awareness,

Consumer engagement activities, including a live data dart that captures people's reactions and booths by SBI and PNB, at the Solar Fair, Dehradun, December 2024, organised by the Government of Uttarakhand, Uttarakhand Power Corporation Limited (UPCL), and Uttarakhand Renewable Energy Development Agency (UREDA), along with CEEW as the knowledge partner and long installation timelines currently hinder deployment. The introduction of capital subsidies can make RTS adoption economically feasible for more consumers, particularly in the lower slabs — 1 to 3 kW category.

PM Surya Ghar addressed some of these concerns by simplifying and digitising the process and offering subsidies for systems up to 3 kW. The Central Financial Assistance (CFA) for residential RTS systems covers approximately 54% of the benchmark cost for a 3-kW system. However, financing is crucial, as consumers bear the remaining system cost, which can vary based on product specifications (system size, technology, and quality) and geographical and market factors, sometimes exceeding the benchmark cost. Additionally, consumers must pay the developer upfront, as the subsidy is transferred only after net metering is completed. Moreover, consumers installing systems beyond 3-kW capacity must bear additional capital expenditure, again highlighting the need for robust financing options.

Existing financing options and challenges

Earlier, most loan offerings for RTS systems were tied to home loans, limiting options for consumers. *PM Surya Ghar* has attempted to overcome this challenge by encouraging participation beyond nationalised banks to include private banks, non-banking financial companies (NBFCs), and fintech institutions. This has introduced a broader range of financing options for residential consumers installing systems of 1–3 kW and 3–10 kW. Some financial products also cater to residential consumers above 10 kW and commercial and industrial consumers. *PM Surya Ghar* portal is linked with the government's Jan Samarth portal for consumers seeking loan options.

Residential consumers' queries regarding rooftop solar, including financing options, were addressed through a workshop in Dehradun, October 2024, organised by CEEW with UPCL and UREDA

Currently, interest rates vary depending on the lending institution. Public sector banks offer the lowest rates at around 7%, while private banks and NBFCs offer rates ranging from 11% to 14%. Most loans are collateral-free and based on asset hypothecation, with tenures up to 10 years. Despite this diversity of financing options, further efforts are needed to improve accessibility and affordability for broader RTS adoption.

As an early-stage industry, the residential RTS segment faces challenges in gaining widespread financial support and investor confidence. Key challenges include:

- **Low and fragmented demand:** Individual households have low and fragmented demand with small ticket sizes and high consumer acquisition costs for banks. The costs associated with onboarding consumers, background verification, and due diligence add to the financial burden on lending institutions.
- **No credit history:** Many individual borrowers have low or no credit ratings and lack collateral, reducing lender confidence in repayment.
- **Limited understanding among financial institutions:** Many institutions lack information on RTS-specific aspects such as metering, billing, credible vendors, installation quality, and real-time performance tracking.

Market opportunity for residential RTS financing

Overcoming these challenges with the right set of information and financing mechanisms is crucial, as the residential sector presents a vast market for RTS adoption. India has an economic potential (i.e., the estimated RTS potential based on the available rooftop area and restricted to the household electricity demand) of 118 GW in the residential RTS segment. Therefore, considering the system cost of INR 60,000 per kW and assuming that 80% of the total consumers require financing for RTS adoption based on stakeholder consultations with financial institutions, the pan-India investment opportunity can be estimated at INR 5.6 lakh crore (approximately 64.6 billion dollars). This potential and investment opportunity spans across states in both urban and rural areas, with urban regions having

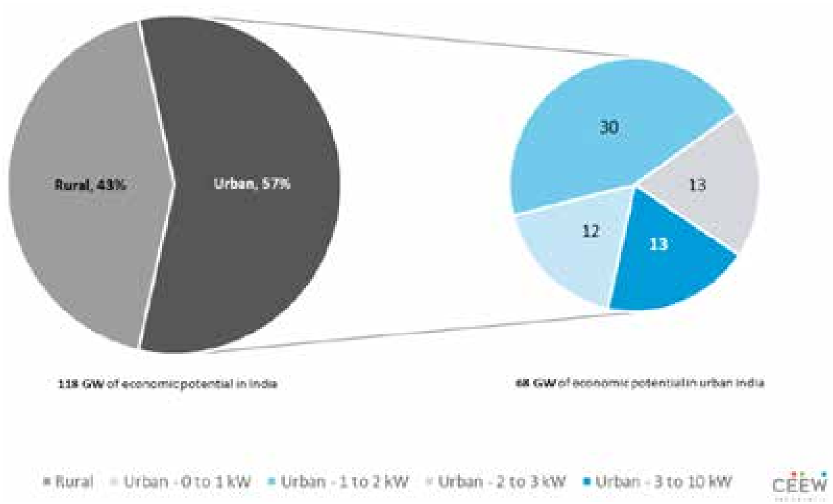


Figure 1: Market opportunity of ~13 GW economic potential lies in the 3–10 kW category in urban India

Source: Authors' adaptation from CEEW (2023)

higher economic potential due to greater electricity demand per square foot (7.7 kWh per sq. ft in urban areas vs 6.8 kWh per sq. ft in rural areas). The market potential is also skewed towards urban geographies due to higher economic feasibility and consumer willingness to pay. While the CFA covers system sizes between 1 and 3 kW, nearly 13 GW of potential lies in the 3–10 kW category in these areas (Figure 1).

Strengthening the financing ecosystem

Financial institutions play a foundational role, given the significant investment opportunities in the sector. To develop a robust financing ecosystem to accelerate RTS adoption in the residential segment, we recommend the following steps:

- Capacity building of financial institutions: Explainers on efficiency, system functioning, metering regimes, and operations and maintenance practices need to be developed for financial institutions to disseminate the required technical information on rooftop solar and build their confidence in the sector. Furthermore, targeted capacity-building exercises will equip the bank personnel handling residential RTS loans with information on the application, installation, and subsidy disbursal process.
- Fast-tracking the vendor rating programme implementation: Under PM Surya Ghar, financial institutions require adequate information to evaluate vendors in the RTS segment. A standardised vendor rating system—based on consistent and specific criteria like consumer feedback, techno-financial assessment, and quality control—needs to be implemented to help lenders partner with technically and financially sound vendors.
- Introduction of innovative financing products: Financial institutions should develop bespoke financial products that offer specific solutions based on technology parameters (e.g., RTS system sizes and metering regimes) and consumer market segmentation. For instance, by enhancing the existing digital processes, financial institutions can provide quick loan approval and disbursal features while also simplifying document requirements. Additionally, digital processes can be used to track repayment schedules and progress, including the subsidy credited to the loan account.

The residential RTS sector holds immense potential, not only as a pathway to sustainable energy transition but also as a lucrative investment opportunity. Financial institutions must recognise this dual benefit and actively participate in accelerating sectoral growth.

Addressing queries of consumers and students at the Solar Fair, Dehradun, December 2024, organised by the Government of Uttarakhand, UPCL, and UREDA, along with CEEW as the knowledge partner

Megha Chaudhary, Arohi Patil, and Bhawna Tyagi

Council on Energy, Environment and Water (CEEW)

megha.chaudhary@ceew.in

Interesting insights into renewable energy throughout history and around the globe

Solar energy is almost 200 years old

Solar energy is not a recent innovation. In 1839, Alexandre Edmond Becquerel discovered the 'photovoltaic effect,' the process of generating electricity from direct sunlight, now known as solar energy. In 1941, Russel Ohl invented the solar cell. In the 1950s, NASA became the first to adopt solar technology, using it on the Vanguard satellite, which remains the oldest satellite in orbit

Iceland leads the world with near 100% energy produced from renewable sources

While many countries globally are focused on reducing their carbon emissions, some have made remarkable progress in eliminating them entirely. Iceland leads the way, now nearly 100% powered by renewable energy, thanks to its vast geothermal and hydro resources.

Romans were the first to use geothermal energy to heat their homes

Geothermal energy usage dates back to the Romans, who designed buildings that allowed warm air to circulate beneath floors and within walls to heat their homes. Additionally, the Romans utilized direct geothermal energy by constructing communal baths at hot springs throughout Italy.

Solar energy can be stored in salt

Molten-salt technology, also known as molten-salt energy storage (MSES), involves using concentrated sunlight to melt salt at 131 degrees Celsius. The liquid salt is stored in an insulated tank, where it can retain thermal energy for up to a week with proper insulation. When electricity is needed, the hot molten salt is pumped to a conventional steam generator, producing superheated steam to power a turbine/generator set, similar to those in coal, oil, or nuclear power plants. This technology is now widely used in most solar thermal power plants.

Wind turbines have around 8,000 parts

Although modern wind turbines appear sleek and streamlined, they are surprisingly complex, made up of roughly 8,000 parts. These giants stand about 60 meters tall, with a total height of 90 meters when the blades and turbine are included. We've come a long way since humans first began using wind power over two thousand years ago. Explore the evolution of wind turbines here.

Source: *brunel.net*

India's PV Quality Infrastructure Boost for Calibrating Solar Cells

As part of MNRE's Research and Development Scheme, CSIR-NPL, in collaboration with PTB, Germany, has rolled out reference solar cell calibration services in August 2024. This service is expected to bring in more transparency and certainty in the assessment of PV product value which could enhance 'informed decision-making' when it comes to investments in the solar PV sector. This is clearly a welcome development as the dependency on national measurements institutions (NMIs) overseas for such assessments is now passè

Introduction

India has been witnessing a 'Solar Revolution' over the past few years. With deployment of solar PV infrastructure dotting the country at an unprecedented scale and spread, the feverish pitch of a 'Solar Revolution' is likely to continue and is expected to be a 'normal' phenomenon in the coming time.

The Government of India's resolve to achieve its 2030 and 2070 climate commitments, the Ministry of New and Renewable Energy's (MNRE's) nimble feet in executing and broadening the RE canvas in the country, and our researchers and scientists in India's R&D institutions stepping up to support the 'climate cause', etc. are all functioning in perfect alignment like a well-oiled machine.

In this fast-paced journey, India has closed a major R&D gap, which is that of measuring the efficiency of PV cells. Assessing the efficiency of PV cells is critical to estimating the investment required in a PV deployment scenario. Till recently, India depended on one of the four external NMIs for this service.

The four qualified 'World Photovoltaic Service' (WPVS) laboratories are (a) the National Renewable Energy Laboratory, NREL, USA; (b) Physikalisch Technische Bundesanstalt (PTB), Germany; (c) the National Institute of Advanced Industrial Science and Technology, AIST, Japan; and (d) Tianjin Institute of Power Sources, TIPS, China.

The CSIR-NPL's National Primary Standard Facility for Solar Cell Calibration, established in collaboration with PTB, Germany, has now come up as the fifth international laboratory. This facility will cater to the needs of stakeholders across the solar PV value chain in the estimation of PV product value with best accuracy.

Mooted in 2017 by MNRE, the objective of the project is to establish 'Laser-based Differential Spectral Responsivity (L-DSR) Measurement System' for reference solar cells at CSIR-NPL. The project work was proposed under scientific co-operation with PTB, Germany, and an agreement was signed between CSIR-NPL and PTB, Germany, in September 2018 for the joint development of the LDSR facility.

L-DSR Facility and Its National Significance

The L-DSR Facility at CSIR-NPL has the ability to measure the uncertainty level to the tune of 0.35% (at k=2) in short-circuit current of WPVS reference solar cell device. In other words, this facility is the best in the world among the four WPVS laboratories, which can measure the short-current with the lowest uncertainty of 0.35% at k=2 in the calibration of reference solar cells.

The facility has a significant role to play in improving the PV quality infrastructure in the country and will enable savings of foreign exchange reserves and the turn-around time as the reference cells of the PV testing and calibration labs and PV industry could be calibrated within the country itself.

Besides providing the cushion of 'self-reliance' for such measurements in the country, the lowest measurement uncertainty helps in estimating the PV product value more accurately and hence avoids financial implications of stakeholders across the solar PV value chain.

For instance, an uncertainty of 1% in efficiency measurement may lead to the ambiguity of Rs 2000 crore in the product value (assuming the cost @ Rs 2 crore per MW) for the solar installations of 100 GW. This would create barriers to the deployment of PV technology and it is deterrence to the investors and other stakeholders in the solar PV value chain.

About the National Primary Standard Facility

The goal of a solar cell calibration is the determination of the short circuit current under standard test conditions (AM1.5G spectrum according to IEC 60904-3, 1000 W/m^2 and cell temperature of 25 °C). This can be performed with integral measurements under a sun simulator or under natural sunlight. In both cases the spectrum of the source, especially with the difficulty to measure its absorption lines, must be measured and taken into account and this leads to additional uncertainty components.

The alternative is to determine the absolute spectral irradiance responsivity and to calculate the short circuit current. In this case the exactly defined spectrum from the standard IEC 60904-3 is used directly, thus there is absolutely no measurement uncertainty concerning the spectrum.

The principle of the new setup is identical to the conventional lamp-based facility in a few ways, such as a chopped uniform monochromatic beam and sun-like bias lamps irradiate the solar cell under test. The signal produced by the solar cell under the chopped beam irradiation is measured with a lock-in amplifier and is used to determine the absolute differential spectral responsivity and therewith the current under standard test conditions.

The main difference of the new setup is the source of the monochromatic light. Instead of a quartz halogen lamp or a xenon lamp, the new setup uses a tunable laser that is coupled into the monochromator via a quartz fiber. The laser beam starts at a widely tunable mode-locked Ti:sapphire laser with a repetition rate of 80 MHz. The pulse duration is about 120 fs. Depending on the wavelength needed, the beam passes an optical parametric oscillator (OPO) and/or a second, third or fourth harmonic generator (SHG, THG, FHG).

Most of the laser components are purpose-built items that have a wider wavelength range, a higher efficiency and better automated to minimize the

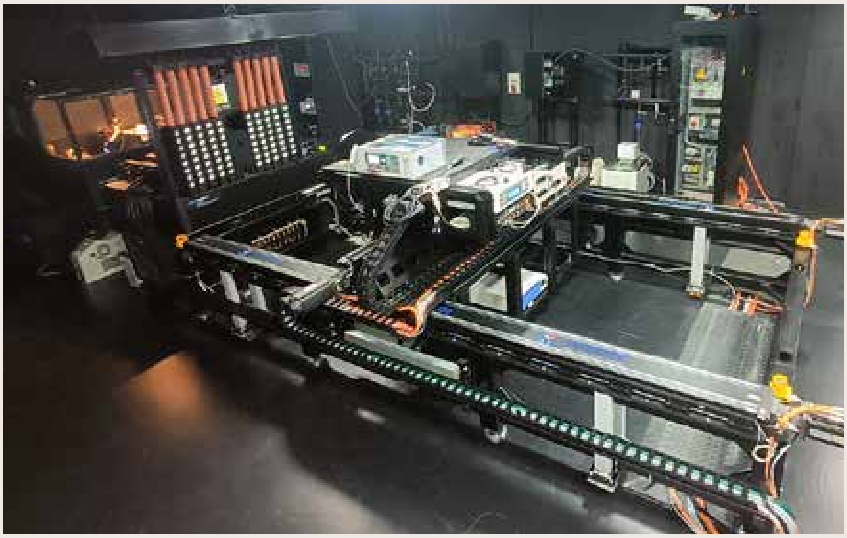


Figure 1. National Primary Standard Facility for Solar Cell Calibration established at CSIR-NPL

measurement intricacies. The beam routing is done by computer-controlled mirror mounts. This enables a fully automated wavelength selection from 210 nm up to 4000 nm.

Before the laser beam is coupled into a fiber, it passes through a neutral density filter wheel and a chopper. A monochromator reduces the spectral bandwidth and two lenses create a uniform monochromatic irradiation at the measuring plane. This is because the spectrum of the pulsed laser has (a) too wide a spectral bandwidth, (b) outer-band peaks, and (c) a small part of the SHG signal in the THG signal. Thus a monochromator is needed to obtain a well-defined wavelength.

Up to 80 individually switchable bias lamps create a uniform bias irradiation of up to 10,000 W/m2. The measurement plane can be tilted from 1° to 91° and rotated from 10° to 370°. Thus it can be used as a solar cell goniometer to irradiate the solar cell from any direction to measure a spectrally resolved angle dependence.

The temperature of the solar cells is controlled by the combination of water cooling and Peltier elements.

A beam splitter reflects a small part of the monochromatic radiation behind the monochromator to a monitor photodiode. This enables a correction if the irradiance level of the monochromatic beam changes.

The power measurements were performed with the laser system in dependence on the wavelength. The maximum power of about 3800 mW is obtained at 800 nm. Behind the monochromator still more than 100 mW of optical power is obtained at this wavelength. The lamp-based system produces a maximum power of about

Figure 2. WPVS reference solar cells 009-2019 and 010-2019 used to assess the performance of the system

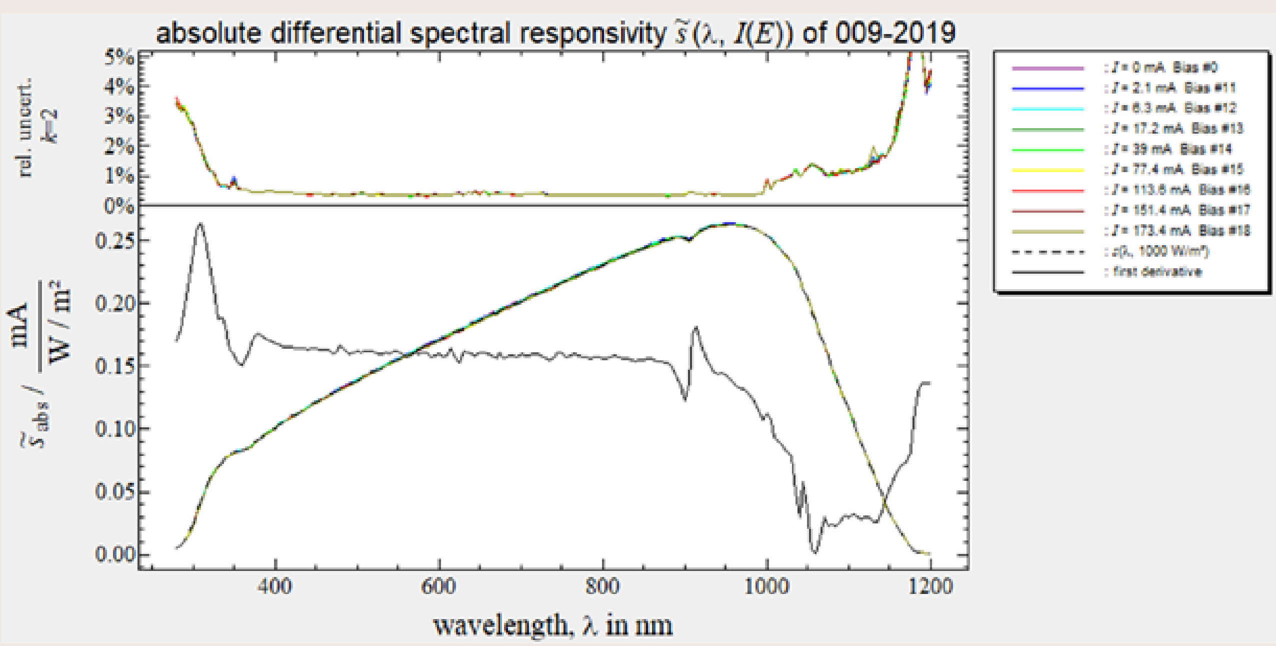


Figure 3. Differential spectral responsivity at different bias levels for WPVS reference c-Si solar cell (009-2019). Graph on top-side of the DSR plots in both the figures show the uncertainty budget of each component involved and their integral as well.

100 µW under the same bandwidth conditions. The increase of the optical power behind the monochromator is a wavelength-dependent factor between 100 and 10,000. The high power is helpful to improve the uniformity of the monochromatic field, and to increase the distance of the solar cell from the effective origin of the radiation and to decrease the spectral bandwidth of the radiation.

The calibration objects were two reference solar cells in WPVS design labelled 009-2019 and 010-2019, as shown in Figure 2. These are made from a crystalline silicon solar cell with glass cover encapsulation. The most crucial measure for PV traceability is the short-circuit current under standard test conditions (ISTC) since it correlates directly to the irradiance conditions defined in the IEC 60904-3 standard. In order to validate calibration facilities, intercomparisons are performed to compare calibration values (CVs) of a common unknown set of PV devices. The intention of this intercomparison was the final assessment of these facilities with regard to calibration at standard test conditions (STC). Standard measurement procedures were applied to measure differential spectral responsivity of WPVS cells and the results are shown in Fig. 3.

The uncertainty analysis uses a detailed Monte Carlo approach and is performed for each measurement. It automatically takes into account the individual noise level of the measurement signal, the spectral responsivity of the particular test cell and the actual uniformity of the measurement field. In addition, correlations of the uncertainties are taken into account, when the uncertainty of the AM1.5-weighted integral is calculated. The different uncertainty components, such as spectral band width, spectral mismatch, non-uniformity of monochromatic radiation etc., are considered. The uncertainty analysis results in a standard uncertainty (type A and type B) of 0.2% for typical reference solar cells area with WPVS design, while for 156x156 mm2 area the standard uncertainty is 0.3%.

The LDSR system performance at CSIR NPL has been ensured with round-robin measurement with the conventional DSR facility of PTB. The primary calibration of a WPVS reference solar cell with an expanded measurement uncertainty of 0.35% at this facility at k=2. This calibration result was consistent within the stated uncertainties with primary calibration performed at PTB DSR system and the data is shown in Table 1.

Table 1. Intercomparison measurements and En numbers evaluated using ISO/IEC 17043

WPVS reference solar cell ID	ISTC / mA LDSR, NPL	ISTC / mA DSR, PTB	EN
010-2019	146.07 ± 0.42	146.20 ± 0.52	0.19
010-2019	146.00 ± 0.42	146.20 ± 0.52	0.30
009-2019	145.78 ± 0.41	145.65 ± 0.53	0.19

The |En| values evaluated according ISO/IEC 17043 standard are smaller than 1 and hence these calibrations are considered to be consistent within their stated uncertainties of the participant laboratories in intercomparison.

Conclusion

A lot of effort has gone into establishing this state-of-the-art facility at CSIR-NPL and the project has been successful. The facility is now open to provide Apex Level Calibration services to the PV stakeholders with highest accurate measurements, the lowest measurement uncertainty (0.35% at k=2) in solar cell current among the WPVS laboratories. The Indian PV community is expected to utilize the in-house opportunity in the country, which saves turn-around time and foreign reserves significantly.

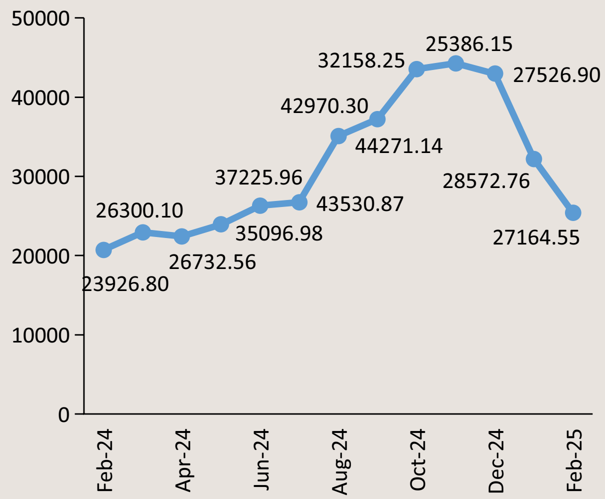
Prathap Pathi
CSIR - National Physical Laboratory
New Delhi
prathap@nplindia.res.in

Arun K Tripathi
Ministry of New and Renewable Energy
Government of India

We invite readers of *Akshay Urja* to share your stories about technology and innovations, as well as your perspectives on future advancements in the renewable energy sector. Submissions can be 400, 800, or 1600 words in length, and should include high-resolution photos that enhance your narrative. Please send your contributions to:

Editor
Akshay Urja
Ministry of New and Renewable Energy
Atal Akshaya Urja Bhawan, Pragati Vihar
New Delhi – 110003
Email: infodesk@teri.res.in
akshayurja@nic.in

All India Total Renewable Energy Generation in February 2025



Source: CEA

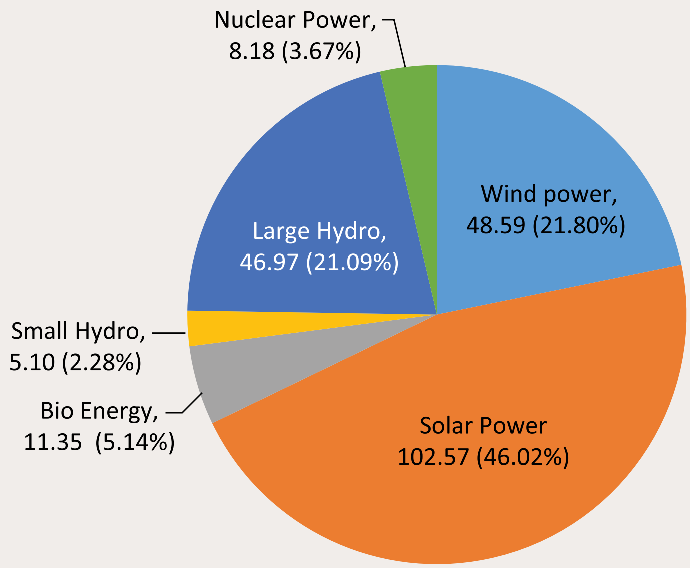
Month	Wind	Solar	Biomass	Bagasse	Small Hydro	Large Hydro	Others	Total (MU)
Feb-24	4907.58	10421.22	271.07	1725.32	442.67	5928.16	230.77	23926.80
Mar-24	4578.06	12225.83	305.15	1455.71	468.22	7015.7	251.42	26300.10
Apr-24	4729.26	12021.05	278.73	781.11	581.9	8109.14	231.36	26732.56
May-24	8257.63	12645.99	295.16	317.07	734.16	12595.42	251.56	35096.98
Jun-24	10134.92	11445.66	273.43	188.61	776.37	14173.69	233.29	37225.96
Jul-24	13627.00	10356.35	284.12	132.36	1323.02	17562.91	245.11	43530.87
Aug-24	10268.88	10157.52	297.05	132.17	1600.37	21565.90	249.24	44271.14
Sep-24	8870.62	11302.62	258.15	118.58	1612.83	20574.25	233.26	42970.30
Oct-24	3238.28	12256.61	337.9	166	1457.59	14455.88	245.98	32158.25
Nov-24	3109.33	11246.52	321.47	980.79	860.92	8630.89	236.23	25386.15
Dec-24	5747.49	10707.21	350.76	1935.01	807.35	7753.43	225.65	27526.90
Jan-25	5637.69	12285.74	356.41	2041.06	624.57	7388.05	239.24	28572.76
Feb-25	4592.48	12913.58	339.16	1556.29	561.87	6970.88	230.79	27164.55

Source: CEA

State wise RE Generation (MU)		
Name of State/UT	**Feb-25**	**Feb-24**
NORTHERN REGION		
Chandigarh	0.40	0.63
Delhi	59.59	63.64
Haryana	194.75	146.51
Himachal Pradesh	1089.87	1272.71
Jammu & Kashmir	327.43	526.43
Ladakh	11.84	12.11
Punjab	448.37	470.60
Rajasthan	4371.48	4029.35
Uttar Pradesh	1051.37	910.68
Uttarakhand	877.65	711.20
SUB TOTAL (NR)	**8432.76**	**8143.86**
WESTERN REGION		
Chhattisgarh	341.08	241.64
Gujarat	3780.65	3283.67
Madhya Pradesh	1606.90	1255.99
Maharashtra	2085.53	1865.50
Dadra and Nagar Haveli and Daman and Diu	2.68	2.63
Goa	5.44	5.44
Sub Total (WR)	**7822.28**	**6654.87**
SOUTHERN REGION		
Andhra Pradesh	1413.90	1388.76
Telangana	785.47	738.33
Karnataka	4034.94	3032.13
Kerala	639.54	565.08
Tamil Nadu	2834.71	2214.54
Lakshadweep	0.01	0.01
Puducherry	1.02	1.02
SUB TOTAL (SR)	**9709.59**	**7939.87**
EASTERN REGION		
Andaman Nicobar	2.42	3.84
Bihar	55.32	40.61
Jharkhand	18.65	8.16
Odisha	475.37	529.23
Sikkim	45.75	30.70
West Bengal	325.38	306.42
SUB TOTAL (ER)	**922.88**	**918.96**
NORTH-EASTERN REGION		
Arunachal Pradesh	108.76	150.00
Assam	77.87	46.20
Manipur	39.25	11.61
Meghalaya	32.34	35.04
Mizoram	12.51	20.00
Nagaland	5.83	5.87
Tripura	0.49	0.53
SUB TOTAL (NER)	**277.05**	**269.25**
ALL INDIA TOTAL	**27164.55**	**23926.80**

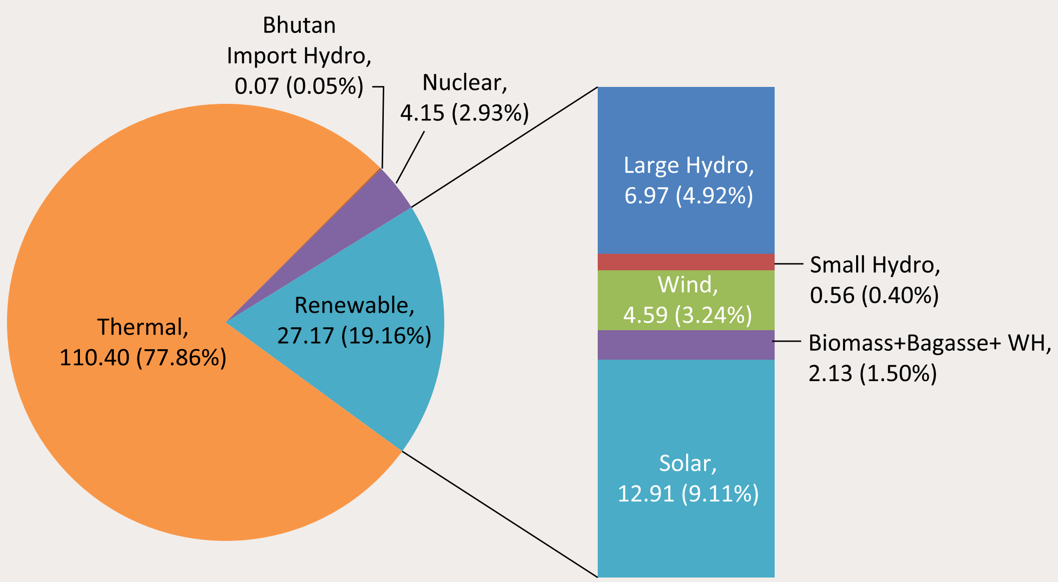
Source: CEA

INSTALLED RE CAPACITY AS ON 28-02-2025: 222.86 GW

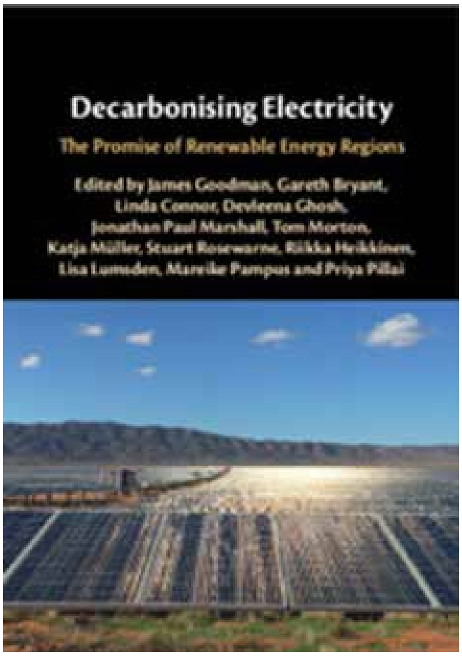


Source: MNRE

ALL INDIA MONTHLY ENERGY GENERATION IN INDIA, 141.79 BU AND SHARE OF RE, 27.17 BU (19.16%) FEBRUARY 2025



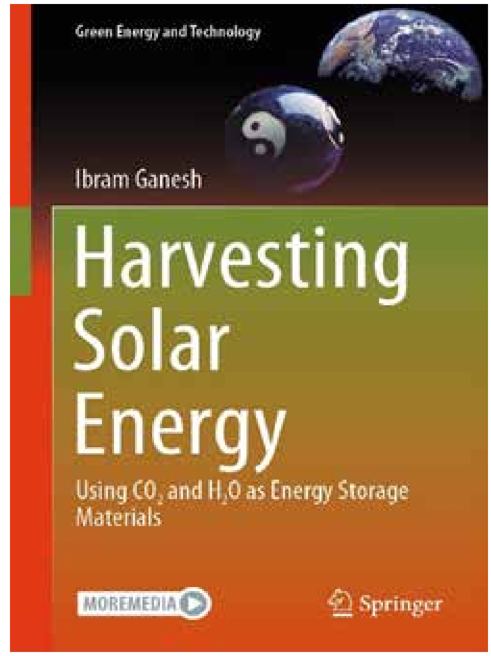
Source: CEA



Decarbonising Electricity: The Promise of Renewable Energy Regions
Author: Goodman, James et. al
Publisher- Cambridge University Press
Year: 2025
ISBN: 9781009485616

The present transition to renewable energy is led by multinational energy corporations constructing extensive wind and solar facilities. This book examines the ramifications and opportunities of this transition in India, Germany, and Australia, concentrating on areas that have predominantly decarbonized their energy generation. The authors illustrate the maintenance of centralized energy provision models and delineate its effects on energy geography, socioeconomic stratification, and socio-ecological appropriation. The chapters underscore the significant influence of state regulation, financial incentives, and public infrastructure on corporate renewables, contending that public provision should be redirected towards distributed renewables, social fairness in impacted areas, and broader societal advantages. This interdisciplinary book offers a robust foundation for study and application in future energy transitions. It offers a comprehensive analysis of the factors facilitating and hindering renewable energy development encountered by nations, irrespective of their economic status. Provides insights into the experiences and effects of energy transitions on local communities. Highlights an interdisciplinary examination of renewable energy transitions, using insights from environmental studies, sustainability studies, and political economy.

https://www.cambridge.org/in/universitypress/subjects/earth-and-environmental-science/environmental-policy-economics-and-law/decarbonising-electricity-promise-renewable-energy-regions?format=HB&isbn=9781009485616



Harvesting Solar Energy: Using CO_2 and H_2O as Energy Storage Materials
Author- Ganesh, Ibram
Publisher- Springer
Year- 2025
ISBN- 978-981-96-2320-4

This book introduces artificial photosynthesis (AP), which enables the capture and storage of solar energy to fulfill our energy requirements. Additionally, renewable, carbon-neutral, high-energy-density liquid fuels compatible with the current energy distribution infrastructure can be synthesized by the AP process utilizing carbon dioxide, water, and solar-derived electricity. The sole method to achieve sustainability in energy, environment, economics, and life is to harness sunlight to fulfill societal energy requirements, utilizing carbon dioxide and water for energy storage.

https://link.springer.com/book/10.1007/978-981-96-2321-1

NATIONAL

Global conference on Renewable Energy and Climate Change (GCRECC)
May 9, 2025 | Ambarnath, India

Mercom India Renewables Summit
July 24-25, 2025 | New Delhi, India

4th Green Hydrogen India
August 6-8, 2025 | New Delhi, India

Energy Transition Summit India
September 16-17, 2025 | New Delhi, India

Renewable Energy India Expo 2025
October 30, 2025 - November 1, 2025 | New Delhi, India

INTERNATIONAL

Intersolar Europe – The World's Leading Exhibition for the Solar Industry
May 7-9, 2025 | München, Germany

All-Energy 2025
May 14-15, 2025 | Scotland, United Kingdom

British Renewable Energy Awards 2025
June 12 , 2025 | Piccadilly, London, UK

SNEC International PV Power Generation and Smart Energy Conference & Exhibition
June 11-13, 2025 | Shanghai, China

ACM e-Energy 2025
June 17-20, 2025 | Rotterdam, Netherlands

RNI No DELENG/2007/22701

The National Bioenergy Programme seeks to advance bioenergy technologies and has achieved key milestones, such as the installation of biogas plants for families and medium-sized businesses, support for biomass-based cogeneration, and the promotion of briquette and pellet production.

https://biogas.mnre.gov.in/