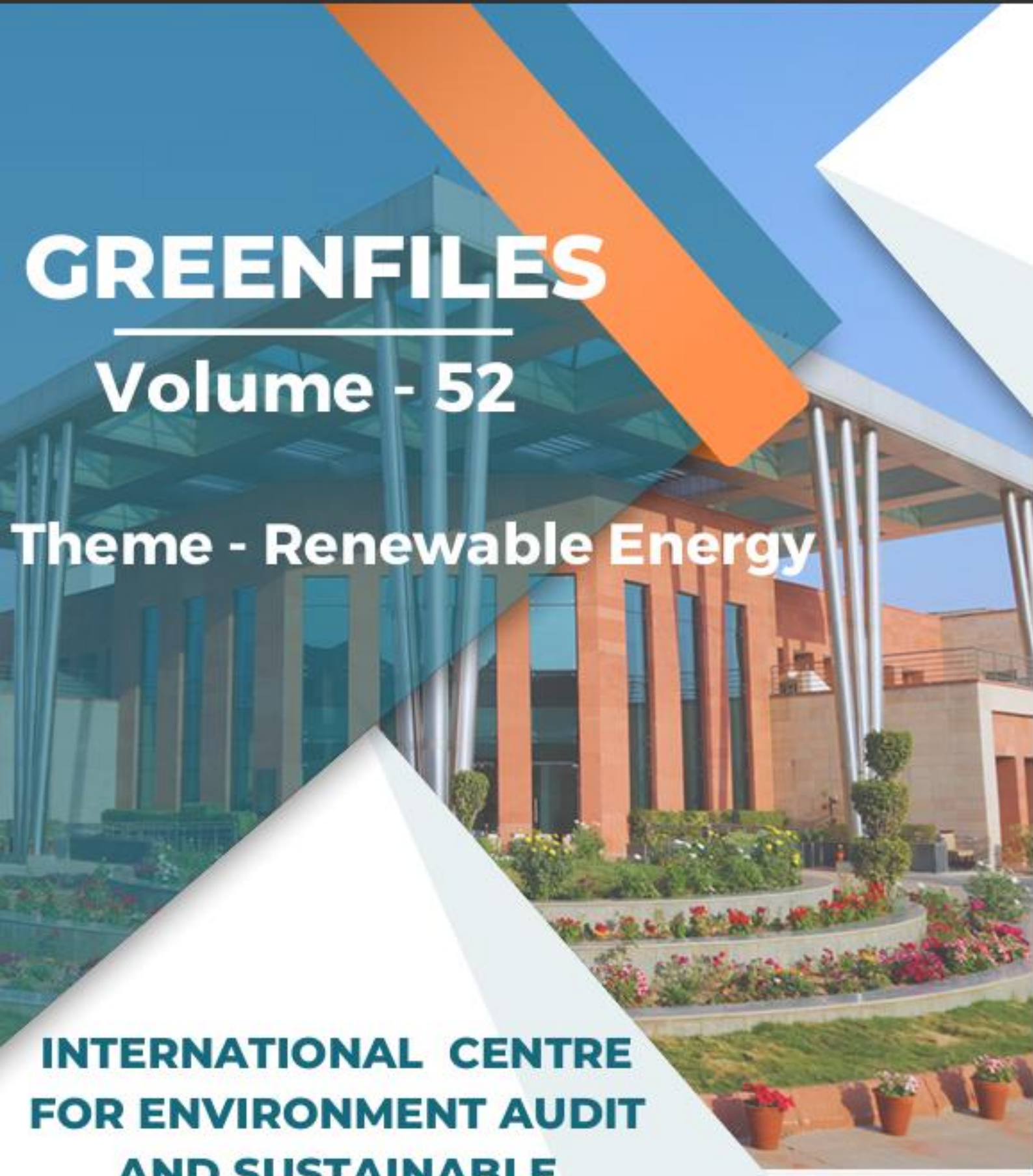
GREENFILES

Volume - 52

Theme - Renewable Energy



INTERNATIONAL CENTRE FOR ENVIRONMENT AUDIT AND SUSTAINABLE DEVELOPMENT

iCED

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We thank all the contributors for their immensely valuable contributions and for making this endeavour a success.

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Foreword

In the 52nd edition of *The Green Files*, iCED's quarterly journal, we delve into the field of India's growth and challenges faced in Renewable Energy.

As the world is transitioning towards a cleaner and sustainable sources of energy, India stands at forefront in clean energy. With its vast potential in Solar, Wind, Hydro, and Biomass Energy, India is making significant strides toward reducing dependence on fossil fuels and mitigating climate change.

For achieving self-sufficiency in energy and accepting its role towards a sustainable energy source for better future of coming generations, India is committed to achieve 500 Gigawatt of non-fossil fuel-based energy. In the year 2024, India demonstrated a record-breaking addition of 24.5 Gigawatt of Solar Energy capacity and 3.4 Gigawatt of Wind Energy capacity.

This newsletter highlights the latest developments, policies, and innovations in India's renewable energy sector. From government initiatives to grassroot efforts, we explore how India's energy shift from fossil based energy to renewable energy is shaping the future.

On behalf of the entire team of "Green Files" at iCED, we look forward to your suggestions to make Green Files as informative and user friendly as possible. Your contributions within the broad scope of this quarterly journal will be highly appreciated, including any feedback you may like to share on the featured articles.

(Dr. Abhishek Gupta)
Additional Dy. Comptroller and Auditor General and Director General,
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Message from the Director (Training & Research)

Dear Readers,

I am happy to present iCED's quarterly journal, "Green Files," 52nd edition. This issue is dedicated to a theme of paramount importance – **Renewable Energy.** In this edition we are focusing on India's pathway towards achieving self-sufficiency in energy in a sustainable way.

This edition brings together diverse perspectives and critical analyses that reflect India's dynamic renewable energy landscape. From the rhythmic interplay of natural forces explored in *The Eternal Dance of Nature's Power* to the strategic direction outlined in *India's Path to Renewable Energy*, the issue offers a comprehensive overview of progress, challenges, and the road ahead.

Further, we delve into the role of government initiatives and landmark policies that are driving growth in clean energy (*Government Initiatives Driving India's Renewable Energy Growth*), and assess sector-specific trends through articles on solar, wind, and hydropower. Each sector carries unique opportunities and ecological considerations, as discussed in *The Rise of Solar Energy in India*, *Challenges and Opportunities in India's Wind Energy Sector*, and *Hydropower in India: Balancing Growth and Environmental Sustainability*. Importantly, we also spotlight emerging frontiers—*India's Green Hydrogen Revolution* and the integration of *Electric Vehicles*—that promise to redefine the future of energy consumption and emissions reduction in India.

We hope this newsletter informs, inspires, and encourages action. The shift to clean energy is not just a necessity—it's an opportunity to build a greener, self-reliant India.

(Mehul Grover)
Director (Training & Research) iCED, Jaipur

Contents

International Events in the Field of Environment

By: Shri Manoj Kumar, SrAO, Shri. Ravi Kumar, Sr Auditor

1. 29th United Nations Climate Change Conference

The 29th United Nations Climate Change Conference (Conference of the Parties 29) took place from November 11 to 24, 2024, in Baku, Azerbaijan. This conference convened nearly 200 countries to deliberate on pressing climate issues, with a central focus on establishing a new global climate finance goal.

The conference commenced with the World Leaders Climate Action Summit on November 12, where Heads of State and Government convened to discuss and reinforce commitments to global climate action.[1]

Outcomes of the Conference

A landmark achievement of Conference of the Parties 29 (COP 29) was the agreement on the New Collective Quantified Goal on Climate Finance (NCQG). Developed countries committed to mobilizing at least $300 billion annually by 2035 to support developing nations in their climate mitigation and adaptation efforts which aims to facilitate the transition to clean energy, enhance climate resilience, and address the impacts of climate change in vulnerable regions[2].

Additionally, COP 29 reached consensus on operationalizing Article 6 of the Paris Agreement, which pertains to carbon markets. This development is expected to enable countries to collaborate more effectively in achieving their climate targets through market-based mechanisms.

India's Role in Conference of Parties 29

India put forth its stance on the following issues that are critical in fight against Climate Change. They are:

New Collective Quantified Goal on Climate Finance (NCQG)

India highlighted that as grant-based concessional Climate Finance is the most critical enabler to formulate and implement the new Nationally Determined Contributions, action will get severely impacted in the absence of adequate means of implementation.

Mitigation

India strongly protested changing the scope of the Mitigation Work Programme (MWP) in the draft text. India further cautioned against shifting of temperature goals, which need to be as per the exact language in the Paris Agreement. India called the introduction to the targets for 2030, 2035 and 2050 in the preamble as purely prescriptive.

India urged to add to the text certain elements like noting the pre-2020 mitigation gap by Annex-I Parties; noting with strong concern that the emission of Annex-I Parties is increasing from 2020 to 2030 etc.

India, also, strongly declined to accept any renegotiation of the shared understanding

[1] Report of the Conference of the Parties on its twenty-ninth session, held in Baku from 11 to 24 November 2024

[2] COP 29 Updates

prevalent on **'Just Transitions'** in the decision from Dubai.

Global Stocktake:-

On the Global Stocktake India stated the following:

i. India does not agree to a follow up of the Global Stocktake outcomes. As per Paris agreement, Global Stocktake is supposed to only inform parties to undertake climate action.

ii. The new chapeau on Enhancing Action, Support and International Cooperation has been drafted without adequate connection or integration with the text, parts of which are under negotiation on the United Arab Emirates dialogue.

iii. The last text from the negotiations undertaken by Parties was one that captured the views of all Parties and was a viable basis for further negotiation. The new options under the Section titled Modalities of the United Arab Emirates dialogue does not capture this at all.

- Further, the phrase "with developed countries (as per the synthesis report of the Biennial Reports) on track to increasing their emissions by 0.5 per cent from 2020 to 2030" may be added after the phrase "by 2.6 per cent by 2030 compared with the 2019 level".
- Though the new chapeau title is general, the text added is completely mitigation centric and completely unbalanced. India does not accept this text.
- India does not accept the way the options have been formulated in the Timing and Format sections of the United Arab Emirates dialogue.

Adaptation

India shared the following points, which are essential to consider the draft decision:

- Outcome should include indicators on means of implementation for this work on global goal on adaptation to be meaningful.
- There is no need to further focus on transformational adaptation. Instead, it is important to focus on other approaches such as incremental adaptation, long term adaptation in the context of national circumstances.
- The data used for reporting on indicators should be taken from Party submitted reports and not from any third party databases. Therefore, this text may be dropped[3].

2. Sixteenth Session of the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD)

The 16th Conference of the Parties (COP16) to the Convention on Biological Diversity (CBD) was convened from October 21 to November 1, 2024, in Cali, Colombia. Delegates from 196 nations gathered to advance global biodiversity conservation efforts, focusing on implementing the Kunming-Montreal Global Biodiversity Framework (KMGBF).

A significant achievement of COP16 was the establishment of the **Cali Fund**, a multilateral mechanism designed to ensure fair and equitable sharing of benefits arising from the use of Digital Sequence Information (DSI) on Genetic Resources. Companies utilizing genetic data,

[3] PIB: India's Intervention at the Plenary Session of the UNFCCC-CoP29

particularly in pharmaceuticals and cosmetics, are encouraged to contribute a portion of their profits to this fund. Notably, 50% of the fund's proceeds are earmarked for Indigenous People and local communities, acknowledging their stewardship of biodiversity-rich regions[4].

Additionally, COP16 established a permanent subsidiary body dedicated to Indigenous People and local communities (IPLCs), granting them a formal platform to influence Convention on Biological Diversity negotiations and policies[5].

India's role in Convention of Biodiversity (COP 16):-

India actively contributed to global biodiversity conservation efforts. The Press Information Bureau (PIB) of India released several documents highlighting these contributions:

- **Updated National Biodiversity Strategy and Action Plan (NBSAP):** India unveiled its Updated National Biodiversity Strategy and Action Plan. This plan adopts a 'Whole-of-Government' and 'Whole-of-Society' approach, aligning with the Kunming-Montreal Global Biodiversity Framework (KMGBF). It emphasizes ecosystem restoration, species recovery programs, and community-driven conservation efforts[6].
- **'Plant4Mother' Campaign:** A plantation drive was initiated under the 'Ek Ped Maa Ke Naam' initiative, also known as the 'Plant4Mother' campaign, at the University of Valle in Cali, Colombia[7].

3. Sixteenth session of the COP16 of the United Nations Convention to Combat Desertification (UNCCD)

The sixteenth session of the Conference of the Parties (COP16) of the United Nations Convention to Combat Desertification (UNCCD) took place in Riyadh, Saudi Arabia, from 2nd to 13rd December 2024 under the theme *Our Land. Our Future*, with aim to address pressing issues related to desertification, land degradation, and drought (DLDD) on a global scale[8].

Key Financial Commitment:
During the conference, over $12 billion was pledged towards combating desertification and enhancing drought resilience, primarily benefiting vulnerable countries[9].

India's role in United Nations Convention to Combat Desertification (UNCCD):-

Union Minister for Environment, Forest and Climate Change, represented India at COP16 of UNCCD. India's achievement and Schemes for desertification:-

- One of the key approaches to address land degradation and drought is the improvement of water conservation practices such as river rejuvenation and creation of water retention structures. In India a special initiative i.e. *Amrit Sarovars,* has been taken to develop and rejuvenate water bodies in each district.
- Soil Health Cards are provided to farmers to understand changes in soil health affected by land management.
- Indian government's target is restoring 26 million hectares of degraded land by 2030, of which more than 22.50 million hectares has already been restored[10].

[4] UNEP: Key Decisions in COP16
[5] COP16: Landmark biodiversity agreements adopted | UN News
[6] PIB: National Biodiversity Strategy and Action Plan
[7] PIB: Plant4Mother
[8] UNCCD: COP16
[9] UNCCD: Press Release
[10] PIB: India's statement at COP16

The Eternal Dance of Nature's Power: Renewable Energy

By: Rahul Yadav, AAO

"Renewable energy is the rhythm of nature, a symphony composed by the elements themselves. Unlike the dwindling fossil fuels that scar our earth, renewable energy flows endlessly, a gentle yet mighty force harnessed by human ingenuity."

- Rahul Yadav

Renewable energy refers to energy derived from natural resources that are replenished on a human timescale or it is the energy derived from natural resources[1] that are replenished at a higher rate than they are consumed.

Unlike fossil fuels, which are finite and contribute significantly to environmental pollution, renewable energy sources are generally more sustainable and have a lower environmental impact. Also, because renewable energy sources are by definition, renewable and replenished, the estimation of the resource quantity is in theory infinite. Sunlight and wind, for example, are such sources that are constantly being replenished, they are plentiful and all around us.

Fossil fuels like coal, oil and natural gases on the other hand, are non-renewable resources that take hundreds of millions of years to form. Fossil fuels, when burned to produce energy, produce harmful greenhouse gas emissions, such as CO_2, CH_3, and NO. Generating renewable energy creates far lower emissions[2] than burning fossil fuels.

Transitioning from fossil fuels, which currently account for the lion's share of emissions, to renewable energy is key to address the climate crisis.

Energy Sources	Solar Energy	Wind Energy	Geothermal Energy	Hyrdropower	Ocean Energy	Bio Energy
Nature's Gift	Sunlight, the celestial brushstroke	The whisper of the winds	Earth's inner warmth	The movement of water	Tides and waves	Organic matter & waste
Method of Harnessing	Photovoltaic panels & mirrors	Onshore & offshore turbines	Wells tapping into reservoirs	Dams & run-of-river systems	Kinetic & thermal energy conversion	Biomass combustion & biogas digesters
Impact & Benefits	Infinite power, reduced costs	High efficiency, clean energy	Reliable, weather-independent	Multi-purpose, strong supply	Immense potential, early-stage development	Reduces waste, but requires sustainable management

Image Created by Editor

Image 1: Classification of Energy Sources

[1] UNECE: Energy 2016

[2] UNECE: Carbon Neutrality in the UNECE Region

The Sun's Masterpiece, Solar Energy: Solar energy is the most abundant of all energy resources and can even be harnessed in cloudy weather. The rate at which solar energy is intercepted by the Earth is about 10,000 times greater[3] than the rate at which humankind consumes energy. Solar technologies convert sunlight into electrical energy either through photovoltaic panels or through mirrors that concentrate solar radiation.

While not all countries have the same level of solar energy resources, every country has the potential to make a meaningful contribution to their energy mix through direct solar energy.

In recent years, the cost of manufacturing solar panels has taken a nosedive, transforming them into an affordable and increasingly popular source of electricity. Solar panels have a lifespan of roughly 30 years,[4] and come in variety of shades depending on the type of material used in manufacturing.

Image Source: Economic Times

Image 2: Solar Pannels

The Wind's Whisper, Wind Energy: Wind energy harnesses the kinetic energy of moving air by using large wind turbines located on land (onshore) or in sea- or freshwater (offshore). Wind energy has been used for millennia, but onshore and offshore wind energy technologies have evolved over the last few years to maximize the electricity produced - with taller turbines and larger rotor diameters.

Though average wind speeds vary considerably by location, the world's technical potential for wind energy[5] exceeds global electricity production, and ample potential exists in most regions of the world to enable significant wind energy deployment. Many parts of the world have strong wind speeds, but the best locations for generating wind power are sometimes remote ones. Offshore wind power offers tremendous potential[6].

The Earth's Hidden Fire, Geothermal Energy: Geothermal energy utilizes the accessible thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs using wells or other means. Reservoirs that are naturally sufficiently hot and permeable are called hydrothermal reservoirs, whereas reservoirs that are sufficiently hot but that are improved with hydraulic stimulation are called enhanced geothermal systems.

Once at the surface, fluids of various temperatures can be used to generate electricity. The technology for electricity generation from hydrothermal reservoirs is mature and reliable, and has been operating for more than 100 years[7].

The Flowing Symphony, Hydropower: Hydropower harnesses the energy of water moving from higher to lower elevations. It can be generated from reservoirs and rivers. Reservoir hydropower plants rely on stored water in a reservoir, while run-of-river hydropower plants harness energy from the available flow of the river. Hydropower reservoirs often have multiple uses -

[3] IPCC: Chapter 3 Direct Solar Energy
[4] IRENA: Solar Energy
[5] IPCC: Chapter 7 Wind Energy
[6] IRENA: Wind Energy
[7] IPCC: Chapter 4 Geothermal Energy

providing drinking water, water for irrigation, flood and drought control, navigation services, as well as energy supply.

Hydropower currently is the largest source of renewable energy[8] in the electricity sector. It generally relies upon stable rainfall patterns and can be negatively impacted by climate-induced droughts or changes to ecosystems which impact rainfall patterns. The infrastructure needed to create hydropower can also impact ecosystems in adverse ways. For this reason, many consider small-scale hydro a more environmentally-friendly option[9], and especially suitable for communities in remote locations.

The Ocean's Might, Wave & Tidal Energy: Oceanic energy is derived from technologies that use the kinetic and thermal energy of seawater, waves or currents for instance, to produce electricity or heat. While the oceanic energy systems are still at an early stage of development, the theoretical potential for ocean energy exceeds the present human energy[10] requirements.

Nature's Recycling, Bioenergy: Bioenergy is produced from a variety of organic materials, called biomass, such as wood, charcoal, dung and other manures for heat and power production, and agricultural crops for liquid biofuels. Mostly biomass is used in rural areas for cooking, lighting and space heating, generally by poorer populations in developing countries. Modern biomass systems [11]include dedicated crops or trees, residues from agriculture and forestry, and various organic waste streams.

Energy created by burning biomass also produces greenhouse gas, but at lower levels than burning fossil fuels like coal. However, bioenergy should only be used in limited applications, given potential negative environmental impacts related to large-scale increases in forest and bioenergy plantations, and resulting deforestation and land-use chang

Benefits of Renewable Energy

- **Environmental Protection**: Reduces greenhouse gas emissions, which are major contributors to climate change.
- **Energy Independence**: Reduces reliance on imported fuels, enhancing energy security.
- **Economic Growth**: Creates jobs in manufacturing, installation, and maintenance of renewable energy infrastructure.
- **Sustainability**: Provides a long-term solution to energy needs without depleting natural resources.

Challenges of Renewable Energy

- **Intermittency**: Some renewable energy sources, such as solar and wind, are not always available, requiring energy storage solutions or hybrid systems.
- **High Initial Costs**: The upfront investment for renewable energy technology can be high, although costs are declining as technology advances.
- **Space Requirements**: Some renewable energy installations, like solar farms and wind turbines, require significant land areas.

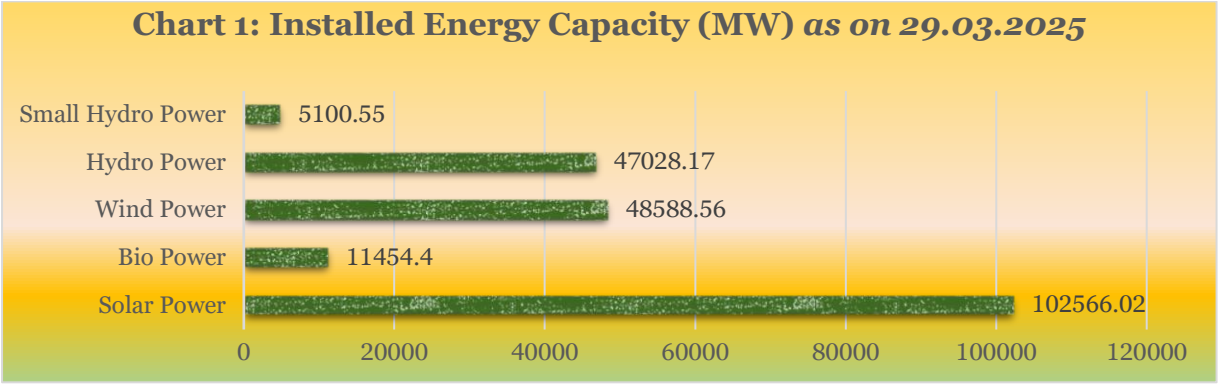
[8] IPCC: Chapter 5 Hydropower
[9] IRENA: Hydropower
[10] IPCC: Chapter 6 Ocean Energy
[11] IPCC: Chapter 2 Bio Energy

Government Initiatives Driving India's Renewable Energy Growth: A Review of Policies Promoting Clean Energy in India

By: Aggraj Sharma, AAO

India is committed to achieving energy security and environmental sustainability, emphasizing renewable energy sources and self-reliance. As of March 2025, India's non-fossil fuel energy capacity has reached 214.73 GW. The government has introduced comprehensive initiatives aimed at promoting renewable energy adoption, enhancing grid stability, and reducing carbon emissions, positioning the nation as a leader in clean energy. The government's proactive renewable energy initiatives have significantly contributed to achieving various Sustainable Development Goals (SDGs). Initiatives such as large-scale solar parks, wind energy expansion, and decentralized renewable systems have advanced SDG 7 (Affordable and Clean Energy) by increasing access to sustainable and affordable energy. Furthermore, these efforts have positively impacted SDG 13 (Climate Action) by substantially reducing greenhouse gas emissions, and SDG 8 (Decent Work and Economic Growth) through the creation of green jobs and promoting innovation. Collectively, these initiatives have also strengthened progress towards SDG 11 (Sustainable Cities and Communities), facilitating cleaner urban environments and enhancing overall quality of life.

Chart 1: Installed Energy Capacity (MW) *as on 29.03.2025*



Source: National Power Portal

Table 1: Cumulative installed capacity since 2014-15

Year	Mode-wise Breakup (GW)					Grand Total	Growth (%)	Share of RE (%)
	Non-RE		Renewable (RE)					
	Thermal	Nuclear	Hydro	RES*	Total RE			
2014-15	188.90	5.78	41.27	39.95	81.22	275.90	10.62	**29.44**
2015-16	210.68	5.78	42.78	47.09	89.87	306.33	11.03	**29.34**
2016-17	218.33	6.78	44.48	58.56	103.04	328.15	7.12	**31.40**
2017-18	222.91	6.78	45.29	70.65	115.94	345.63	5.33	**33.54**
2018-19	226.28	6.78	45.40	79.41	124.81	357.87	3.54	**34.88**
2019-20	230.60	6.78	45.70	88.26	133.96	371.34	3.76	**36.07**
2020-21	234.73	6.78	46.21	95.80	142.01	383.52	3.28	**37.03**
2021-22	236.11	6.78	46.72	109.89	156.61	399.50	4.17	**39.20**
2022-23	237.27	6.78	46.85	125.16	172.01	416.06	4.15	**41.34**
2023-24	243.22	8.18	46.93	143.64	190.57	441.97	6.23	**43.12**
Growth*	28.76%	41.52%	13.71%	259.55%	134.63%	60.19%		
CAGR*	**2.85%**	**3.93%**	**1.44%**	**15.28%**	**9.94%**	**5.38%**		

Source: Renewable Energy Statistics 2023-24, MNRE
RES: Comprising of Solar, Wind, Bio-Power and Small Hydro Power*
*CAGR: Compound Annual Growth Rate *2014-15 to 2024-25*

Solar Energy Initiatives

National Institute of Solar Energy (NISE) has assessed the country's solar potential of about 748 GW assuming 3% of the waste land area to be covered by Solar PV modules. Solar energy has taken a central place in India's National Action Plan on Climate Change with National Solar Mission (NSM) as one of the key Missions.

National Solar Mission (NSM)[1]

NSM was launched on 11th January, 2010. NSM is a major initiative of the Government of India with active participation from States to promote ecological sustainable growth while addressing India's energy security challenges. The Mission's objective is to establish India as a global leader in solar energy by creating the policy conditions for solar technology diffusion across the country as quickly as possible. This is line with India's Nationally Determined Contributions (NDCs) target to achieve about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources and to reduce the emission intensity of its GDP by 45 percent from 2005 level by 2030.

Government has taken several steps for promotion of solar energy in the country. These include:

- Permitting Foreign Direct Investment (FDI) up to 100 percent under the automatic route,
- Waiver of Inter State Transmission System (ISTS) charges for inter-state sale of solar and wind power for projects to be commissioned by 30th June 2025,
- Declaration of trajectory for Renewable Purchase Obligation (RPO) up to the year 2029-30,
- Notification of standards for deployment of solar photovoltaic system/devices,
- Setting up of Project Development Cell for attracting and facilitating investments,
- Standard Bidding Guidelines for tariff based competitive bidding process for procurement of Power from Grid Connected Solar PV and Wind Projects.
- Launch of Green Term Ahead Market (GTAM) to facilitate sale of Renewable Energy power including Solar power through exchanges.

These prescient and sustained past initiatives have led to significant achievements:

- Installed solar capacity grew from 9.01 GW (2016) to 97.86 GW (2025).
- Increased solar parks from 34 parks (20 GW capacity in 2016) to 58 parks (40 GW capacity in 2024).
- Rooftop solar installations expanded significantly to 11,503 MW by March 2024.
- Enhanced off-grid solar systems, including 17.23 lakh home lights and 9.44 lakh streetlights.
- Achieved 5th rank globally in solar power deployment by 2023.

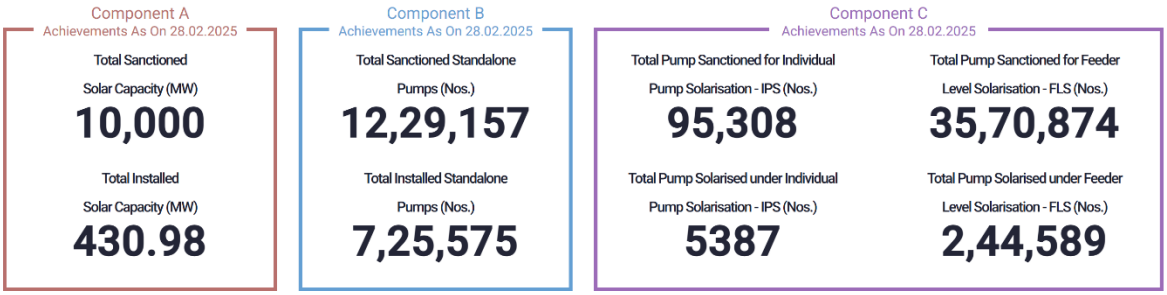
PM-KUSUM Scheme[2]

Launched in March 2019, the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) aims to support farmers by providing financial assistance for

[1] MNRE: Solar Overview

[2] National Portal for PM-KUSUM

Image 1: Component wise classification of PM-KUSUM



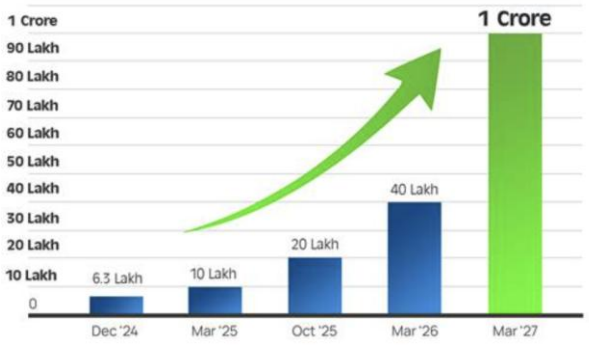
installing solar-powered irrigation systems, including solar pumps and grid-connected solar power plants. The scheme provides central government subsidies of up to 30% (or 50% for North Eastern/Hilly regions/Islands) of the total cost for the installation of standalone solar pumps and for the solarization of existing grid-connected agricultural pumps. All three components of the scheme aim to add Solar capacity of about 34,800 MW by March 2026 with the total Central Financial support of ₹ 34,422 crore.

Component	Target
Component A	Setting up of 10,000 MW of Decentralized Ground/ Stilt Mounted Grid Connected Solar or other Renewable Energy based Power Plants by the farmers on their land.
Component B	Installation of 14 Lakh Stand-alone Solar Agriculture Pumps.
Component C	Solarisation of 35 Lakh Grid Connected Agriculture Pumps including Feeder Level Solarization

PM Surya Ghar Muft Bijli Yojana[3]

The PM Surya Ghar: Muft Bijli Yojana, the world's largest domestic rooftop solar initiative, is transforming India's energy landscape with a bold vision to supply solar power to one crore households by March 2027. By March 2025, installations under the scheme are expected to exceed 10 lakh, with the numbers doubling to 20 lakh by October 2025, reaching 40 lakh by March 2026, and ultimately achieving the target of one crore by March 2027.

Image 2: Projected Growth in installation under PM Surya Ghar: Muft Bijli Yojana



Source: Press Release: Press Information Bureau PM Surya Ghar: Muft Bijli Yojana

Additional Initiatives

- Solar Parks and Ultra Mega Solar Power Projects: Establishment of large-scale solar parks to facilitate accelerated deployment and infrastructure support.

[3] Press Release: PIB PM Surya Ghar: Muft Bijli Yojana

- Wind-Solar Hybrid Policy (2018): Encourages hybrid projects to optimize land use and improve grid stability.

Wind Energy Initiatives[4]

India's wind energy sector is led by indigenous wind power industry and has shown consistent progress in India. The wind power projects are promoted through private sector investment by providing various fiscal and financial incentives such as Accelerated Depreciation Benefit, Concessional Custom Duty Exemption Certificate (CCDC) on certain components of wind electric generators. Driven by policies like National Offshore Wind Energy Policy, National Wind Solar Hybrid Policy, Policy for Repowering of old Wind Power Projects, there has been a robust growth in wind power installation and generation. The country currently has the fourth highest wind installed capacity in the world.

CCDC Wind Initiative[5]

Launched in June 2020, this initiative enhances wind resource assessments and encourages wind energy investments. Under this initiative, a Viability Gap Funding of Rs. 7,453 crore has been approved for development of offshore wind projects, including 1 GW offshore capacity each for Gujarat and Tamil Nadu.

Enhanced wind resource mapping has contributed to the successful identification of over 50 potential wind energy sites nationwide and has contributed to the development of over 10 GW of new wind energy capacity from 2020-2024, increasing India's wind energy capacity by 30%.

National Green Hydrogen Mission[6]

Launched in January 2023, this ambitious mission targets India's transition towards a hydrogen-based economy. With an overarching objective to make India the Global Hub for production, usage and export of Green Hydrogen and its derivatives leading to significant decarbonisation of the economy, reduced dependence on fossil fuel imports, and enable India to assume technology and market leadership in Green Hydrogen.

The Mission aims to identify and develop regions capable of supporting large scale production and utilization of Hydrogen as Green Hydrogen Hubs. The initial outlay for the Mission will be ₹ 19,744 crore, including an outlay of ₹ 17,490 crore for the Strategic Interventions for Green Hydrogen Transition (SIGHT) programme up to 2029-30, ₹ 1,466 crore for pilot projects, ₹ 400 crore for R&D, and ₹ 388 crore towards other Mission components.

Image 3: Outcomes of National Green Hydrogen Mission

Source: National Green Hydrogen Mission | MINISTRY OF NEW AND RENEWABLE ENERGY | India

Under the SIGH) programme, financial incentives mechanisms have been proposed to support domestic manufacturing of

[4] MNRE: Wind Overview India
[5] CCDC
[6] MNRE: National Green Hydrogen Mission India

Electrolysers and offer incentives on production of Green Hydrogen.

Hydro Power Initiatives

The Government of India has introduced several significant initiatives to bolster hydropower and Pumped Storage Project (PSP) development:

Equity Support for North-Eastern States: In August 2024, the Union Cabinet approved a Central Financial Assistance (CFA) scheme with an outlay of ₹4,136 crore, to be implemented from FY 2024-25 to FY 2031-32. This scheme aims to support the development of approximately 15,000 MW of hydropower capacity in the North Eastern Region (NER) through Joint Ventures between state entities and Central Public Sector Undertakings (CPSUs)[7].

Waiver of Inter-State Transmission System (ISTS) Charges: To enhance the financial viability of hydropower projects, the Ministry of Power issued an order in December 2022, waiving ISTS charges for electricity generated from new hydropower projects. This waiver applies for 18 years from the date of commissioning for projects where construction is awarded and Power Purchase Agreements (PPAs) are signed on or before June 30, 2025[8].

Recognition of Surface Hydrokinetic Turbine (SHKT) Technology: In November 2024, the Central Electricity Authority (CEA) recognized SHKT technology under the Hydro Category. Unlike traditional methods that require structures like dams to create potential head, SHKT generates electricity by harnessing the kinetic energy of flowing water, necessitating minimal infrastructure. These turbines are easy to install and offer a cost-effective generation method, with electricity production costs ranging from ₹2 to ₹3 per unit[9].

Other Notable Initiatives

- National Bio Energy Mission: Promotes sustainable bioenergy utilization.
- Renewable Purchase Obligation (RPO): Mandates renewable energy procurement by utilities and industries up to 2029-30.
- Green Energy Corridor Phase II: Strengthens transmission infrastructure to integrate renewable energy into the national grid.
- Renewable Energy Research and Technology Development Programme: Supports innovation in geothermal and other renewable technologies.
- PM JANMAN Solar Power Scheme: Electrifies isolated and underserved tribal communities with off-grid solar systems, promoting socio-economic growth and energy equity.

Conclusion

The extensive government initiatives and strategic investments are significantly enhancing India's renewable energy landscape. These concerted efforts underpin India's leadership in global renewable energy, ensuring environmental sustainability, energy security, and substantial contributions to global climate change mitigation.

[7] PIB Press Release: Equity support to NE States
[8] PIB Press Release: Waiver of ISTS charges
[9] PIB Press Release: SHKT Technology

Challenges and Opportunities in India's Wind Energy Sector - Analysing the contributions of wind energy and areas for enhancement

By: Rohit Kirodiwal, AAO

"*The fuel in the earth will be exhausted in a thousand or more years, and its mineral wealth, but man will find substitutes for these in the winds, the waves, the sun's heat, and so forth*"-

John Burroughs from Under the Apple-Trees (1916).

John Burroughs with this statement identified the issues of non-renewable energy for future generations and envisaged that human will shift towards a cleaner and renewable sources of energy like wind, hydro, solar, biogas and others.

Humanity has been harnessing the power of wind for ages by using it from irrigation and sailing to grinding of food grains and other daily activities. However, in 1887, James Blyth in Marykirk, Scotland used wind to generate electricity for the first time which helped in shifting towards a cleaner source of electricity.

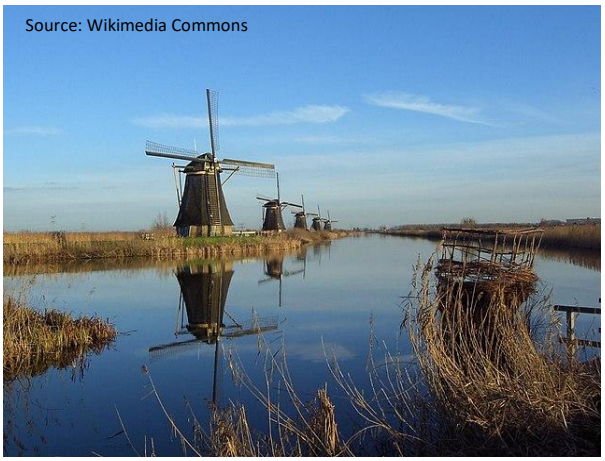


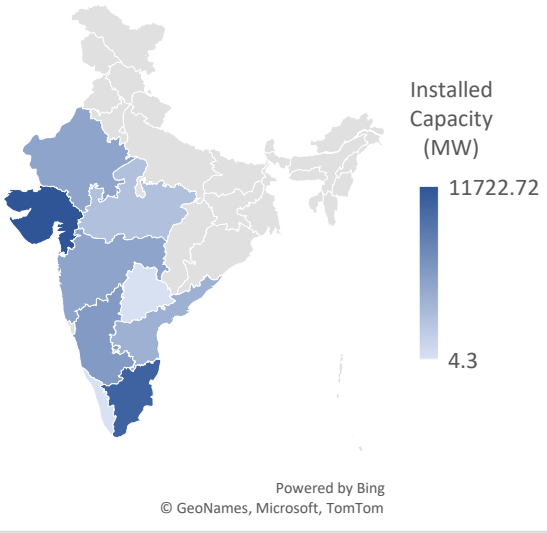
Image 1: Windmill

Wind also known as air in motion, when used to generate electricity by converting kinetic energy into electricity is known as wind energy[1].

Wind Energy Prospects in India

As on 31 March 2024, India has an installed renewable energy capacity of 143.64 Gigawatt in which contribution of wind energy is 45.89 Gigawatt (32 *per cent of* installed renewable energy) making India the **fourth highest wind energy installed capacity country** in the world. During 2023-24, India generated 83.39 billion units. Further, the wind energy contributes 10 *per cent* in total installed power capacity of India[2].

Chart - 1: State-wise Wind Power Installed as on 31.03.2024



[1] IRENA

[2] MNRE Annual Report 2023-24

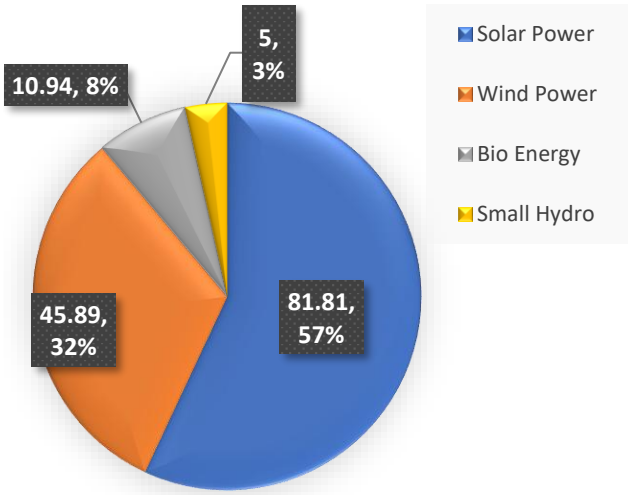


Chart - 2: Installed Renewable Energy Capacity as on 31 March 2024. (MNRE)

Challenges for India's Wind Energy Sector

As per Ministry of New and Renewable Energy, India has wind power potential of 695.50 Gigawatt at height of 120 metre and 1163.9 Gigawatt at height 150 metre above ground level[3].

Though, India is regularly progressing towards achieving its energy targets, there are still some challenges to achieve this potential in wind energy sector which are as follows:

A. Environmental Issues –

- Wind turbines contributes to local warming by impacting the cloud formation, as wind turbines reduces the speed of winds which further affects the evaporation process in the region.
- Wind turbines negatively impact the breeding, nesting and habitat of birds. Turbines with tighter spacing, shorter rotor diameter and lower hub heights lead to death of birds.
- In wind farms, where many wind turbines are installed high noise levels occur. Further, poor maintenance, design, and wear tear increases mechanical noises[4].

B. Land Acquisition hurdles –

- Lands in high wind regions are almost used up, making land acquisition an onerous task for developers.
- Though, the land acquisition is not required in case of offshore wind energy projects, the harsh

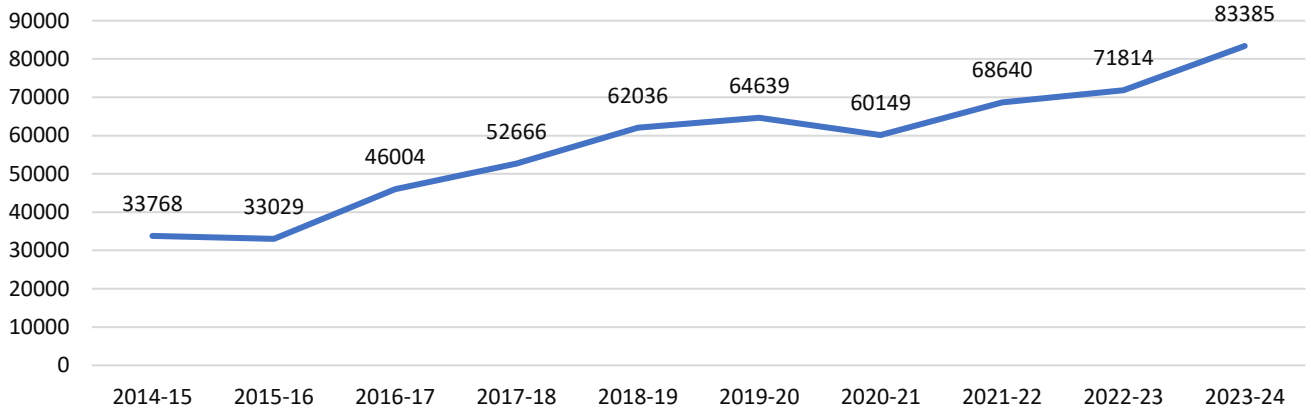


Chart 3: Year-wise Electricity Generation from Wind Energy Sources

[3] MNRE, Wind Overview

[4] IUCN: Biodiversity impacts associated to onshore wind power projects here

conditions make it difficult to implement the projects[5].

C. Technical Issues –

- Issues in Grid integration - Inadqeuate availability of transmission lines. Further, as high wind regions are at remote locations, connecting them with grid requires more infrastructure.
- Lack of adequate research and development institutions in field of wind energy such as energy storage lead towards reduced efficiency.
- Integration of offshore wind energy projects is also difficult and expensive due to technical complexities like integration with grid and energy storage[7].

D. **Policy Uncertainties** –

- Frequent policy changes and regulatory inconsistencies like shift in tariff structures and delay in approvals create uncertainty for investors and developers.

E. Financial Barriers –

- High initial capital cost for both onshore and offshore wind energy projects which makes its unviable for small developers.
- Payment delays from power distribution companies (DISCOMs) threaten project sustainability.
- Delays in land acquisition and change in technology increase the cost of project for developers[6].

Opportunities in India's Wind Energy Sector

A. Untapped Potential –

- As given above, India has total **identified potential of 1858.5 Gigawatt** of wind energy. Achieving this potential will help India in its target of Renewable Energy capacity[7].
- With a coastal boundary of about 7600 Km, India has opportunity to harness the **offshore wind energy.** Ministry of New and Renewable Energy is planning to auction 37 Gigawatt of offshore wind energy projects[8].

B. Technological Innovations –

- While onshore projects faces the length and height challenge of wind turbine due to environmental sustainability, the issue is not present in case of offshore projects. India may focus further on its offshore projects.
- Use of artificial intelligence in mapping of projects at commercial as well as household levels, which will help in improved efficiency and optimisation of projects. Further, AI can help in predictive maintenance and creation of bird collision avoidance system.

C. Hybrid Renewable Energy Projects–

- As solar and wind energy are complementary energy sources, hybridisation of both technologies will make high potential in

[5] Down to Earth - Uncharted waters: India's offshore wind energy has high potential but remains low on implementation

[6] CEEW - A Second Wind for India's Wind Energy Sector

[7] MNRE, Wind Overview

[8] MNRE, Offshore Wind

renewable energy sector by optimising the infrastructure. It also promotes, efficient utilisation of transmission infrastructure.

D. Government Policies and Incentives –

- Government of India through policies like viability gap funding, concessional custom duty, engagement of private sector and waiver of interstate transmission charges to promote for development of wind energy projects which boost the installed capacity in this sector[9].

  However, Government of India may try to engage public through awareness program and concessions/subsidies for installing small wind turbines in households and wind energy projects in unused lands.

- As China is leading in 61 per cent share of global wind-energy turbine energy capacity, India should also aim for increasing its export potential by providing incentives such as Remission of Duties and Taxes on Export Products (RoDTEP) scheme.

Conclusion

Though, India faces challenges in its wind energy sector, India should accelerate its efforts in deployment of wind energy projects both onshore and offshore to achieve its renewable energy targets. A well-planned approach with policy stability, technological and infrastructure development and financial incentives will help India in its sustainable growth.

[9] MNRE, National Wind Solar Hybrid Policy, 2018

The Rise of Solar Energy in India

By: Shri Ajay Babu Meena, AAO

Solar energy is the never ending fountain, which can fulfill the ever increasing energy needs of humanity.

Introduction

The Sun has been worshiped as a life-giver to our planet since ancient times. The industrial ages gave us the understanding of sunlight as an energy source. India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sqm per day. Solar photovoltaic power can effectively be harnessed providing huge scalability in India. Solar energy also provides the ability to generate power on a distributed basis and enables rapid capacity addition with short lead times. Off-grid decentralized applications will be advantageous from a rural & urban application perspective and meeting other energy needs for power, heating and cooling in both rural and urban areas. From an energy security perspective, solar is the most secure of all sources, since it is abundantly available. Theoretically, a small fraction of the total incident solar energy (if captured effectively) can meet the entire country's power requirements[1].

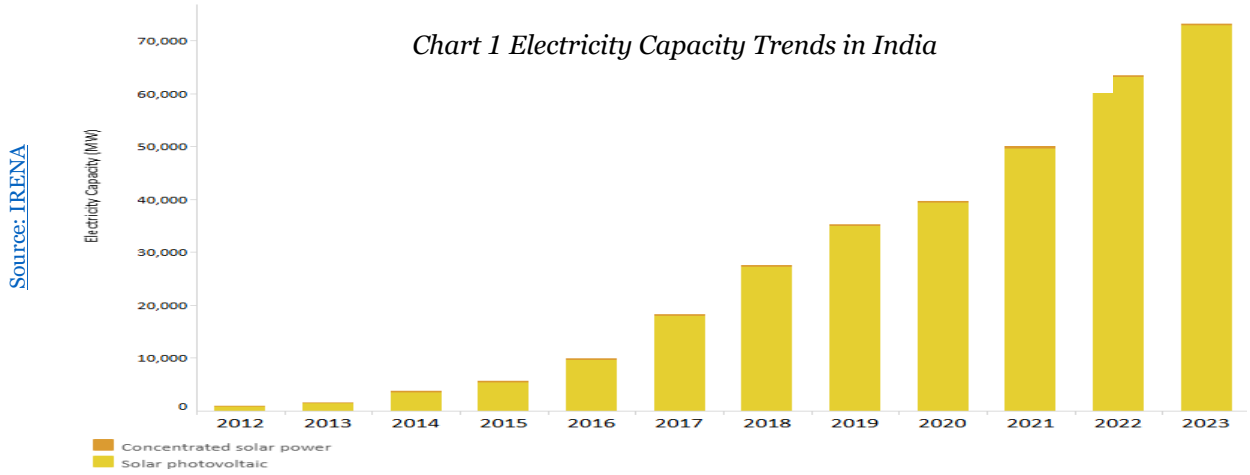
Growth of Solar Energy in India

Out of total installed Renewal energy capacity of 167.71 GW in the country, Solar energy is the largest contributor with 102.57 GW as of February 2025. During FY 2024-25 (Till 28th Feb 2025), India added **20.75 GW installed solar capacity**, reflecting a 38.04 % increase in solar installations compared to FY 2023-24[2]. The country's total installed and pipeline solar projects combined stand (as on Nov 2024) at 261.15 GW, reflecting a strong pipeline for future growth and expansion in the solar sector[3].

Challenges Facing the Solar Sector[4]

1. Mobilization of the necessary finance and investment on competitive terms: Gearing up the banking sector for arranging finances for

Chart 1 Electricity Capacity Trends in India



[1] Solar Overview: Ministry of New and Renewable Energy
[2] MNRE: Year Wise Achievement
[3] PIB Year End Review, 2024: MNRE
[4] Press Information Bureau blogs

larger deployment goals, exploring low-interest rate, long-term international funding, and developing a suitable mechanism for risk mitigation or sharing by addressing both technical and financial bottlenecks are major challenges. The ongoing efforts for mitigating investment risks and easing approval processes would also need to be strengthened.

2. Land acquisition issues: The reasons for delay in establishing Solar Parks include challenges in acquisition of clear land, mismatch in timelines between solar projects and power evacuation infrastructure, environmental issues like Great Indian Bustard (GIB) issue, regulatory challenges like non- approval of solar tariff by SERCs, etc[5].

3. Other Challenges: The solar energy sector in India faces challenges in establishing a robust innovation and manufacturing ecosystem, economically integrating a larger share of renewables with the grid, ensuring firm and dispatchable power supply from renewable sources, and enabling deeper penetration of renewables in hard-to-decarbonize sectors.

Image 1: Rooftop Solar Pannels

Government Initiatives

1. PM-Surya Ghar: Muft Bijli Yojana[6]

The government launched the PM Surya Ghar: Muft Bijli Yojana on 13th February 2024, approved with ₹75,021 crore outlay. The scheme targets installation of rooftop solar in one crore households, provides up to 300 units free electricity monthly and offers subsidies ranging from ₹30,000 to ₹ 78,000 per household. States such as Gujarat, Maharashtra, Kerala, and Uttar Pradesh have demonstrated exceptional progress in solar rooftop installation, reflecting robust infrastructure and stakeholder collaboration. Government of India issued Guidelines for 'Incentives to DISCOMs' with a financial outlay of Rs 4,950 crore, covering net meter availability and installation facilitation[7].

2. International Solar Alliance (ISA): India launched ISA on the sidelines of COP21 in Paris, as a collaborative initiative between India and France aimed at unifying efforts to combat climate change by implementing solar energy solutions. Currently, more than 100 countries have become member of this alliance[8].

3. Development of Solar Parks and Ultra Mega Solar Power Projects: In this scheme, the government has authorized 50 solar parks across 12 states, aiming for a total capacity of 37,990 MW.

4. Production Linked Incentive (PLI) Scheme: The primary objective of the scheme is to boost domestic module manufacturing and reduce dependence on imports. With a substantial outlay of US$

[5] PIB brief dt. 16.03.2025
[6] Press Information Bureau 29.02.2024
[7] Press Information Bureau
[8] International Solar Alliance

2.9 billion (Rs. 240 billion), the scheme aims to achieve GW-scale manufacturing capacity in high-efficiency solar photovoltaic (PV) modules[9].

5. FDI: Under the extant Foreign Direct Investment (FDI) policy of the Government of India, FDI in renewable energy sector is permitted up to 100% under the automatic route[10].

6. Launch of Green Term Ahead Market (GTAM): This market was launched to facilitate the sale of renewable energy power, including solar power, through exchanges[11].

7. PM KUSUM Yojana: Under the Scheme, central government subsidy upto 30% or 50% of the total cost is given for the installation of standalone solar pumps and also for the solarization of existing grid-connected agricultural pumps. Further, farmers can also install grid-connected solar power plants up to 2MW under the Scheme on their barren/fallow land and sell electricity to local DISCOM at a tariff determined by state regulator.

Technological Innovations

India is exploring innovative solutions like floating solar farms[12], transforming reservoirs into energy hubs. Despite higher costs and environmental concerns, floating arrays help save land, reduce evaporation, and slow algal blooms, all while generating serious power. Bifacial solar panels[13] can capture sunlight on both the front and back sides, increasing energy generation compared to traditional monofacial panels. Advances in manufacturing and installation techniques have made bifacial panels more cost effective and practical.

Way Forward

India needs a well-rounded and practical approach to sustain its progress in solar energy. Improving the power grid, developing better energy storage, and encouraging the use of rooftop and local solar systems[14] can help solve issues of reliability and access. There is need for a robust regulatory framework that ensures smooth integration of rooftop solar into the national grid. At the same time, raising public awareness and training workers will help build the skilled workforce needed for this shift. These efforts together can help India meet its goal of 500 GW of non-fossil fuel capacity by 2030 and become a global leader in clean energy[15].

Conclusion

India's rapid expansion in solar energy marks a pivotal step toward a sustainable and energy-secure future. With government-driven initiatives, policy reforms, and technological advancements, the country is steadily progressing toward its ambitious renewable energy goals. However, challenges such as dependency on imports, land constraints, and financial barriers must be addressed to ensure long-term success. Strengthening domestic manufacturing, improving financing mechanisms, and streamlining land acquisition processes will be crucial. By overcoming these hurdles, India can establish itself as a global leader in solar energy, fostering economic growth, reducing carbon emissions, and ensuring a cleaner, greener future for generations to come.

[9] Press Information Bureau 23.03.2023
[10] Press Information Bureau 19.12.2023
[11] Press information bureau 09.02.2023
[12] Press Information Bureau 01.07.2022
[13] PIB brief dt. 18.02.2025
[14] Press Information Bureau 13.03.2025
[15] Press Information Bureau

Hydropower in India: Balancing Growth and Environmental Sustainability

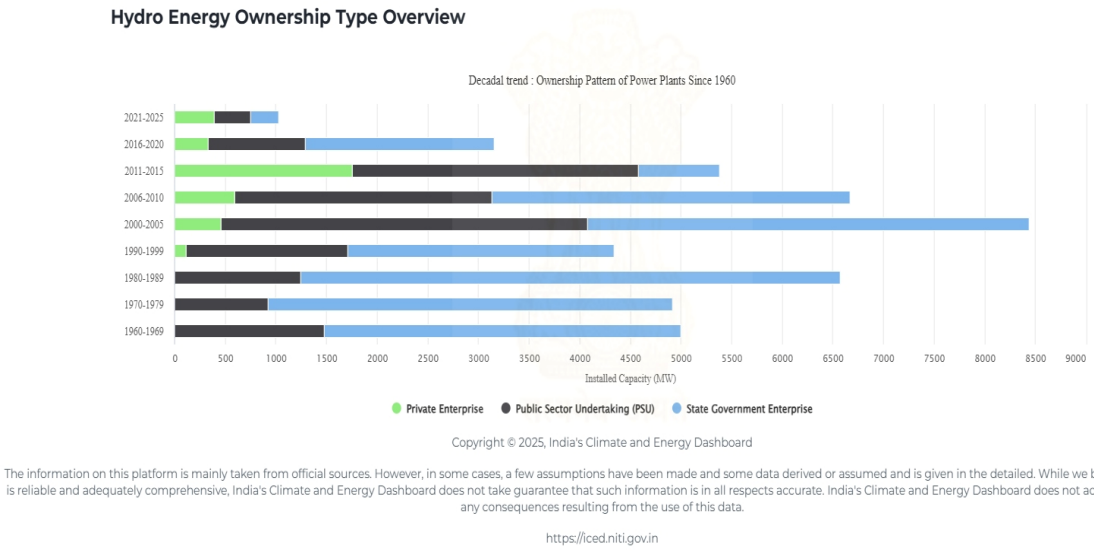
By: Shri Rohan Sharma, AAO

Hydropower plays a pivotal role in India's renewable energy strategy, contributing significantly to the nation's electricity generation. As of 2024, India's installed hydroelectric capacity stands at approximately 42 gigawatts (GW), with an additional 15 GW under construction, aiming to reach 67 GW by 2031-32—a more than 50 per cent increase over the current capacity.

Source: maharashtratourism.gov.in

Hydropower Potential and Development

The Central Electricity Authority (CEA) has assessed India's hydroelectric potential for projects above 25 megawatts (MW) at 84,044 MW. Additionally, the Ministry of New and Renewable Energy (MNRE) has identified a potential of 21,133 MW from 7,133 sites suitable for small hydro projects (up to 25 MW).



Source: Niti Aayog

Image 2: Ownership Type of Hydro Energy

- **Historical Milestone**: India's hydropower journey began with a 130 kW plant near Darjeeling in 1887, marking the inception of hydroelectric power development in the country. (Source: India WRIS)
- **State-wise Potential**: The hilly states, including Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, and Uttarakhand, constitute around half of India's small hydro potential. (Source: Ministry of New and Renewable Energy)
- **Policy Evolution**: In 2019, the government declared large hydro projects (>25 MW) as renewable energy sources, integrating them into India's renewable energy targets. (Source: Press Information Bureau)

Government Initiatives and Policies

To harness this potential, the Government of India has implemented several measures:

1. **Policy on Hydro Power Development**: Aimed at preventing a decline in hydro share and promoting the exploitation of vast hydroelectric potential, especially in the North and North Eastern regions[1].
2. **Promotion of Small Hydro Projects**: The MNRE supports the development of small hydro projects through assessment studies and facilitating project implementation[2].
3. **Measures to Promote Hydro Power Sector (2019)**: These include declaring large hydro projects (>25 MW) as renewable energy sources, implementing tariff rationalization to reduce hydropower costs, and providing budgetary support for flood moderation and enabling infrastructure such as roads and bridges[3].

Environmental Implications

While hydropower is cleaner than coal or oil-based power generation, it has notable ecological drawbacks:

1. **Displacement and Livelihood Impact**: Large dams often lead to the displacement of communities, affecting their livelihoods and cultural heritage.
2. **Biodiversity Threats**: The alteration of river flows affects aquatic ecosystems, disrupting fish migration and breeding patterns.
3. **Deforestation and Habitat Loss**: Large-scale dam construction leads to deforestation, impacting local flora and fauna.
4. **Sedimentation and Water Quality**: Dams trap sediments, reducing downstream nutrient flow and impacting agriculture.
5. **Seismic Concerns**: Many large-scale hydropower projects are located in seismically active regions, increasing risks of landslides and earthquakes.

[1] Power Ministry of India
[2] Press Information Bureau: Hydro energy projects
[3] Press Information Bureau: Promotion of Hydropower

In conclusion, hydropower remains a cornerstone of India's renewable energy landscape. Through strategic policies, sustainable practices, and community engagement, India aims to balance the growth of hydropower with environmental stewardship and social responsibility.

The Royal Poinciana (Gulmohar)

Image Credit: Shri Rahul Yadav, AAO

The Role of Electric Vehicles in India's Renewable Energy Future: Impact of Electric Vehicles on reducing carbon emissions

By: Saurabh Sharma, AAO

India is the 4th largest automobile market in the world after China, USA and Japan due to transport needs of more than 1.4 billion population[1]. India has taken significant efforts in its transition to green energy and electrification. At COP26, the Hon'ble Prime Minister presented the five nectar elements (Panchamrit) of India's climate action which inter alia incudes reduction of total projected carbon emissions to one billion tonnes by 2030 and reduction of the carbon intensity of the economy by 45 per cent by 2030, over 2005 levels[2].

It is well known fact that the fossil fuels is limited on earth and their continued use is causing significant harm to our planet due to emission of harmful gases, creating long-term public health issues. In contrast, Electric Vehicles (EVs) offer a much cleaner alternative. If we look at efficiency standpoint, EVs can convert approximately 60% of the electricity from the grid into power at the wheels, whereas petrol and diesel vehicles convert only about 17%–21% of the fuel's energy—resulting in nearly 80% energy loss[3].

Given these advantages, Electric Vehicles represent the future of sustainable transport in India and emerging as a cornerstone of this shift for reducing carbon emissions and integrate with renewable energy sources.

Impact of Electric Vehicles on reducing carbon emissions

Electric Vehicles (EVs) can play an important role in reducing the carbon emissions, particularly in the transport sector, which is one of the major contributors to global greenhouse gas (GHG) emissions.

In India, Electric Vehicles (EVs) are playing an increasingly important role in reducing carbon emissions, offering a cleaner alternative to the millions of petrol and diesel vehicles that pollute the air. Unlike traditional cars that burn fuel and release large amounts of carbon dioxide and other harmful gases, EVs run on electricity and produce no exhaust while driving, which is a huge relief for heavily polluted cities like Delhi, Mumbai, and Kolkata. Beyond reducing carbon, EVs also help clear the smog in urban centres, making life healthier and more pleasant.

Electric Vehicles (EVs) can play a significant role in reducing carbon emissions in India, particularly when supported by strong climate policies and a cleaner electricity mix. Under a low-carbon scenario—where a global carbon price is applied and electricity generation shifts toward renewable sources—EVs can lead to deep decarbonisation of the transport sector.

Integration of EVs with renewable energy sources

Integrating Electric Vehicles (EVs) with renewable energy sources is a powerful strategy that could transform transportation and energy systems worldwide, with a particularly promising impact in a country

[1] NITI Aayog. *Promoting Clean Energy Usage Through Accelerated Localization of E-Mobility Value Chain*. New Delhi: NITI Aayog, 2022

[2] PIB: India's stand at COP26

[3] Niti Aayog: Benefits of EV

like India, where both pollution and renewable energy growth are major focuses. EVs rely on electricity to run, and when that electricity comes from renewable source such as solar panels, wind turbines and other sources, this may result in significant reduction in carbon emissions. Unlike traditional cars that burn petrol or diesel and pump out greenhouse gases, EVs charged with clean energy can operate with little to no environmental harm, especially as India works toward its ambitious goal of 500 gigawatts of renewable energy by 2030.

To support this, India is actively promoting the installation of solar-powered EV charging stations, especially in urban areas and along national highways, through programs like FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) and PM-KUSUM, which promotes solar power in rural areas. This integration not only eliminates tailpipe emissions but also addresses the core source of pollution by cleaning up the energy supply, positioning transportation as a vital contributor in the fight against climate change.

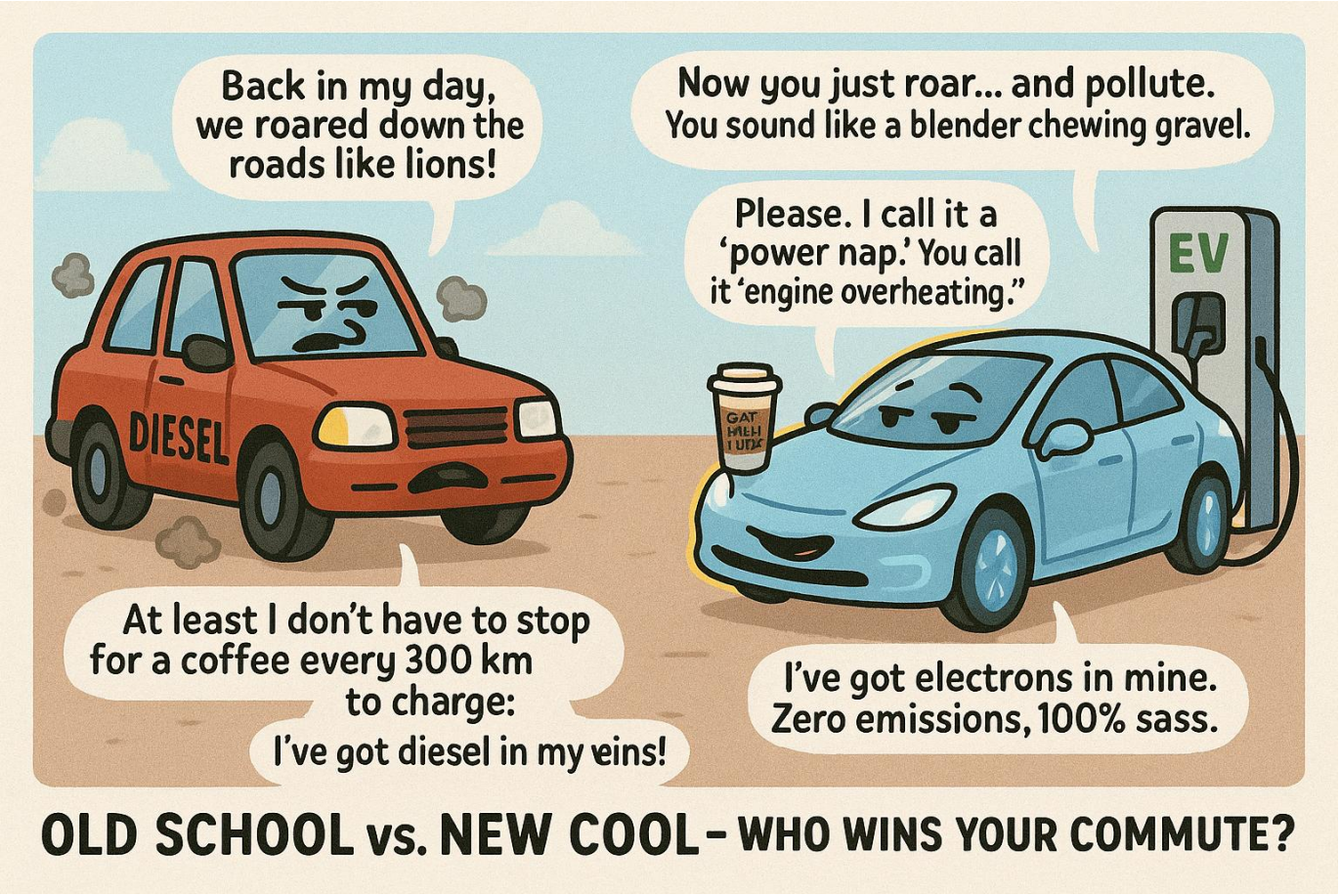
India's natural resources make the integration of EVs with renewable energy a strong and practical fit. With over 300 sunny days in many parts of the country and strong coastal winds along its 7,500-kilometer shoreline, India has immense potential to power Electric Vehicles sustainably. Supportive government policies—such as subsidies for solar panel installations, incentives for EV purchases, and programs like the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme—are driving this transition forward. Now, several private companies and start-ups in India are leading innovation in the development of solar-powered EV charging stations and battery-swapping networks—particularly for two-wheelers, which form the majority of vehicles on Indian roads.

Summing Up and Way Forward

India is moving in the right direction when it comes to clean and sustainable transport. Using Electric Vehicles (EVs) along with renewable energy like solar and wind power can help the country cut down on pollution, reduce its dependence on fossil fuels, and improve overall air quality. Programs like FAME and increasing investment in clean energy are already helping. At the same time, many start-ups and private companies are stepping up with new ideas like battery swapping and solar-powered charging stations, especially for two-wheelers.

To strengthen India's shift toward clean mobility, the focus must be on expanding renewable-powered charging infrastructure, especially in rural and semi-urban areas through solar and wind-based solutions. Policymakers should encourage public-private partnerships (PPPs) so as to facilitate innovation and investment to scale up EV services and infrastructure. At the same time, the more focus should be given on R&D activities particularly in battery technologies, smart grids and digital EV platforms.

In conclusion, capacity development initiatives such as training the engineers, technicians and planners will certainly support the growth of India's green mobility sector and for this, it is equally important to ensure the policy alignment across the EV, energy and transport sectors at both central and state levels.



Graphic designed using ChatGPT

India's Green Hydrogen Revolution: A Clean Energy Future

By: Shri. Vikas Dhir, AAO

Introduction

What is Green Hydrogen?

Green Hydrogen, is produced by the process of electrolysis, where water is split into hydrogen and oxygen using electricity generated from renewable sources like solar, wind, or hydropower. This process results in a clean and emission-free fuel that has immense potential to replace fossil fuels and reduce carbon emissions[1].

Green Hydrogen in India

India's adoption of Green Hydrogen is currently at an early, demonstration stage[2]. Key initiatives include GAIL's(Gas Authority of India Limited) pioneering project blending hydrogen into the city gas distribution grid in Indore (2% in CNG and 5% in PNG) and NTPC's(National Thermal Power Corporation) blending of up to 8% Green Hydrogen in the PNG network at Kawas Township, Surat. Other PSUs are piloting hydrogen-based fuel cell electric buses in Leh and Greater Noida, and Oil India has developed a 60 kW hydrogen fuel cell bus. Indian Oil is operating pilot plants producing Green Hydrogen for refuelling hydrogen buses. Additionally, several entities have announced plans to set up Green Hydrogen and green ammonia production facilities across the country.

National Green Hydrogen Mission: - India has launched the National Green Hydrogen Mission, approved with an outlay of ₹19,744 crore[3].

Strategic Framework and Implementation

In its initial phase, the National Green Hydrogen Mission incentives via the Strategic Interventions for Green Hydrogen Transition (SIGHT) program proposes two financial incentive mechanisms with a total outlay of ₹17,490 crore up to 2029-30[4], focusing on incentivizing the manufacturing of electrolysers and the production of Green Hydrogen, as outlined by the MNRE. These incentives are designed to evolve with market dynamics and technological advancements, ensuring adaptability as the mission progresses. To maintain quality and performance, eligibility criteria for competitive bidding in the procurement of Green Hydrogen and its derivatives mandate the use of equipment approved by the Government of India, adhering to specified quality and performance standards[5]

Requirement: India's Renewable Energy Drive for Green Hydrogen (Ref: https://static.pib.gov.in/WriteReadData/specificdocs/documents/2024/may/doc2024510336301.pdf)

- India needs 125 GW renewable energy for 5 MMT Green Hydrogen by 2030.
- Targeting 500 GW total renewable capacity by 2030.
- Solar growth driven by Solar Energy Corporation of India Limited (SECI).
- Exploring Concentrated Solar Power (CSP) for low-cost generation.
- New pumped storage projects announced by Tata, JSW, Torrent.
- Tenders issued for offshore wind and pumped storage projects.

[1] MNRE: Hydrogen Overview
[2] PIB: Status of adoption of green hydrogen in the country
[3] MNRE: National Green Hydrogen Mission
[4] MNRE: National Green Hydrogen Mission
[5] MNRE: National Green Hydrogen Mission

Mission Objectives and Targets

The mission sets ambitious targets by 2030, as outlined on the MNRE website (National Green Hydrogen Mission MNRE official page):

- Green Hydrogen production: 5 MMT annually.
- Renewable energy capacity addition: 125 GW.
- Total investments: ₹8 lakh crore.
- Job creation: 600,000 jobs.
- Fossil fuel import savings: ₹1 lakh crore.
- Emission reductions: 50 MMT annually.

These targets align with India's broader climate commitments, including energy independence by 2047 and net-zero emissions by 2070[1], which provides a spotlight on the mission's alignment with national goals, emphasizing renewable energy integration and economic benefits.

The mission's framework includes, infrastructure development through Green Hydrogen Hubs for pipelines and storage, research and development under the **Strategic Hydrogen Innovation Partnership (SHIP)**, and skill development programs[6].

Key Government Policies Driving India's Green Hydrogen Growth[7]

a) The Production Linked Incentive (PLI) Scheme supports domestic manufacturing of renewable energy equipment, with a financial outlay of INR 24,000 crore under the Aatma Nirbhar Bharat initiative. By making it feasible to produce these things in India, the PLI scheme helps build up the local industry needed to make Green Hydrogen.

b) Customs duties have been imposed on solar cells and modules to promote local production and reduce import dependence. By making foreign-made equipment more expensive, it encourages Indian companies to buy local, which again boosts the Indian renewable energy industry

c) The Renewable Purchase Obligation (RPO) under the Energy Conservation Act, 2001, requires designated consumers to progressively increase their use of renewable energy—from 29.91% in 2024-25 to 43.33% by 2029-30—with a separate RPO for Distributed Renewable Energy (DRE). The RPO creates a guaranteed demand for renewable energy. As big energy users are forced to buy more renewable power to meet their RPO targets, this encourages investment in new solar, wind, and other renewable energy projects. This increased renewable energy capacity then provides the electricity needed to produce Green Hydrogen. The DRE component of the RPO can specifically help Green Hydrogen production in decentralized locations. RPO acts like a catalyst which allows the market to embrace renewable energy, which then provides the fuel for the Green Hydrogen revolution

Challenges [8]

a) **Incentivising Demand**: Switching from traditional hydrogen (made using fossil fuels, also called "grey hydrogen") to Green Hydrogen (produced with renewable energy) is still very expensive. Green Hydrogen is much more expensive than traditional hydrogen, costing about $3.5–$5 per kilogram, while industries need it to be under $2 to use it widely. High costs are made worse by project delays and complex rules. Without government support like subsidies, Green Hydrogen will remain too costly for most companies to adopt

b) **Limited enabling infrastructure for Green Hydrogen deployment**:

India faces major hurdles in rolling out Green Hydrogen because it lacks pipelines, storage, and delivery systems, unlike its established networks for electricity and gas. Most

[6] MNRE: National Green Hydrogen Mission
[7] MNRE: India's Green Hydrogen Revolution
[8] CEEW: How India can boost investment for financing domestic green hydrogen production

hydrogen infrastructure is limited to a few industrial sites, making it hard to supply Green Hydrogen nationwide or export it from ports. Building the needed factories, pipelines, and export facilities is expensive and slow, making investors cautious and slowing large-scale adoption.

c) **High Financing Costs in emerging markets**

Private investment in India's Green Hydrogen sector faces major hurdles because projects require high upfront costs and borrowing is expensive, with the Weighted Average Cost of Capital (WACC) typically around 9–11% for green projects. When interest rates rise in developed countries, investors often move money out of emerging markets like India, making loans even harder and costlier to obtain. Currency fluctuations and economic uncertainty add more risk. Additionally, key technologies like electrolysers and hydrogen storage are still new and unproven at scale in India, making investors cautious about reliability and costs. All these factors slow down private investment in green hydrogen.

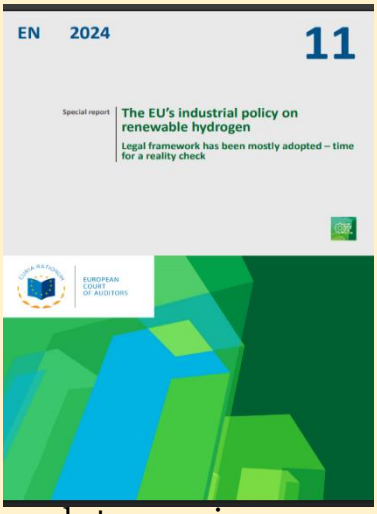
Applications and Environmental Impact[9]

- **A) Decarbonization Potential**: Reduces emissions in transportation, shipping, steel production; replaces fossil fuels.
- **B) Industrial Applications**: Cleaner alternative for ammonia, methanol, steel production; lowers carbon footprint.
- **C)Energy Backup**: Reliable backup for renewables; ensures energy supply stability.
- **D) Versatile Uses**: Powers fuel cells, vehicles, heating systems, chemical and fertilizer production.
- **E) Efficiency Benefits**: High energy density; efficient fuel cells; supports microgrids and remote electrification.
- **F) Energy Independence (India)**: Renewable-based production; reduces fossil fuel dependence and costly imports.
- **G) Community Support**: Biomass-based hydrogen offers revenue for farmers; promotes sustainable development.

[9] MNRE: Hydrogen Overview

Probable Audit Framework for India's National Green Hydrogen Mission – Insights from EU's Special Report

Special Report 11/2024-The EU's industrial policy on renewable hydrogen [11]



Based on the Special Report 11/2024-

Some of the important findings are as under:

a) The Commission set unrealistic hydrogen production and import targets - the EU is not on track for achieving them.

b) The Commission set capacity targets without thoroughly studying or using strong, detailed data and robust analysis.

c) Member states have divergent ambitions which are not necessarily aligned with the EU targets.

d) The adoption of the EU rules for renewable hydrogen provided certainty, but the Commission did not assess their effects on the market expansion.

e) There are multiple EU funding sources for hydrogen projects, but no guarantee that they will be appropriate for developing an EU-wide market.

f) Insufficient coordination efforts by the Commission, both internally and with member states, but also with industry.

Recommendations

a) The Commission should, with Member States, update the Hydrogen Strategy and REPowerEU targets based on careful analysis of incentives, funding, and geopolitical impacts—ensuring targets are ambitious but realistic and do not harm EU industry competitiveness or risk deindustrialisation.

b) The Commission, working with Member States, should publish a hydrogen value chain roadmap to 2030+ and track progress on targets using a scoreboard.

c) The Commission should, with Member States, collect and report data on hydrogen investment plans and public funding across the value chain, and review if current EU funding is suitable for future hydrogen development.

d) The Commission should establish a one-stop shop through the European Hydrogen Bank to guide project developers on EU funding, and clarify the future scope and mandate of the Clean Hydrogen Alliance, including its roundtables

A probable audit approach for the Indian National Green Hydrogen Mission, in the light of *Special Report 11/2024-The EU's industrial policy on renewable hydrogen*, would emphasize target realism, regulatory effectiveness, funding coordination, and implementation challenges. Specifically, the audit can scrutinize the achievability of production targets, assess the impact of regulations and certification, examine the efficiency of funding mechanisms, and address implementation hurdles related to technology and infrastructure development.

[11] European Union Special Report 11/ 2024

India's Path to Renewable Energy: Progress & Future Goals

By: Rahul Yadav, AAO

India, the world's third-largest energy consumer[1], has undergone a remarkable transformation in its energy sector since gaining independence in 1947. Over the last 75 years, the nation has transitioned from an energy-deficient country to a global leader in renewable energy. Energy self-sufficiency was identified as the major driver for new and renewable energy in the country in the wake of the two oil shocks of the 1970s (Yom Kippur War in 1973 and Iranian Revolution of 1979).

With a commitment to sustainability and reducing carbon emissions, the country has set ambitious targets to transition from fossil fuels to renewable energy sources. India's progress in renewable energy is driven by policy initiatives, technological advancements, and international collaboration.

Early Years (1947-1980s): Laying the Foundation

In the initial decades after independence, India relied predominantly on coal and hydropower. Hydropower was the primary source of renewable energy. Major projects like the Bhakra Nangal and Damodar Valley dams were constructed. The establishment of the **Central Electricity Authority (CEA)** and the **Rural Electrification Corporation (REC)** focused on energy expansion.

1980s-2000s: Emergence of Renewable Energy[2]

The 1980s and 1990s marked the beginning of systematic efforts in renewable energy development. The sudden increase in the price of oil (from $2.90 to $11.65 per barrel), uncertainties associated with its supply and the adverse impact on the balance of payments position led to the establishment of the Commission for Additional Sources of Energy in the Department of Science & Technology in March 1981. In September 1982, a new department, i.e., Department of Non-conventional Energy Sources (DNES), that incorporated CASE, was created in the then Ministry of Energy. In 1992, DNES became the Ministry of Non-conventional Energy Sources. In **1986** India commissioned its first commercial **wind power project** in Gujarat.

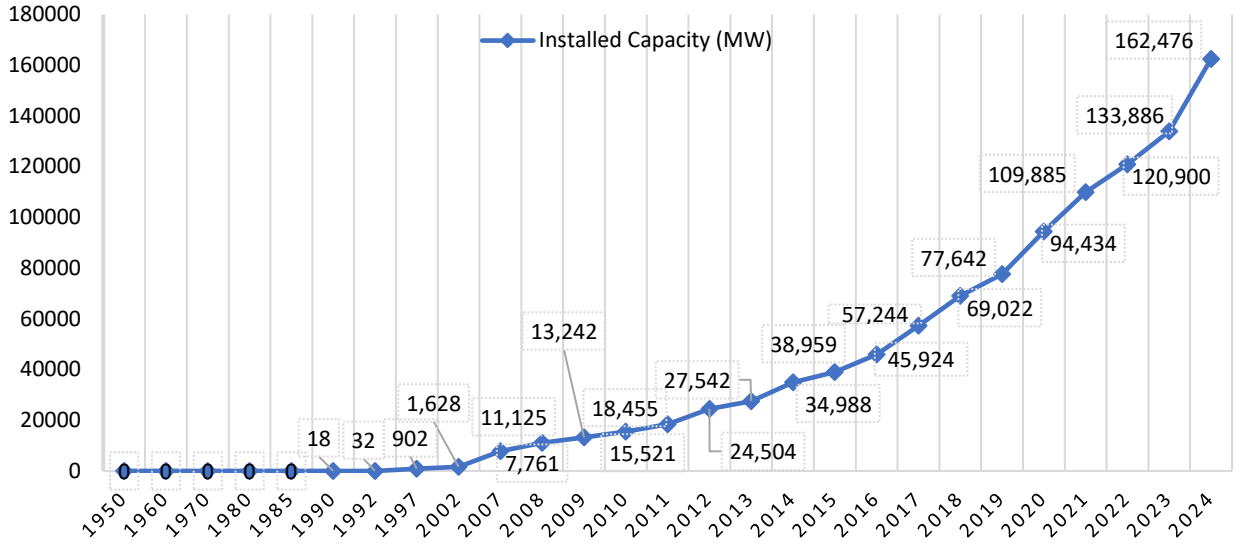
2000s-2020s: Acceleration and Leadership in Renewables

With global climate concerns rising, India has taken steps to expand its renewable energy capacity in the 21st century. Efforts have been made to efficiently use the energy[3] in the demand side through various innovative policy measures under the overall ambit of Energy Conservation Act 2001.

India released the National Action Plan on Climate Change (NAPCC) on 30th June 2008 to outline its strategy to meet the challenge of Climate Change. It outlined a national strategy that aimed to enable the country adapt to climate change and tried to enhance the ecological sustainability of India's development path. It stressed that

[1] PIB, India Energy Week, 2025;
[2] MNRE: Introduction
[3] Ministry of Power: Energy Efficiency

Chart 1: Installed Renewable Energy Capacity (MW)



maintaining a high growth rate is essential for increasing living standards of the majority of people of India but also made efforts for reducing their vulnerability of the impacts of climate change.[4]

1. National Solar Mission and Wind Power Expansion

- **2010:** Launch of the **Jawaharlal Nehru National Solar Mission (JNNSM)** to promote ecologically sustainable growth[5].
- **2015:** India set an ambitious renewable energy target of 175 GW by 2022, including 100 GW solar, 60 GW wind, 10 GW biomass, and 5 GW small hydro[6].
- **2024:** The country became the fourth-largest wind power producer globally[7].

2. Green Energy Investments and Global Commitments

- **2015:** India co-founded the **International Solar Alliance (ISA)** to promote solar energy worldwide[8].
- **2021:** Prime Minister Narendra Modi pledged to achieve **500 GW of non-fossil fuel capacity** by 2030 and net-zero emissions by 2070 at the COP26 summit[9].
- **2024:** India surpassed 200 GW of renewable capacity, with solar and wind making up the largest share[10].

3. Innovations and Rural Electrification

- **Solar microgrids and wind farms** provide power to remote villages.
- **Offshore wind and green hydrogen initiatives** were launched to further diversify energy sources.
- **Energy storage projects** address grid stability issues.

Progress in Renewable Energy

India's renewable energy landscape is robust and central to its sustainable energy strategy. As on March 31, 2024, the total estimated renewable power potential is about 2,109,655 MW. Wind energy leads this potential with roughly 55%

[4] National Action Plan on Climate Change (NAPCC)
[5] Jawaharlal Nehru National Solar Mission (JNNSM)
[6] PIB Year End Review 2014: MNRE
[7] PIB: Global Wind Day
[8] PIB: Cabinet approval to ISA
[9] PIB: Statement at COP26
[10] PIB: India's Renewable Energy Capacity

(1,163,856 MW), followed by solar energy contributing about 35.5% (748,990 MW). Large hydropower accounts for around 6.3% (133,410 MW) of the potential, while smaller contributions come from small hydro (1%), biomass (1%), and cogeneration from bagasse (1%).

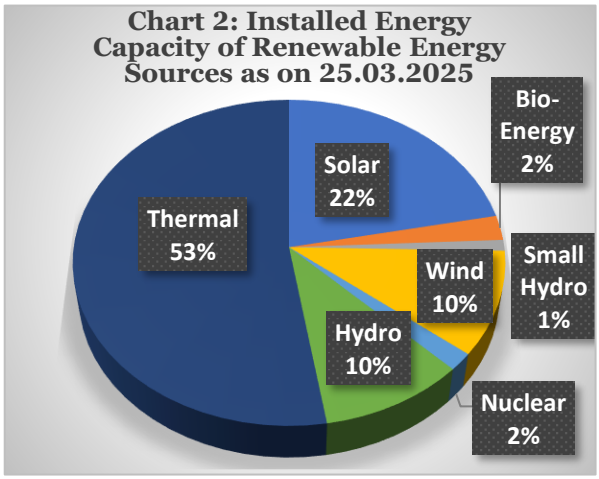
Table 1: Installed Renewable Energy Capacity (Trend Over the Years)

Year	Total Renewable Capacity (GW)	Solar (GW)	Wind (GW)	Hydro (GW)	Bio-energy & Others (GW)
2015	38.0	4.6	25.1	6.2	2.1
2017	60.8	17.0	32.9	7.3	3.6
2019	85.0	30.0	37.6	9.1	4.5
2021	110.0	50.0	39.5	10.0	5.5
2023	160.0	72.0	44.0	11.5	6.5
2025*	180.0+ (Projected)	90.0	46.0	12.0	7.0

On the utilization side, India's installed grid-interactive renewable power capacity has reached 143,645 MW. This capacity mix is dominated by solar power, which represents around 57% of the installed capacity, followed by wind power at 32%, with bio power & waste-to-energy and small hydro constituting approximately 8% and 3% respectively.

1. Expansion of Installed Capacity[11]

India has emerged as a global leader in renewable energy, particularly in solar and wind power. As of 2024, India's installed renewable energy capacity exceeds 180 GW, comprising solar (over 72 GW), wind (more than 44 GW), bio-energy (over 10 GW), and small hydro projects. The country has witnessed rapid growth, especially in solar energy, due to initiatives such as the Jawaharlal Nehru National Solar Mission (JNNSM).



2. Policy and Government Initiatives

The Indian government has introduced several policies to promote renewable energy adoption:

- **Renewable Energy Development Agency (IREDA):** Provides financial support for renewable projects.

[11] National Power Portal: Dashboard

- **Production-Linked Incentive (PLI) Scheme:** Encourages domestic manufacturing of solar modules and wind turbines.
- **Green Energy Corridor:** Enhances the transmission infrastructure for renewable energy integration.

3. Investment and Foreign Collaboration

India's renewable energy sector has attracted substantial investment from both domestic and foreign investors. The government has facilitated 100% foreign direct investment (FDI) in renewable energy projects. Countries like the United States, Germany, and Japan have partnered with India to support green energy initiatives, enhancing research and technology exchange.

4. Rural Electrification and Decentralized Renewable Energy

India has successfully utilized renewable energy for rural electrification, providing power to remote areas. Solar microgrids, biogas plants, and wind energy solutions have improved electricity access and enhanced livelihoods in off-grid regions.

Future Goals and Challenges

1. Achieving Net Zero by 2070: India has pledged to achieve net-zero carbon emissions by 2070. To meet this target, the government aims to increase the share of non-fossil fuel energy to 50% by 2030 and expand its renewable energy capacity to 500 GW.

2. Green Hydrogen and Storage Solutions: Green hydrogen is a key component of India's future energy strategy. The National Hydrogen Mission seeks to develop hydrogen production, storage, and distribution infrastructure to decarbonize industries like steel, cement, and transportation.

3. Offshore Wind and Hydropower Development: India is exploring offshore wind energy potential along its coastline. Projects in Tamil Nadu and Gujarat are expected to contribute significantly to the wind energy portfolio. Additionally, large-scale hydropower projects are being developed to complement solar and wind energy.

4. Overcoming Challenges: Despite remarkable progress, challenges persist:

- **Grid Integration:** The intermittent nature of solar and wind energy requires advancements in battery storage and smart grids.
- **Land Acquisition:** Large-scale renewable projects require vast land areas, leading to potential conflicts and delays.
- **Financial Viability:** Ensuring cost-effective financing for renewable energy projects remains a challenge.

India's journey towards renewable energy is marked by impressive achievements and ambitious targets. With strong policy frameworks, technological innovation, and international collaboration, the country is well-positioned to lead the global transition to clean energy. Overcoming existing challenges will be crucial for India to meet its sustainability goals and ensure energy security for future generations. India’s renewable energy journey from 1947 to 2022 showcases a commitment to sustainability and energy security. As the country moves towards achieving 500 GW of renewable energy by 2030 and net-zero emissions by 2070, its leadership in clean energy will play a crucial role in global climate action.

Biodiversity at iCED Campus

The Jungle Babbler (*Argya striata*),

Image Source: Captured by Shri. Vikas Dhir, AAO

The Jungle Babbler[1] (*Argya striata*), is a gregarious bird native to the Indian subcontinent. These birds are known for their social behavior, often foraging in groups of 6 to 10 individuals. This group dynamic has earned them the nickname "Seven Sisters" in urban Northern India and "Saath Bhai" (seven brothers) in Bengali. They have a dull plumage, primarily brownish-grey, but are distinguished by their bright yellow bills.

In terms of diet, jungle babblers exhibit a diverse feeding behavior. They are both carnivores, primarily consuming insects, and herbivores, feeding on grains, nectar, and berries.

Red Vented Bulbul

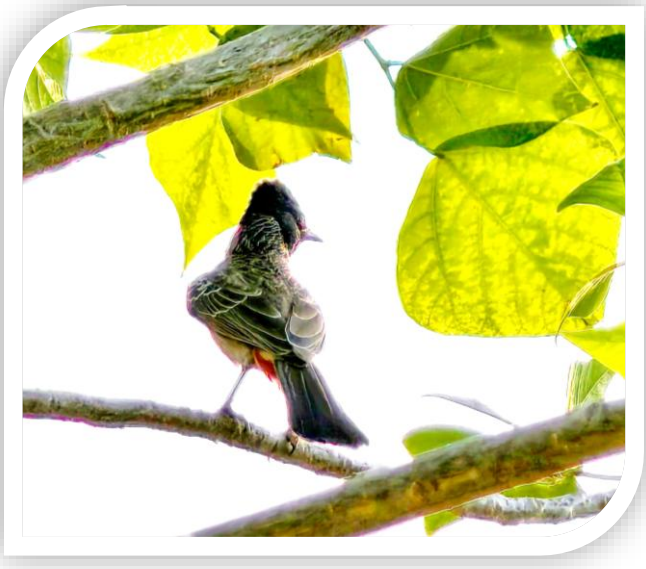


Image Source: Captured by Shri. Vikas Dhir, AAO

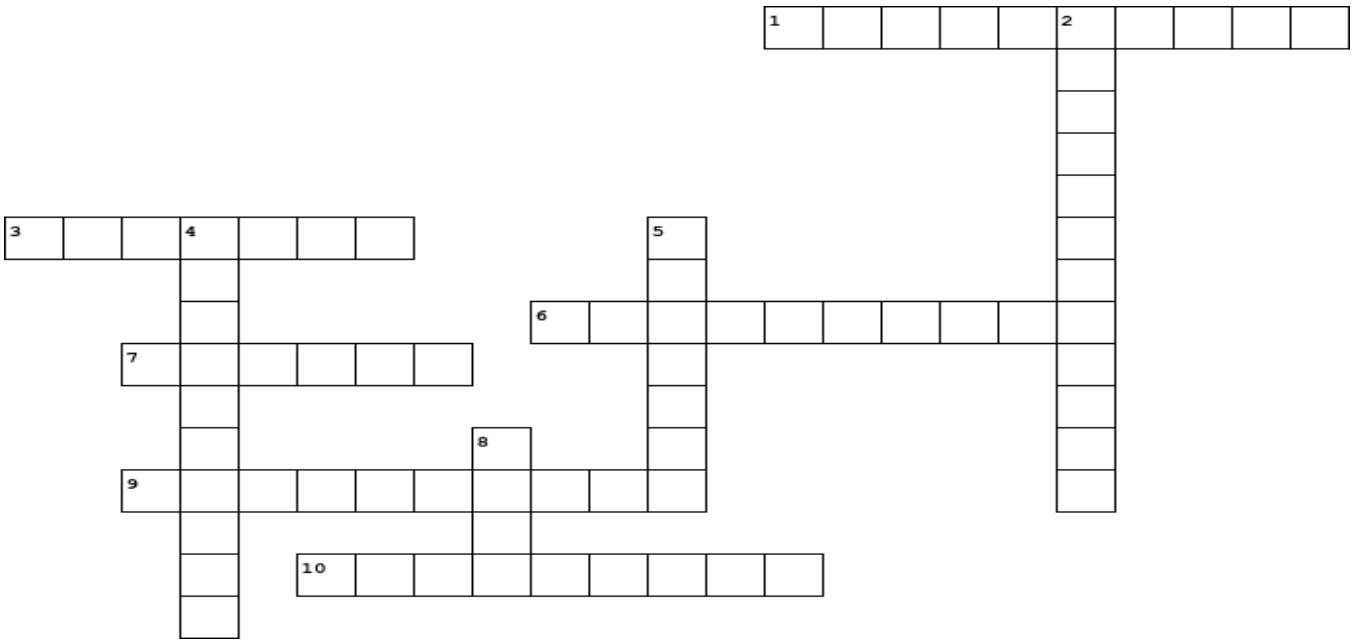
The Red-Vented Bulbul[2] (*Pycnonotus cafer*) is a medium-sized songbird belonging to the bulbul family of passerines. It is a resident breeder widely distributed across the Indian subcontinent, including Sri Lanka, extending eastward to Burma, as well as parts of Bhutan and Nepal. Recognizable by its distinctive short crest that gives its head a squarish appearance, this bird is a common sight in various habitats.

Red-vented bulbuls are non-migratory and thrive in dry scrublands, open forests, plains, cultivated areas, parks, and gardens. Outside the breeding season, they often form large flocks and gather at communal roosts. These birds have an omnivorous diet, feeding on fruits, flower petals, nectar, and insects. Occasionally, they may even prey on house geckos.

[1] https://animalia.bio/jungle-babbler
[2] https://animalia.bio/red-vented-bulbul?environment=371

Crossword Puzzle

By: Ms. Manju Godara, Auditor



Across

1. A renewable energy source harnessed from moving water.

3. India's leading state in wind energy production.

6. Energy harnessed from underground reservoirs of steam.

7. Country partnered with India to launch the International Solar Alliance.

9. These are localized energy systems that can operate independently or in conjunction with the main power grid

10. State where India's largest solar park is situated.

Down

2. The process of converting sunlight into electricity.

4. The 29th Conference of the Parties (COP29) to the United Nations Framework Convention on Climate Change (UNFCCC) was held in.

5. A renewable energy source that comes from organic materials like wood and crop waste.

8. The first 'U' in the PM-KUSUM stands for.

Answers of the crossword puzzle

Across
1.Hydropower 3.Gujarat 6.Geothermal 7.France 9.Microgrids 10.Rajasthan
Down
2.Photovoltaic 4.Azerbaizan 5. Biomass 8. Urja