# India’s Energy Evolution

***This editorial is based on “India shows the way on energy transformation” which was published in The Hindustan Times on 03/01/2025. The article brings into picture India's rapid economic growth, marked by an 8% rise in electricity demand, its ambitious 500 GW renewable energy target, and progress in adding 24.2 GW in 2023-24, while highlighting challenges in grid infrastructure, storage, and equitable access.***

**For Prelims: Electricity demand, Renewable energy, PM-KUSUM, Electric buses, Faster Adoption and Manufacturing of Hybrid and Electric Vehicles, International Solar Alliance, COP29, Perform, Achieve, and Trade (PAT) scheme, UJALA scheme, Battery Energy Storage Systems, Coal-based electricity, Green Energy Corridor, PLI Scheme for Solar Manufacturing , Production-Linked Incentive (PLI) scheme.**

**For Mains:** India’s Energy Transition, Key Issues Associated with India’s Energy Transition.

As India maintains its position as the **fastest growing major economy in the world,** its surging electricity demand, **expected to rise by 8% this year,** reflects the **nation's rapid digital transformation and economic expansion.** The country's ambitious target of deploying **500 GW of renewable energy showcases its commitment to sustainable growth**, having already achieved universal electricity access and **added 24.2 GW of renewable energy in 2023-2024**.

While India's renewable energy journey marks significant progress and sets an example for other emerging economies, **critical challenges remain in grid infrastructure, storage capacity, and equitable access** that need careful attention to ensure the sustainability of this energy revolution and its benefits for all citizens.

## How India is Navigating Energy Transformation?

- **Decentralized Energy Access Solutions:** Decentralized renewable solutions like **solar mini-grids and rooftop solar systems** have emerged as critical tools to bridge India’s energy divide.
    - Micro-grids, such as the **Tata Power initiative** covering 10,000 villages, provide electricity to remote areas that were historically underserved, supported by subsidies under the **PM-KUSUM** scheme.
    - Moreover, the adoption of **solar powered irrigation will not only help reduce the burden of over Rs 1 lakh crore** towards electricity subsidy for agriculture but also reduce oil import bill by reducing diesel consumption by **1.38 billion liters per annum.**
- **Energy Storage-Tackling Intermittency Challenges:** To ensure a reliable grid with high renewable penetration, India is ramping up investments in battery storage systems.
    - For instance, JSW Group is set to establish **50 GWh battery manufacturing capacity in India by 2030.**

    - The **Global Energy Alliance for People and Planet (GEAPP)**, active in India, has begun deploying energy storage solutions, including battery-integrated solar farms.
    - This will enable India to stabilize its grid while meeting the growing demand for electricity.
- **Electrifying the Mobility Sector:** India is leveraging clean energy to decarbonize its transportation sector, aiming for 30% electric vehicle (EV) penetration by 2030.
    - **Electric buses** and **Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME II)** schemes have enhanced urban public transport while reducing emissions.
    - EV sales surged to over **1.5 million units in 2023**, driven by the government's **PLI Scheme for Advanced Chemistry Cells** and partnerships with companies like **Tesla**.
- **Global Advocacy and International Leadership:** India's global leadership in renewable energy is evident in initiatives like the **International Solar Alliance (ISA)** and its push for equitable energy funding at **COP29 in Baku.**
    - The **International Solar Alliance (ISA)** aims to unlock **USD 1 trillion in solar investments by 2030** through its 'Towards 1000' strategy
    - India advocates for free access to green technology and climate finance while criticizing unilateral actions by developed nations **at COP29.**
        - These efforts solidify India's role as a catalyst for global energy transformation.
- **Balancing Energy Security with Sustainability:** India's energy strategy balances a shift to renewables with the need for **reliable coal-based power during peak demand.**
    - **Coal's share**, including lignite, in India's total power generation capacity dropped **below 50% for the first time since the 1960s,** but also ensured stability amid an increase in electricity demand.
    - Between April and November of 2024 alone, **India added nearly 15 GW of renewable energy capacity**, almost double the 7.57 GW added during the same period in 2023.
    - The government's phased approach ensures energy security while scaling sustainable alternatives.
- **Investing in Energy Efficiency:** Energy efficiency programs are critical to reducing emissions and improving affordability.
    - Initiatives under the **Perform, Achieve, and Trade (PAT) scheme** have saved over **68 million tonnes of $CO_2$ emission.**
    - More than **36 crore LED bulbs** have been distributed across India over the past decade under the **UJALA scheme,** leading to annual savings of **Rs 19,153 crore.**
        - These efforts demonstrate India's dual focus on demand-side management and clean energy supply.
- **Harnessing Offshore Wind Potential:** India is exploring **offshore wind energy** to diversify its renewable portfolio.
    - Recently, India approved its first **1 GW offshore wind projects in Tamil Nadu and Gujarat**, aiming fo**r 140 GW installed capacity by 2030.**
    - Supported by international collaborations like Denmark's **Energy Partnership**, this sector could attract investments while reducing emissions significantly.
    - Offshore wind can complement **India's solar energy push, ensuring a more balanced renewable mix.**
- **Fostering Private Sector Participation:** Private investments are central to India's energy transformation.
    - Adani Group plans to build **10 gigawatts of hydroelectric projects** overseas to achieve net zero carbon emissions by 2050.
    - India's Reliance Industries Ltd plans to convert **around 5,000 existing internal combustion engine (ICE)-powered trucks into hydrogen ICE trucks**, reinforcing the importance of public-private synergies in achieving energy goals.

## What are the Key Issues Associated with India's Energy Transition?

- **Intermittency and Reliability of Renewables:** India's rapid shift to renewable energy faces challenges due to the **intermittency of solar and wind power.**
    - A lack of robust energy storage infrastructure limits the grid's ability to supply power consistently during peak demand.
    - India's **Battery Energy Storage Systems (BESS) i**nfrastructure remains inadequate, with the capacity to store only **33 MW,** despite generating **213 GW** of renewable energy,

according to a **Confederation of Indian Industry (CII) report.**
    - Recent blackouts in states like **Maharashtra** highlight the need for greater **investment in grid stabilization technologies** like pumped hydro and advanced battery systems.
- **Dependence on Coal for Baseline Energy:** Despite the growth in renewable energy, **coal continues to dominate India's electricity generation**, creating challenges for decarbonization efforts.
    - India remained **heavily reliant on coal-based electricity during the summer of 2024**, with peak demand expected to surpass 260 gigawatts.
    - However, coal-based emissions undermine India's global commitments, including the **pledge to achieve net-zero emissions by 2070**. Balancing coal usage with renewable integration remains a critical concern.
- **Inadequate Financial Support for Green Energy:** The transition to green energy is capital-intensive, and funding gaps hinder progress, particularly for large-scale renewable projects.
    - India would need cumulative investments of USD 10.1 trillion to achieve net-zero emissions by 2070.
    - Moreover, **delays in subsidy disbursal under schemes like PM-KUSUM** have slowed adoption of solar irrigation systems, impacting farmers and rural electrification.
- **Grid Infrastructure and Integration Issues:** India's aging grid infrastructure struggles to handle the **growing share of renewable energy,** leading to frequent curtailment of solar and wind power.
    - Outdated turbines have reduced wind energy's share to **just 15% of Tamil Nadu's power generation.**
        - Additionally, shortcomings in the state's wind energy repowering policy have hindered its ability to fully realize its potential.
    - **Green Energy Corridor**, aimed at improving grid connectivity for renewables, has faced delays.
- **Energy Access Inequality:** Despite achieving universal village electrification in 2018, energy access disparities persist, especially in remote and rural areas.
    - Recent survey revealed that **2.4% of Indian households still remain unelectrified,** most of them concentrated in rural northern and eastern states of Uttar Pradesh, Madhya Pradesh, Rajasthan, Haryana and Bihar.
- **Dependence on Imported Technology:** India's renewable energy expansion heavily depends on **imported solar modules, batteries, and wind turbines,** making the sector vulnerable to geopolitical risks and supply chain disruptions.
    - In 2023-24, India imported **$7 billion worth of solar equipment,** with China supplying **62.6%** of it.
    - The **PLI Scheme for Solar Manufacturing**, is a step forward but is yet to achieve significant domestic capacity.
- **Land Acquisition and Environmental Concerns:** Renewable energy projects require **vast land parcels,** often leading to conflicts with local communities and biodiversity concerns.
    - For example**, protests against solar parks in Rajasthan and Gujarat** highlighted displacement issues and ecological disruptions.
        - In 2024, residents of Baiya village in Jaisalmer staged a demonstration attempting to **halt the construction of the Adani Solar Power Project.**
    - Additionally, studies show that **wind farms in Western Ghats have affected migratory bird patterns,** raising the need for sustainable project planning.

## What Measures can be Adopted for a More Efficient and Sustainable Energy Transition in India

- **Promoting Domestic Manufacturing of Renewable Technology:** To reduce dependency on imports, India must strengthen its domestic renewable manufacturing ecosystem, particularly in **solar modules, wind turbines, and battery systems**.
    - Expanding the **PLI Scheme for Solar Manufacturing**, can attract more investments in giga-factories. Partnerships with global leaders**, such as Reliance Industries' tie-up for advanced battery technology**, can further bolster local capacity.
        - This will shield India from geopolitical risks and supply chain disruptions.
- **Transitioning to Green Hydrogen:** Green hydrogen, derived from renewable energy, can **decarbonize hard-to-abate sectors like steel, cement, and heavy transport.**

    - The government's National Green Hydrogen Mission should include subsidies for electrolysis technology and support for R&D.
    - Large-scale hydrogen hubs should be developed near renewable energy zones to ensure affordability and accessibility.
    - This aligns with India's goal to become a global leader in green hydrogen production, leveraging its abundant solar resources.
- **Modernizing Transmission and Distribution Infrastructure:** A robust and smart grid system is crucial for handling the variability of renewable energy.
    - Investments in **smart meters, AI-based grid management, and predictive maintenance technologies** can enhance efficiency.
    - The Revamped Distribution Sector Scheme (RDSS) must prioritize reducing **Aggregate Technical and Commercial (AT&C) losses.**
- **Integrating Circular Economy Principles:** Adopting circular economy practices in energy systems can reduce waste and resource use.
    - Initiatives like **recycling solar panels and reusing materials from decommissioned wind turbines** should be incentivized.
    - Coal-dependent regions can explore **waste-to-energy projects** to manage urban waste sustainably.
        - These measures ensure resource efficiency while providing livelihood opportunities in rural areas.
- **Focus on Just Energy Transition for Coal-Dependent States:** A fair transition for coal-dependent states like **Jharkhand, Odisha, and Chhattisgarh** is critical to avoid socio-economic disruptions.
    - Skill development programs for coal workers, **alternative employment in renewable energy,** and financial assistance to state governments can facilitate a smoother transition.
    - Setting up **green industries in coal belts ensures economic diversification** while utilizing existing infrastructure.
    - A just transition framework aligns with India's equitable growth objectives and ensures no community is left behind.
- **Expanding Energy Storage Solutions:** Investing in scalable and affordable energy storage technologies like **lithium-ion, solid-state batteries, and pumped hydro** is essential for addressing the intermittency of renewables.
    - Recent battery swapping policies should be expanded for smaller EVs and rural applications.
    - Encouraging domestic production of energy storage systems under the **Production-Linked Incentive (PLI) scheme** can reduce costs and dependence on imports.
        - Energy storage will **enable round-the-clock availability of renewable energy,** stabilizing the grid and supporting peak demand.
- **Promoting Agri Voltaics for Dual Use of Land:** Integrating solar panels with agricultural practices, known as agrivoltaics, can optimize land use and benefit farmers.
    - By installing **solar panels above crops, farmers can earn additional income from** selling surplus electricity while protecting crops from extreme weather.
    - Scaling this through **subsidies or buy-back guarantee**s will improve rural energy access while reducing the strain on agricultural lands.
- **Waste Heat Recovery in Industries:** India's energy-intensive industries, such as cement, steel, and chemicals, generate significant waste heat, which often goes unused.
    - Mandating **waste heat recovery systems (WHRS) in large-scale manufacturing** units can reduce overall energy consumption and emissions.
    - For instance, the adoption of such systems in cement plants has led to energy savings and reduced carbon footprints.
        - Providing fiscal incentives for WHRS installation can accelerate its uptake across industries.
- **Exploring Small Modular Reactors (SMRs) for Clean Nuclear Energy:** **Small modular reactors (SMRs)** represent an innovative nuclear technology that can **provide scalable and safer clean energy.**
    - These reactors require **smaller initial investments** compared to traditional nuclear plants, making them ideal for developing economies like India.

    - By partnering with countries like the **US, w**hich are advancing in SMR technology, **India can diversify its energy mix while maintaining low emissions.** SMRs also hold potential for off-grid energy applications in remote areas.
- **Policy Support for Carbon Capture and Utilization (CCU): Carbon capture and utilization (CCU) technologies** can complement India's efforts to decarbonize fossil-fuel-based industries.
    - Establishing policies to **incentivize the adoption of CCU in sectors like thermal power, steel, and cement** can turn emissions into valuable by-products **(e.g., industrial-grade carbonates or synthetic fuels).**
    - India's burgeoning startup ecosystem can be mobilized to develop affordable CCU technologies, reducing reliance on costly imports.
- **Energy Transition in Urban Planning:** Integrating energy-efficient infrastructure into urban development is critical to manage the rising energy demands of India's growing cities.
    - **Green building norms, district cooling systems, and the promotion of energy-efficient public transport** like metros and electric buses can significantly reduce urban energy intensity.
    - Programs like **Smart Cities Mission** **should prioritize sustainable energy solutions in planning urban expansions**.
    - By adopting low-energy urban designs, cities can contribute to the national energy transition goals.
- **Tapping Into Geothermal Energy:** Though underexplored, India has geothermal potential in regions like **Ladakh, Himachal Pradesh, and Gujarat.**
    - Developing pilot geothermal projects, particularly for heating applications, can diversify the renewable energy mix.
    - **Geothermal energy provides a stable, low-maintenance, and base-load power source,** suitable for remote regions with extreme climates.
    - Partnerships with countries experienced in geothermal technology, like Iceland, can accelerate India's capacity in this domain.
- **Biomass-Based District Heating Systems:** Biomass, sourced sustainably from agricultural residues, can be utilized for district heating systems in cold regions like **Himachal Pradesh and Uttarakhand.**
    - Such systems can replace conventional coal or diesel-based heating solutions, reducing emissions and energy costs.
    - Policies to **incentivize biomass collection and processing,** along with community-led operations, can ensure the long-term viability of these systems.
        - This approach **addresses both agricultural waste management and energy access challenges.**
- **Mandatory Renewable Energy Procurement for Corporates:** To engage the private sector in the energy transition, the government can mandate a **percentage of renewable energy procurement in corporate energy consumption.**
    - Large energy-intensive industries, IT firms, and commercial establishments can be incentivized to invest in captive renewable power projects or purchase green power from developers.
    - This can complement **India's Renewable Energy Certificates (REC) market** and encourage large-scale investments in renewables.
- **Incentivizing Vehicle-to-Grid (V2G) Technology:** Vehicle-to-grid (V2G) technology allows **electric vehicles to feed electricity back into the grid when not in use,** thus acting as decentralized energy storage units.
    - Incentives for **V2G-enabled EVs** and integration with smart grids can help balance peak demand.
    - Deploying this **technology in urban hubs can reduce dependency on standalone energy storage systems.** This approach enhances grid stability while promoting electric mobility.

## Conclusion:

India's energy transition is driven by a vision for a **sustainable, inclusive future, leveraging clean technologies, decentralized solutions, and strong policies**. While progress is seen in renewable energy scaling, decentralized access, and private sector involvement, challenges like **grid instability, coal dependence, and energy access gaps remain**. By investing in **smart grids, energy storage,**

**and innovations like green hydrogen,** India can build a more resilient energy system. Prioritizing just transitions for coal-dependent states and improving energy efficiency will ensure broad benefits, supporting both national growth and global sustainability goals **(SDGs 7 and 13)**.

***Drishti Mains Question:***

Discuss the key challenges and opportunities in India's transition towards renewable energy, considering limitations in storage and grid infrastructure. Suggest measures to ensure a sustainable and equitable energy future.

## UPSC Civil Services Examination, Previous Year Question (PYQ)

### *Prelims*

**Q. With reference to the Indian Renewable Energy Development Agency Limited (IREDA), which of the following statements is/are correct? (2015)**

1. It is a Public Limited Government Company.
2. It is a Non-Banking Financial Company.

**Select the correct answer using the code given below:**

(a) 1 only

(b) 2 only

(c) Both 1 and 2

(d) Neither 1 nor 2

**Ans: (c)**

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### *Mains*

**Q.** “Access to affordable, reliable, sustainable and modern energy is the sine qua non to achieve Sustainable Development Goals (SDGs)”.Comment on the progress made in India in this regard. (2018)