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 CO2 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)

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)
