

**MAINS iMPACT 2025****30-12-2025****RENEWABLE ENERGY****SYLLABUS:**

GS 3 > Economic Development >> Energy Infrastructure

REFERENCE NEWS:

India recorded its **highest-ever renewable energy capacity addition in 2025**, adding **44.51 GW** up to November, nearly **double** the **24.72 GW** installed during the same period in 2024.

- **Total renewable energy capacity reached 253.96 GW in November 2025**, up by over **23%** from **205.52 GW** in November 2024.
- **Solar energy** led the growth with **34.98 GW** added in 2025. India crossed **100 GW of solar capacity in January 2025**, and total solar capacity rose to **132.85 GW**, a **41% increase** from **94.17 GW** a year earlier.
- **Wind energy** capacity additions stood at **5.82 GW**, compared to **3.2 GW** last year. Installed wind capacity crossed **50 GW in March 2025** and reached **53.99 GW in November 2025**, marking a **12.5% growth**.
- India crossed the **250 GW non-fossil capacity milestone in August 2025**. By November 2025, **non-fossil fuel-based capacity reached 262.74 GW**, accounting for **51.5%** of the country's total installed electricity capacity of **509.64 GW**.
- Notably, India achieved **50% of cumulative installed power capacity from non-fossil sources in June 2025**, **five years ahead** of its **2030 NDC target** under the Paris Agreement.

Overall, the data highlights rapid progress towards India's goal of **500 GW of non-fossil energy capacity by 2030**, with solar and wind driving the transition.

POTENTIAL OF INDIA FOR RENEWABLE ENERGY:

Solar Energy Potential: India is endowed with vast solar energy potential, with an average of 300 sunny days a year and an annual solar potential of around 5,000 trillion kWh. The country has the technical potential to generate over 748 GW of solar power.

- **Bhadla Solar Park, Rajasthan:** One of the largest solar parks in the world, with a capacity of 2,245 MW.
- **Rewa Ultra Mega Solar Park, Madhya Pradesh:** A significant solar project with a capacity of 750 MW.
- Initiatives like ISA, PM Surya Ghar Yojana etc boost solar power production

Wind Energy Potential: India's wind energy potential is estimated at 302 GW at 100 meters above ground level. The country has a coastline of over 7,500 km, which is favorable for offshore wind energy development.

- **Muppandal Wind Farm, Tamil Nadu:** The largest onshore wind farm in India with an installed capacity of 1,500 MW.
- **Gujarat Wind Farms:** Gujarat has significant wind energy installations with a capacity of over 7,000 MW.
- Initiatives like offshore wind energy policy boost the wind energy capacity

Hydropower Potential: India has a potential of around 145 GW of hydropower, including small hydro projects. The country's vast river systems provide ample opportunities for hydroelectric power generation.

- **Tehri Dam, Uttarakhand:** One of the largest hydroelectric projects in India with a capacity of 1,000 MW.

Nuclear Energy Potential: India's nuclear energy potential is substantial, with an emphasis on thorium-based reactors due to the country's large thorium reserves. The government aims to increase nuclear capacity to 22.48 GW by 2031.

- **Kudankulam Nuclear Power Plant, Tamil Nadu:** The largest nuclear power station in India, with a capacity of 2,000 MW (two reactors of 1,000 MW each)

Biomass Energy Potential: India has a biomass potential of about 18 GW, with an additional 5 GW potential from bagasse-based cogeneration in sugar mills. Agricultural residues and organic waste provide ample biomass resources.

- **Punjab Biomass Power Plant:** One of the largest biomass-based power plants in India with a capacity of 12 MW.
- **Sugarcane Bagasse Cogeneration Projects:** Various sugar mills in Uttar Pradesh and Maharashtra utilize bagasse for power generation.

Geothermal Energy Potential: India has moderate geothermal potential, with estimates around 10 GW. Regions like the Himalayas, Western Ghats, and certain parts of the Deccan Plateau are promising for geothermal energy exploration.

- **Puga Valley, Ladakh:** Identified as a high-potential geothermal field with plans for pilot projects.
- **Tatapani, Chhattisgarh:** Another potential site for geothermal energy development.

India's renewable energy ecosystem is set for a major transformation over the next five years, driven primarily by **energy storage and green hydrogen**, according to ReNew Energy.

- **Energy storage** will be a game changer by addressing the intermittency of renewables and enabling **firm, dispatchable power**. Battery-backed and hybrid projects are already delivering **four or more hours of reliable supply**, which is crucial for rising industrial and commercial demand.
- **Green hydrogen** is expected to play a transformative role in **decarbonising hard-to-abate sectors** such as steel, cement, fertilisers and heavy transport. Under the **National Green Hydrogen Mission**, India aims to produce **5 million tonnes by 2030**, supported by dedicated renewable capacity and falling costs due to scaling of electrolyser manufacturing.
- Together, storage and green hydrogen can shift renewables from being viewed as variable sources to a **baseload alternative**, enhancing **grid stability, energy security and India's global competitiveness** in clean energy manufacturing and exports.
- Achieving India's target of **500 GW of non-fossil capacity by 2030** will require investments of around **₹30 lakh crore**, mobilised through green bonds, blended finance, multilateral funding and global investors. Financing momentum is also growing for **hybrid and storage-backed projects**, improving bankability.
- Grid integration will depend on **green energy corridors, transmission upgrades, battery storage**, and policy tools like **time-of-day tariffs, round-the-clock (RTC) contracts and demand flexibility mechanisms**.

- On manufacturing, ReNew is expanding India's domestic solar supply chain with module, cell and planned **wafer manufacturing**, including a proposed **6 GW PV ingot and wafer facility in Andhra Pradesh**. India is expected to develop a **fully domestic solar manufacturing ecosystem** in the next 4–5 years, emerging as a global alternative supplier to China.
- ReNew's sustainability efforts extend beyond energy generation, impacting **1.7 million lives** through CSR initiatives, promoting **gender diversity**, climate-resilient livelihoods and strong ESG governance, with global recognition for its sustainability performance.

CHALLENGES TO INDIA'S CLEAN ENERGY TRANSITION:

Financial Constraints:

- **High Initial Costs:** The initial capital expenditure for setting up renewable energy infrastructure, such as solar and wind farms, is significantly high.
 - Example: Solar power plants require substantial investment in photovoltaic cells and storage systems.
- **Limited Access to Finance:** Small and medium enterprises (SMEs) and individual consumers often face difficulties in accessing finance for renewable energy projects.
 - According to the International Finance Corporation (IFC), there is a financing gap of around \$450 billion for renewable energy projects in India.

Technological Challenges:

- **Intermittency of Renewable Sources:** Solar and wind energy are intermittent and depend on weather conditions, leading to reliability issues.
 - Solar panels generate power only during daylight, and wind turbines are dependent on wind speeds. Changing weather patterns led to a 15% fall in hydropower generation in 2023.
- **Energy Storage:** Effective and affordable energy storage solutions are necessary to balance supply and demand.
 - The implementation of large-scale battery storage systems, such as Tesla's Powerwall, is still in nascent stages in India.

Infrastructure and Grid Integration:

- **Inadequate Grid Infrastructure:** The existing power grid infrastructure is not adequately equipped to handle the variable nature of renewable energy.
 - Example: The integration of renewable energy into the national grid requires significant upgrades to transmission and distribution networks.
- **Transmission Losses:** High transmission and distribution losses reduce the efficiency of energy delivery.
 - India has one of the highest transmission and distribution losses in the world, averaging around 20%.

Regulatory and Policy Challenges:

- **Inconsistent Policies:** Frequent changes in policies and regulatory frameworks create uncertainty for investors.
 - The lack of a stable policy environment can deter long-term investments in renewable energy.

- **Subsidies and Incentives:** While subsidies for renewable energy exist, they are often insufficient or inconsistently applied.
 - Example: The delay in disbursing subsidies for rooftop solar installations has slowed their adoption.

Land Acquisition and Environmental Concerns:

- **Land Acquisition:** Acquiring land for large-scale renewable energy projects can be challenging due to high population density and land ownership issues.
 - The proposed solar park in Rajasthan faced delays due to land acquisition disputes with local communities.
- **Environmental Impact:** Renewable energy projects, particularly hydropower, can have significant environmental impacts, such as habitat disruption.
 - Example: Large hydropower projects in the Himalayas like Joshimath, Malana have faced opposition due to their potential impact on local ecosystems.

Social Acceptance and Awareness:

- **Public Awareness:** There is a lack of awareness and understanding among the general public about the benefits of renewable energy.
 - Example: Misconceptions about the reliability and cost of renewable energy can hinder adoption.
- **Community Resistance:** Local communities may resist renewable energy projects due to concerns about displacement and livelihood disruption.
 - Wind farm projects in Tamil Nadu faced opposition from local farmers concerned about land use changes. Kudankulam Nuclear plant protests

Skill Gaps and Workforce Training:

- **Technical Expertise:** There is a shortage of skilled professionals with expertise in renewable energy technologies.
 - The renewable energy sector requires specialized training programs to build a competent workforce.
- **Vocational Training:** Existing vocational training programs are insufficient to meet the growing demand for skilled labor in the renewable energy sector.
 - Example: Institutes like the National Institute of Solar Energy (NISE) need to scale up their training efforts.

WAY FORWARD:

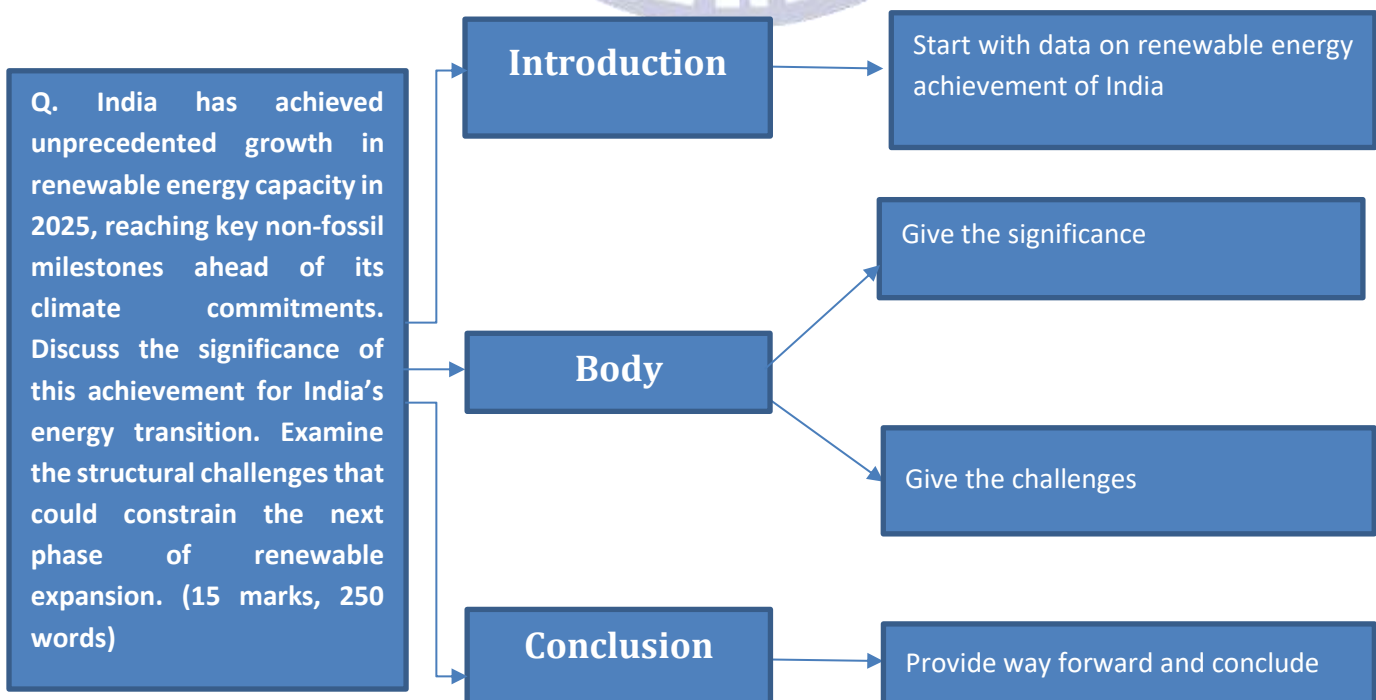
- **The government must raise targets for renewable energy and storage systems** to go beyond 500 GW in 2030. Its share in India's power generation mix is just 13%. Renewables and storage can support peak demand, are cost-competitive, and are faster to build.
- **Steer faster deployment of diverse clean energy resources.** This requires tapping the RE potential in more States as well as faster grid connectivity and access to suitable, conflict-free land for the timely commissioning of projects.

- In 2023 alone, China added 300 GW of solar and wind capacity, while the European Union added 73 GW. India’s cumulative renewable capacity stood at 144 GW, with another 128 GW in the pipeline.
- **Implement measures to improve the availability of energy.** The low liquidity (volume being traded) in the power exchange presents price volatility risks.
 - During FY23, only 6.3% of India’s power generation was procured through power exchanges, with the rest coming through bilateral agreements.
- **Ensure effective maintenance and utilisation of the coal fleet.** Even as we add more renewables, coal plays an important role. CEEW’s analysis of MERIT data shows that, in FY24, more than 210 GW of coal capacity generated about 80% of the power during non-solar hours. State regulators must revise the norms to enable timely upkeep of the coal fleet and compensate for investments to make select coal plants flexible.
- **Fast-track digitalisation to empower discoms and consumers to play an active role in India’s energy transition.** Smart meters would enable discoms to forecast power demand accurately, plan networks better, and integrate renewables cost-effectively. However, India’s smart metering drive is far from the 250 million target. But keeping consumer privacy and system preparedness against cyberattacks at the heart of regulations and digitalisation efforts would be crucial.
 - More than 11 million smart meters have already been installed in India, with half of these in Bihar and Assam. Discoms must overcome their hesitation and take inspiration from Bihar and Assam, which are already reaping benefits like reduced losses and timely bill delivery to consumers through smart metering.

PRACTICE QUESTION:

Q. India has achieved unprecedented growth in renewable energy capacity in 2025, reaching key non-fossil milestones ahead of its climate commitments. Discuss the significance of this achievement for India’s energy transition. Examine the structural challenges that could constrain the next phase of renewable expansion. (15 marks, 250 words)

APPROACH:



MODEL ANSWER:

India recorded its **highest-ever renewable energy capacity addition of 44.51 GW in 2025**, nearly doubling the installations of the previous year. As of November 2025, total renewable capacity reached **253.96 GW**, while **non-fossil sources accounted for over 51.5% of total installed power capacity**, achieved **five years ahead of India's NDC target** under the Paris Agreement

Significance of the Achievement

- **Climate leadership:** Early achievement of NDC targets strengthens India's credibility in global climate negotiations.
- **Energy security:** Diversification away from fossil fuels reduces import dependence and exposure to global price shocks.
- **Solar and wind dominance:** Rapid expansion of solar (132.85 GW) and wind (53.99 GW) demonstrates scalability of renewables.
- **Economic opportunity:** Large-scale capacity creation stimulates domestic manufacturing, jobs and green investments.
- **Foundation for 500 GW target:** Momentum supports India's goal of **500 GW non-fossil capacity by 2030**.
- **Grid decarbonisation:** Higher share of clean power lowers emissions intensity of electricity generation.

Challenges Ahead

- **Inadequate Energy Storage Infrastructure:** India's renewable growth has outpaced the development of **battery storage and pumped hydro systems**. Storage deployment remains limited and costly. Experts note that storage is essential to convert renewables into firm, dispatchable power, yet large-scale storage capacity is still at a nascent stage. Excess generation leads to curtailment, while peak demand still relies on coal.
- **Grid and Transmission Constraints:** Renewable generation is often concentrated in resource-rich but demand-poor regions (e.g., Rajasthan, Gujarat). **Transmission infrastructure has not expanded at the same pace. Issues include** congestion in inter-state transmission, delays in green energy corridors
- **Financing and Investment Requirements:** Achieving **500 GW of non-fossil capacity by 2030** requires massive capital investment (estimated at **₹30 lakh crore**). High cost of capital, limited access to low-cost long-term finance
- **DISCOM Financial Weakness:** State distribution companies (DISCOMs) remain financially stressed, with **high losses and delayed payments**. Weak power purchase agreements (PPAs), reduced bankability of renewable projects, hesitation in signing long-term contracts, especially for RTC power
- **Land Acquisition and Environmental Concerns:** Large-scale solar and wind projects require significant land, often leading to conflicts with agriculture and local communities, **environmental concerns** in ecologically sensitive zones Project delays, litigation, and rising costs, slowing capacity addition.
- **Domestic Manufacturing and Supply Chain Gaps:** While solar capacity has grown rapidly, **India still depends on imports for key components**, especially wafers and polysilicon. Slows progress towards energy security and global competitiveness.

- **Skill and Workforce Limitations:** The renewable sector requires a workforce skilled in **advanced technologies** such as storage systems, hydrogen electrolyzers, smart grids and power electronics. Skill shortages can constrain project execution, O&M efficiency, and innovation.

Way Forward

- Scale up **energy storage and green hydrogen** to enable round-the-clock renewable power.
- Invest in **green energy corridors, transmission upgrades and smart grids**.
- Mobilise finance through **green bonds, blended finance and multilateral support**
- Ensure **policy stability** and faster clearances.
- Strengthen **domestic manufacturing** across the solar value chain.
- Expand **skill development and vocational training** in clean energy.

India's 2025 renewable milestone marks a decisive shift towards a low-carbon energy future. Sustaining this transition will depend on resolving grid, storage and financing constraints to transform capacity growth into reliable, affordable and resilient clean power.

