NEXT IAS

DAILY EDITORIAL ANALYSIS

TOPIC

ENERGY STORAGE IN INDIA FOR SCALING UP ITS RENEWABLE ENERGY CAPACITY

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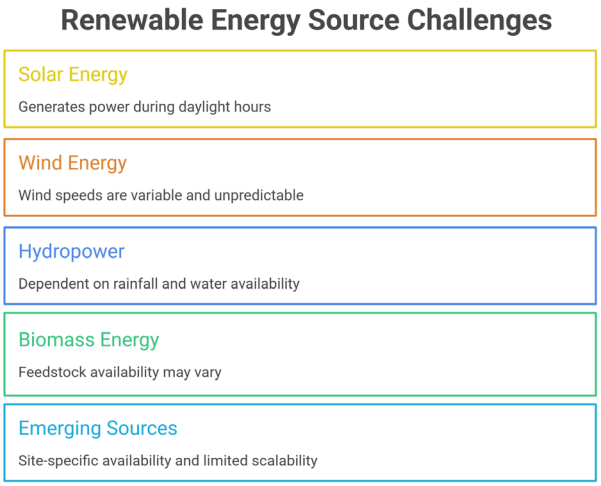
Context

- The mismatch between generation and consumption of electricity makes **energy storage systems (ESS)** indispensable for ensuring grid stability, reliability, and efficient utilization of renewable power.

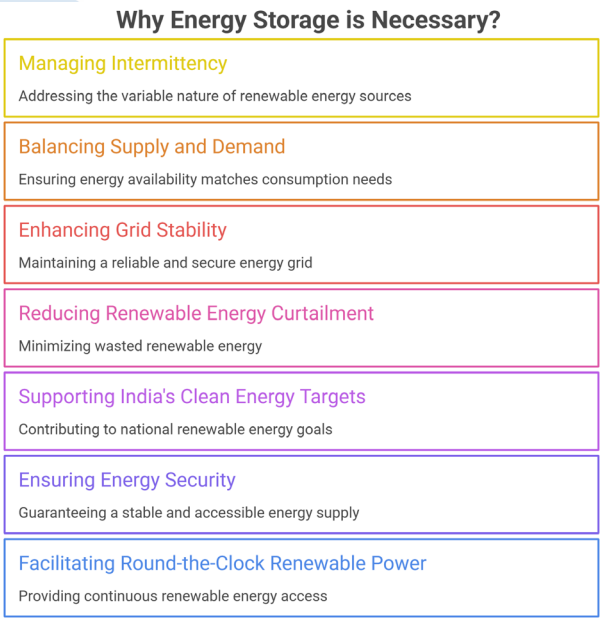
India's Renewable Energy Capacity

- India is rapidly expanding its renewable energy capacity to meet its climate commitments and energy security goals.
- Renewable energy sources account for nearly **53% of India's installed power capacity (283 GW out of 532 GW)**, with solar energy contributing more than **150 GW**.
- However, the increasing share of renewable energy brings a **critical challenge i.e. intermittency** (a state of stopping and starting repeatedly, or operating at irregular intervals rather than continuously).



What is Energy Storage?

- Energy storage refers to technologies that capture excess electricity generated during periods of high renewable energy production and release it when demand exceeds supply.
  - It acts as a buffer between electricity generation and consumption.
- It helps balance supply and demand, reduce renewable energy curtailment, enhance grid reliability, support peak-load management, and facilitate round-the-clock renewable power supply.



Global Scenario

- **Pumped Hydro Storage:** Global installed capacity stands at approximately **160 GW**.
  - **Leading countries:** China (~66 GW), Japan (~21.8 GW), and United States (~18.9 GW)
- **Battery Energy Storage:** Global battery storage capacity is estimated at around **270 GW**.
  - According to the International Energy Agency (IEA), **108 GW** of new battery storage was added in 2025, representing a **40% increase** over 2024.
  - China accounted for nearly **60% of global additions**, followed by the United States and Europe.
  - Deployment is accelerating in Australia and the Middle East, where storage is increasingly viewed as essential for energy security and renewable integration.

India's Energy Storage Status

- **Current Installed Capacity:** BESS (~0.27 GW); PHS (~7.2 GW)
- **Central Electricity Authority (CEA) Projections for 2035-36: 174 GW / 888 GWh** by 2035-36.

- BESS (80 GW / 321 GWh); PHS (94 GW / 567 GWh)
- Storage systems with **4–6 hours duration** will be crucial for integrating growing volumes of renewable energy beyond 2030.

Expansion Pipeline

- **Pumped Hydro Projects:**
  - **13,120 MW** under construction.
  - **9,580 MW** approved and awaiting construction.
  - Nearly **75,000 MW** under survey and investigation.
- **Battery Storage Projects:**
  - **10,658.94 MW / 28,739.32 MWh** under construction.
  - **22,347.15 MW / 69,836.70 MWh** under tendering.

Major Energy Storage Technologies

- **Pumped Hydro Storage (PHS):** It is the most mature and widely used large-scale storage technology globally.
  - **Advantages:** Suitable for long-duration storage, high reliability and long operational life, and large-scale energy storage capability.
  - **Limitations:** Requires specific geographical conditions, high initial capital investment, environmental and land acquisition concerns.
- **Battery Energy Storage Systems (BESS):** It stores electricity in electrochemical form and releases it when required.
  - Lithium-ion batteries, particularly **Lithium Iron Phosphate (LFP) batteries**, dominate the global market, and **accounted for over 90% of global battery storage additions in 2025**.
  - **Advantages:** Fast response time, modular deployment, and suitable for short-duration storage (4–6 hours).
  - **Limitations:** Dependence on critical minerals, battery degradation over time, and import dependence for cells and components.

Other Emerging Storage Technologies

- **Concentrated Solar Thermal Storage:** Uses mirrors and molten salts to store solar heat, which is later converted into electricity.
- **Compressed Air Energy Storage (CAES):** Stores compressed air in underground caverns and releases it to drive turbines during peak demand.
- **Flywheel Energy Storage:** Stores energy in rapidly spinning rotors and provides instant power support for grid stabilization.
- **Gravity-Based Storage:** Stores energy by lifting heavy masses and generates electricity when they descend.

Challenges in Energy Storage in India

- **Import Dependence:** About **75–80% of lithium-ion cells used in India are imported**, while cells account for nearly **80% of a battery system's cost**.
  - It creates risks related to geopolitical tensions, supply-chain disruptions, trade restrictions, and price volatility.
- **High Capital Costs:** BESS requires substantial upfront investment. Although battery prices are declining globally, large-scale deployment remains expensive.
- **Limited Domestic Manufacturing:** Domestic production of advanced battery cells and critical components remains inadequate.

- Reliance on imported technology affects self-reliance and cost competitiveness.

- **Critical Mineral Constraints:** Lithium, cobalt, nickel, and graphite are essential for battery manufacturing.
  - India has limited reserves of many of these minerals and depends on imports.
- **Land and Environmental Concerns:** Pumped Hydro Storage Projects (PSPs) require large land areas and suitable topography.
  - Environmental clearances, biodiversity concerns, and displacement issues can delay projects.
- **Long Gestation Period of PHS Projects:** Pumped hydro projects involve extensive surveys, approvals, and construction timelines.
  - Delays can affect the pace of renewable energy integration.
- **Grid Integration Challenges:** Integrating storage systems into existing transmission and distribution networks requires significant upgrades.
  - Operational and regulatory frameworks are still evolving.
- **Financing and Investment Risks:** Uncertainty regarding revenue streams and market mechanisms can discourage private investment.
  - Long payback periods increase financial risks.
- **Battery Disposal and Recycling Issues:** Large-scale deployment will generate significant battery waste in the future.
  - India's battery recycling ecosystem is still developing.
- **Regulatory and Policy Gaps:** Standardized regulations for storage procurement, pricing, and grid services are evolving.
  - Policy uncertainty can slow investment and adoption.
- **Technological Dependence:** Advanced battery technologies and manufacturing know-how are concentrated in a few countries.
  - It limits India's technological autonomy in the storage sector.
- **Growing Future Demand:** Storage requirements are expected to rise sharply as renewable energy capacity expands.
  - Scaling storage infrastructure at the required pace remains a major challenge.

Initiatives and Efforts to Promote Energy Storage in India

- **National Energy Storage Requirement Planning: CEA** has projected a requirement of **174 GW/888 GWh** of energy storage capacity by 2035-36.
  - Provides a roadmap for integrating large-scale renewable energy into the grid.
- **Viability Gap Funding (VGF) for BESS:** It aims to make projects financially viable, and to reduce storage costs and accelerate deployment.
- **Production Linked Incentive (PLI) Scheme for ACC Batteries:** Supports domestic manufacturing of **Advanced Chemistry Cells (ACC)**.
  - Reduces dependence on imported battery cells and strengthens the domestic value chain.
- **National Programme on Advanced Chemistry Cell (ACC) Battery Storage:** Encourages indigenous manufacturing of next-generation battery technologies.
  - Promotes technological self-reliance and energy security.
- **Development of Pumped Storage Projects (PSPs):** Fast-tracking approval and construction of pumped hydro storage projects.
  - Several projects are under construction, while many more are under survey and investigation.
- **Renewable Energy Storage Obligation (ESO):** Introduced by the Ministry of Power as part of Renewable Purchase Obligations (RPOs).

  - Mandates designated entities to procure a certain share of electricity from energy storage-backed renewable sources.
- **Green Energy Corridor Programme:** Strengthens transmission infrastructure for integrating renewable energy and storage systems.
  - Facilitates efficient evacuation of renewable power across regions.
- **National Green Hydrogen Mission:** Promotes green hydrogen production using renewable energy.
  - Hydrogen can serve as a long-duration energy storage medium in the future.
- **PM Surya Ghar: Muft Bijli Yojana:** Encourages rooftop solar adoption and distributed energy resources.
  - Creates opportunities for future integration of household-level battery storage systems.
- **Battery Waste Management Rules, 2022:** Introduces **Extended Producer Responsibility (EPR)** for battery manufacturers.
  - Promotes recycling, resource recovery, and sustainable battery disposal.
- **Critical Minerals Strategy:** India is securing overseas mineral assets and strengthening domestic exploration of lithium and other critical minerals.
  - Supports long-term battery manufacturing and storage deployment.
- **International Cooperation:** Participation in initiatives such as the **International Solar Alliance (ISA)** and partnerships for clean energy technologies.
  - Facilitates technology transfer, investment, and best-practice sharing in energy storage.

Daily Mains Practice Question

[Q] Discuss the role of energy storage systems in integrating renewable energy into the power grid. Examine the challenges associated with scaling up energy storage capacity in India.

Source: IE