El Niño Threatens India's Power System with Rising Climate-Driven Energy Security Risks

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Recent Developments:

Key Highlights:

- According to the **Centre for Research on Energy and Clean Air (CREA)**, **India's power system** is likely to experience greater stress from the developing **El Niño** than that of any other country.
- The **India Meteorological Department (IMD)** has confirmed the emergence of **El Niño** conditions over the **equatorial Pacific Ocean**, with further strengthening expected during the **Southwest Monsoon** season.
- The **IMD** has forecast **below-normal Southwest Monsoon rainfall** at **90% of the Long Period Average (LPA)**, with a **60% probability** of a deficient monsoon season.
- Weaker hydropower generation, reduced wind output and rising cooling demand are expected to widen the gap between electricity demand and supply during **2026–27**.

El Niño:

Meaning and Characteristics:

- **El Niño**, meaning **"Little Boy"** in Spanish, is a recurring **ocean-atmosphere climate phenomenon** characterised by abnormal warming of **Sea Surface Temperatures (SSTs)** in the **central and eastern equatorial Pacific Ocean**.
- During **El Niño**, the normally strong **Trade Winds** weaken, allowing warm surface waters to move eastward towards the western coast of the Americas.
- The weakening of **Trade Winds** suppresses the upwelling of cold, nutrient-rich water along the Pacific coast, disrupting global atmospheric circulation.
- **El Niño** is one phase of the **El Niño-Southern Oscillation (ENSO)**, while **La Niña** represents the opposite cooling phase and **ENSO-neutral** indicates neither phase is dominant.

Impact of El Niño on India:

Monsoon and Climate:

- **El Niño** generally weakens the **Southwest Monsoon**, increasing the probability of below-normal rainfall over India.
- Deficient rainfall reduces reservoir levels, lowers hydroelectric generation and affects agricultural productivity.
- Higher temperatures during **El Niño** increase electricity demand due to greater use of cooling appliances.
- The phenomenon also increases the likelihood of **heat waves**, droughts and forest fires across several regions.

Power Sector Impact:

- **CREA** estimates that India could face an electricity generation deficit of nearly **18 TWh** during the one-year period ending **June 2027**.
- Reduced **wind** and **hydropower** generation, coupled with rising electricity demand, may widen the supply-demand gap.
- The shortfall is expected to be largely met through **coal-fired thermal power plants**, increasing fossil fuel dependence.
- Additional coal-based generation may emit nearly **17 million tonnes of Carbon Dioxide (CO?)**, slowing India's decarbonisation efforts.

India's Electricity Sector:

Current Status:

- During **2025**, India's total electricity generation increased by about **1%**.
- **Coal-based electricity generation** declined by about **4%**, while **renewable electricity generation** increased by nearly **22%**.
- As of **March 2026**, India's installed **non-fossil fuel capacity** reached **283.46 GW**, including:
- **Solar Power: 150.26 GW**
- **Wind Power: 56.09 GW**
- **Large Hydropower: 51.41 GW**
- **Nuclear Power: 8.78 GW**
- India added **44.6 GW** of solar capacity and **6 GW** of wind capacity during **2025–26**.
- **Coal** continues to remain the single largest source of installed electricity capacity, accounting for nearly **42%** of the total capacity.

Emerging Challenges:

- Despite rapid renewable expansion, limited **grid flexibility** resulted in curtailment of nearly **2.1 TWh** of solar and wind electricity to maintain grid stability.
- Greater climate variability is making electricity demand increasingly weather-sensitive rather than only generation-sensitive.
- Peak electricity demand is expected to rise significantly because of increasing urbanisation, industrialisation and widespread use of cooling appliances.

Role of Solar Energy During El Niño:

Strategic Importance:

- Unlike **hydropower** and **wind energy**, **solar power generation** is expected to remain relatively stable during **El Niño** conditions.
- Stable solar generation strengthens the role of **solar energy** in enhancing India's energy security.
- However, greater solar deployment must be complemented with adequate **energy storage** and **grid balancing** infrastructure.

Energy Storage Systems:

Meaning:

- **Energy Storage Systems (ESS)** store surplus electricity generated during periods of high renewable energy production and supply it when electricity demand exceeds generation.
- Energy storage improves **grid reliability**, enhances renewable integration and reduces dependence on fossil fuel-based peaking power plants.

Major Types:

- **Pumped Hydro Storage (PHS):** Surplus electricity pumps water to an elevated reservoir, and stored water later generates electricity through turbines during peak demand.
- **Battery Energy Storage Systems (BESS):** Batteries chemically store electricity and discharge it whenever required.
- **Lithium-ion Batteries**, particularly **Lithium Iron Phosphate (LFP)** batteries, currently dominate grid-scale storage because of high efficiency, declining costs and long operational life.
- **Concentrated Solar Thermal Storage** stores heat, generally in **molten salt**, for electricity generation after sunset.
- **Compressed Air Energy Storage (CAES)** stores compressed air in underground caverns or storage tanks for later electricity generation.
- **Flywheel Energy Storage** stores electrical energy in the form of high-speed rotational energy.
- **Gravity Energy Storage** stores energy by lifting heavy masses and generates electricity when they descend.

India's Energy Storage Capacity:

Present Status and Targets:

- India presently focuses primarily on **Battery Energy Storage Systems (BESS)** and **Pumped Hydro Storage (PHS)**.
- Current installed **Battery Energy Storage System** capacity is about **0.27 GW**.
- Installed **Pumped Hydro Storage** capacity is about **7.2 GW**.
- According to the **Central Electricity Authority (CEA)**, India aims to achieve **174 GW / 888 GWh** of total energy storage capacity by **2035–36**, comprising:
- **Battery Energy Storage Systems: 80 GW / 321 GWh**
- **Pumped Hydro Storage: 94 GW / 567 GWh**.

Government Initiatives:

Policy Measures:

- The **National Electricity Plan (Transmission)** emphasises expansion of transmission infrastructure to integrate large-scale renewable energy.
- The **National Green Hydrogen Mission** complements renewable expansion by creating additional demand for clean electricity.
- The **Viability Gap Funding (VGF) Scheme** for **Battery Energy Storage Systems** supports deployment of grid-scale battery storage to improve renewable integration.
- The **Green Energy Corridor Programme** strengthens interstate and intrastate transmission networks for renewable energy evacuation.

Way Forward:

Priority Measures:

- Climate variability should be integrated into long-term electricity demand forecasting and power system planning.
- India should accelerate deployment of **Battery Energy Storage Systems**, **Pumped Hydro Storage** and flexible grid infrastructure.
- Modernisation of transmission networks and adoption of **smart grids** can improve renewable energy integration.
- Greater investment in demand-side management, energy-efficient cooling technologies and distributed renewable energy can reduce peak demand stress.
- Diversification of renewable energy sources alongside advanced forecasting systems will strengthen the resilience of India's electricity sector.

Value Addition for UPSC:

Important Facts:

- **ENSO** is the most influential source of year-to-year global climate variability.
- **El Niño** generally weakens the **Indian Southwest Monsoon**, whereas **La Niña** often strengthens monsoon rainfall, though exceptions may occur.
- **Long Period Average (LPA)** is the average rainfall calculated over a standard **30-year** period by the **India Meteorological Department**.
- **1 TWh (Terawatt-hour)** equals **1 billion kilowatt-hours (kWh)** of electricity.
- **Grid Flexibility** refers to the ability of an electricity system to balance supply and demand despite fluctuations in renewable energy generation.
- **Battery Energy Storage Systems** provide rapid response for frequency regulation, peak-load management and renewable energy integration, whereas **Pumped Hydro Storage** remains the most mature and largest-capacity electricity storage technology globally