2. Indian's Nuclear Power- Science & Technology

According to the Department of Atomic Energy, NPCIL has, for the first time, crossed 50 billion units (BUs) of electricity generation in FY 2024–25

Nuclear Power in India- An Expanded Analysis

Strategic Context of Nuclear Power in India- Nuclear energy occupies a strategic niche in India's energy mix due to

1. Limited domestic reserves of fossil fuels.
2. Long-term energy security concerns.
3. Commitment to low-carbon development pathways under climate obligations.

India's nuclear programme is indigenous, state-driven, and technology-intensive, shaped significantly by decades of technology denial regimes. The three-stage nuclear power programme is uniquely designed to leverage India's abundant thorium reserves, which constitute nearly 25% of global thorium resources.

Current Status of Nuclear Power Generation- Installed nuclear capacity stands at around 8.78 GW, generated through 24 operational reactors located across multiple states. Nuclear energy contributes approximately 3.1% of India's total electricity generation (as of July 2025). Reactor types in operation-

1. Pressurised Heavy Water Reactors (PHWRs) – backbone of the programme.
2. Light Water Reactors (LWRs) at Kudankulam (Russian collaboration).

Despite modest share, nuclear power provides-

1. Baseload electricity.
2. High-capacity factor compared to intermittent renewables.
3. Minimal lifecycle greenhouse gas emissions.

Conceptual Understanding- Nuclear energy is released from the atomic nucleus during

1. **Fission** – splitting of heavy nuclei like Uranium-235 or Plutonium-239.
2. **Fusion** – merging of light nuclei (currently experimental).

In nuclear fission

1. Controlled chain reactions release enormous heat.
2. Heat converts water into steam, driving turbines to generate electricity.

Nuclear power plants differ from thermal plants only in heat source, not in power conversion technology.

India's Three-Stage Nuclear Programme

Stage I- PHWRs using natural uranium produce electricity and plutonium.
Stage II- Fast Breeder Reactors (FBRs) use plutonium to breed more fissile material.
Stage III- Thorium-based reactors (Advanced Heavy Water Reactors) utilise Uranium-233 derived from thorium. This closed fuel cycles

1. Enhances fuel efficiency.
2. Minimises long-term waste.
3. Strengthens energy sovereignty.

Government Initiatives for Nuclear Expansion

Nuclear Energy Mission (Viksit Bharat 2047)- Target of 100 GW nuclear capacity by 2047. Envisages nuclear power as

1. A clean baseload complements to renewables.
2. A pillar of long-term decarbonisation.

Small Modular Reactors (SMRs)- ₹20,000 crore R&D mission announced for indigenous SMR development. Salient features

1. Lower capital cost per unit.
2. Shorter construction timelines.
3. Enhanced passive safety systems.

Target- Deployment of at least five indigenously developed SMRs by 2033.

SMRs are suitable for

1. Remote locations.
2. Industrial clusters.
3. Replacement of retiring coal plants.

Institutional and Project-Level Developments- NPCIL and NTPC have entered a supplementary Joint Venture agreement. The JV, ASHVINI, will

1. Build, own, and operate nuclear power plants.
2. Develop the 4×700 MWe PHWR Mahi-Banswara Rajasthan Atomic Power Project.

Rawatbhata Atomic Power Project – Unit 7

1. Connected to the Northern Grid.
2. Commenced commercial operations.

Atomic Energy Commission approval-

1. Pre-project activities for 10 additional 700 MWe PHWRs.
2. Expansion beyond the 22.5 GW capacity planned by 2032.

Applications of Nuclear Technologies Beyond Power

Agriculture and Food Processing- Radiation-based mutation breeding improves crop traits. Developed by DAE

1. TBM-9- Early-maturing, high-yield banana variety.
2. RTS-43- High-yield, stress-tolerant sorghum.

Nuclear techniques also aid

1. Food irradiation for shelf-life extension.
2. Pest control through Sterile Insect Technique (SIT).

Strategic and Advanced Scientific Applications- Heavy Water Board achieved 99.8% enrichment of Boron-11 Critical for semiconductor and advanced electronics.

India-based Neutrino and Dark Matter Experiments- First experimental run of Index initiated at Jaduguda Underground Science Laboratory. Nuclear technologies contribute to Space missions. Medical diagnostics (radiotherapy, PET scans). Industrial radiography and non-destructive testing.

Concerns and Challenges Associated with Nuclear Technology

Economic and Financial Constraints- High upfront capital costs and long gestation periods. Cost overruns due to

1. Regulatory clearances.
2. Public resistance.
3. Complex supply chains.

Per-unit cost higher than solar or wind in the short term.

Radioactive Waste Management- Spent nuclear fuel remains hazardous for thousands of years. Requires

1. Reprocessing.
2. Secure interim storage.
3. Long-term geological repositories.

Public perception remains sceptical despite scientific safeguards.

Safety and Risk Perception- Historical accidents (Chernobyl, Fukushima) highlight Low-probability but high-impact risks. Issues include Evacuation challenges. Long-term land contamination. Loss of livelihoods. Public acceptance and trust deficit remain critical hurdles.

Water Intensity and Environmental Constraints- Nuclear reactors require large volumes of water for cooling. Limits site selection in

1. Drought-prone regions.

2. Water-stressed basins.

Climate change-induced water scarcity may aggravate risks.

Way Forward- Strengthening Nuclear Power in India

Integrating nuclear energy into India's clean energy transition alongside renewables. Priorities include

1. Accelerated deployment of PHWRs and SMRs.
2. Strengthening nuclear safety regulation and transparency.
3. Public engagement and risk communication.
4. Indigenous manufacturing and fuel cycle self-reliance.

The Nuclear Energy Mission for Viksit Bharat is positioned

1. Enhance energy security.
2. Support industrial growth.
3. Enable deep decarbonisation.
4. Establish India as a global leader in advanced nuclear technology by 2047.

Source- https-//ddnews.gov.in/en/indias-nuclear-power-generation-reaches-record-high-in-fy-2024-25/