NUCLEAR ENERGY MISSION - ECONOMY

NEWS: *The **Union Budget 2025** introduced a **Nuclear Energy Mission** as part of a significant expansion in India's nuclear power sector.*

WHAT'S IN THE NEWS?

India's Big Push in the Nuclear Energy Sector

- The mission aims to accelerate the **research, development, and deployment** of **Small Modular Reactors (SMRs)**, which are being positioned as a next-generation nuclear power solution.
- The government has set an ambitious target of **operationalising at least five SMRs by 2033**, marking a shift towards compact and modular nuclear technology.
- To support this initiative, a **budgetary allocation of ₹20,000 crore** has been announced to facilitate research, technological advancements, and the eventual deployment of SMRs.

Key Announcements in the Union Budget 2025

a. Financial and Policy Support for SMRs

- The **₹20,000 crore Nuclear Energy Mission** is aimed at boosting indigenous nuclear technology development and expanding India's nuclear energy capacity.
- The funding will be directed towards **research, prototype development, regulatory approvals, and early-stage deployment** of SMRs across different locations in India.

b. Proposed Legislative Amendments to Enable Private Participation

- The **Atomic Energy Act** and the **Civil Liability for Nuclear Damage Act** are set to be **amended** to encourage **private sector participation** in the nuclear power industry.
- These amendments will enable private companies to **not only supply equipment** but also **participate in the construction, operation, and maintenance** of nuclear power plants.
- This move is expected to **break the monopoly** of state-owned enterprises like **Nuclear Power Corporation of India Limited (NPCIL)** and create a **more competitive and investment-friendly ecosystem** for nuclear energy.

c. Strategic Importance of Nuclear Energy in India's Power Mix

- Unlike **renewable energy sources such as solar and wind**, which are intermittent and depend on weather conditions, **nuclear power provides a stable and reliable source of electricity generation**.
- The **International Atomic Energy Agency (IAEA)** has emphasized that nuclear energy capacity must **more than double by 2050** if the world is to achieve net-zero carbon emissions.
- However, traditional nuclear power plants have been **challenged by high construction costs, long gestation periods, and safety concerns**.
- The government sees **SMRs as a potential solution to these challenges**, offering **lower costs, faster deployment, and enhanced safety features**.

Understanding Small Modular Reactors (SMRs)

a. India's Strategic Interest in SMRs

- The Indian government is promoting the development of **Bharat SMRs** as part of its clean energy transition plan and as a way to position itself as a **global leader in modular nuclear technology**.
- The initiative is also being framed as a **technology-driven foreign policy move**, where India can potentially **export SMR technology** to other countries seeking clean and scalable energy solutions.

b. What are Small Modular Reactors (SMRs)?

- SMRs are **advanced, small-scale nuclear reactors** designed to generate between **30 MWe and 300 MWe** of electricity per unit.
- In contrast, traditional nuclear reactors, such as those currently in operation in India, typically produce **500 MWe or more** per reactor.
- The modular design of SMRs allows for **factory-based manufacturing**, reducing **on-site construction time and costs**, making them an attractive option for faster deployment.

c. Advantages of SMRs Over Traditional Nuclear Reactors

- **Lower Costs & Faster Deployment:** Unlike large nuclear plants, which require **huge capital investments and take 10-15 years to build**, SMRs are **cheaper and can be deployed within a few years**.
- **Scalability & Flexibility:** SMRs can be **installed in remote locations**, **used as standalone power units**, or **grouped together for higher energy output**.
- **Enhanced Safety Features:** Modern SMRs incorporate **passive cooling systems**, reducing the risk of overheating and catastrophic failures.
- **Energy Security & Clean Transition:** SMRs can provide **reliable, low-carbon electricity**, supporting India's commitment to **reducing greenhouse gas emissions** while ensuring **energy independence**.

d. Types of SMRs Based on Coolant Technology

- There are four primary types of SMRs, classified based on the **coolant technology** used to manage the nuclear fission process:
    1. **Light Water Reactors (LWRs):** The most commonly used type, similar to traditional nuclear reactors, where water is used as both a coolant and neutron moderator.
    2. **High-Temperature Gas Reactors (HTGRs):** Uses gas (helium or carbon dioxide) as the primary coolant, allowing for higher operational temperatures.
    3. **Liquid Metal Reactors (LMRs):** Uses liquid metals (sodium, lead, or lead-bismuth) as a coolant, enabling **compact reactor design and high efficiency**.
    4. **Molten Salt Reactors (MSRs):** Uses molten fluoride or chloride salts as a coolant and fuel carrier, offering **inherent safety and long-term sustainability**.
- **LWR-based SMRs** are currently the most favored worldwide because they align well with **existing nuclear regulations** and can be approved more quickly than other designs.

e. Global SMR Projects Already in Operation

- **Akademik Lomonosov (Russia):** The world's first **floating SMR power plant**, equipped with two **35 MWe modules**, started commercial operations in **May 2020**.
- **HTR-PM (China):** A demonstration **high-temperature gas-cooled SMR**, which was **grid-connected in December 2021** and reportedly began commercial operations in **December 2023**.

India's SMR Push and Private Sector Participation

a. Institutional Backing for Private Participation

- The budget has introduced **institutional mechanisms** to promote **private sector investment** in SMR development.
- A **new vertical within the Department of Atomic Energy** will be created to focus specifically on **engaging private players**, following the successful model used in India's space sector.

b. Key Amendments to the Atomic Energy Act, 1962

- Under the current framework, **private companies are allowed only as equipment suppliers**.
- The proposed amendments will **allow private firms to directly participate in the construction and operation of nuclear power plants**, thereby breaking the **state monopoly** of NPCIL.

c. Proposed Changes to the Civil Liability for Nuclear Damage Act, 2010

- The **existing law assigns liability for nuclear accidents to operators**, discouraging foreign companies from investing in India's nuclear sector.
- Companies like **GE-Hitachi, Westinghouse, and Areva** have raised concerns about **potential financial risks** if liability provisions remain unchanged.
- The government is likely to **introduce amendments** to **ease liability concerns and attract foreign investment** in SMRs.

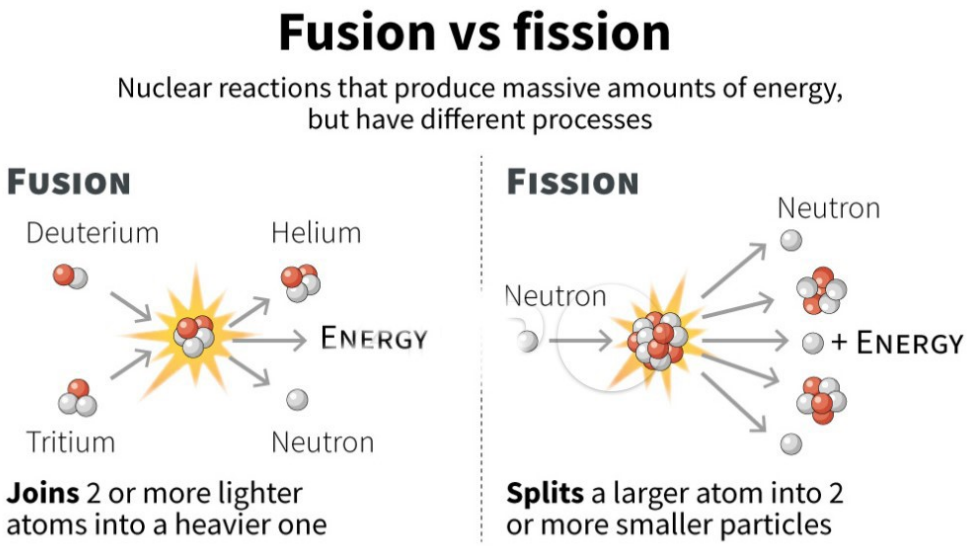
A Transformative Step for India's Energy Future

- The **Nuclear Energy Mission** marks a significant milestone in India's transition to **clean, reliable, and efficient energy production**.
- The government's decision to **embrace SMRs** reflects a forward-looking approach that balances **energy security, economic viability, and climate commitments**.
- With **policy support, private sector participation, and international collaboration**, India has the potential to **become a global hub for SMR technology and manufacturing** in the coming decades.

What is Nuclear Energy?

- Nuclear energy is a form of **energy that is released from the nucleus, or core**, of atoms.
- Nuclear energy is **known for its high energy density**, meaning that a relatively small amount of nuclear fuel can produce a large amount of energy.
- There are two primary methods of harnessing nuclear energy:

- **Nuclear Fission**: This is the process of **splitting the nucleus of an atom into two smaller nuclei,** releasing a large amount of energy in the process.
    - Nuclear power plants use this method, primarily using uranium-235 or plutonium-239 as fuel.
    - When the nucleus of these heavy isotopes is **bombarded with neutrons, it becomes unstable and splits into two or more smaller nuclei**, along with a few neutrons.
        - This chain reaction can release a significant amount of heat, which is used to generate steam and drive turbines, ultimately producing electricity.
- **Nuclear Fusion:** This is the **process of combining the nuclei of two light atoms to form a heavier nucleus.**
    - This is the process that **powers the sun and other stars.**
    - While it holds great potential for clean and virtually limitless energy, it is extremely challenging to achieve controlled nuclear fusion on Earth.



What is the Status of Nuclear Energy in India?

- Nuclear energy is the **fifth-largest source of electricity in India,** contributing about 2% of the country's total electricity generation.
- India currently has over **22 nuclear reactors in 7 power plants** across the country, which together produce 6,780 MW of nuclear power.
    - Of these reactors, 18 are **Pressurized Heavy Water Reactors (PHWRs)** and 4 are **Light Water Reactors (LWRs).**
- In January 2021, **the Kakrapar Atomic Power Project (KAPP-3), India's first 700 MWe unit** and the biggest indigenously developed variant of the PHWR, was connected to the grid.
- The Indian government has allowed joint ventures between the **Nuclear Power Corporation of India Limited (NPCIL)** and public sector undertakings (PSUs) to enhance India's nuclear program.

    - NPCIL is now in joint ventures with the **National Thermal Power Corporation Limited (NTPC)** and the **Indian Oil Corporation Limited (IOCL).**
- The government is promoting the expansion of nuclear installations to other parts of the country. For example, an **upcoming nuclear power plant in Gorakhpur town in Haryana** will become operational in the near future.
- India is also **working on an entirely indigenous thorium-based nuclear plant, "Bhavni,"** which will be the first of its kind using Uranium-233. The **experimental thorium plant "Kamini"** already exists **in Kalpakkam.**

Why does India Need Nuclear Energy?

- **Limited Reserves of Fossil Fuels:** India has limited reserves of fossil fuels, and nuclear energy can help reduce the country's dependence on coal, oil, and gas imports. This is important for enhancing energy security, as it reduces the vulnerability to supply disruptions and price fluctuations in global fossil fuel markets.
    - Hypothetically, even if the entire barren uncultivable land in India is used up for setting up solar plants, it would still fall way short of the target. The potential of wind energy is even smaller.
    - A recent report by BMI Research said **India's power demand would grow by 70% by 2032**. Conventional energy sources won't be able to cater this increasing demand.
- **Clean and Carbon-Free**: Nuclear energy is considered a **clean and carbon-free source of energy. It doesn't produce direct greenhouse gas emissions during electricity generation,** making it a viable option for addressing climate change and achieving India's climate goals.
- **Cheaper to Operate:** Nuclear power plants are cheaper to operate than coal or gas plants, despite the cost of managing radioactive fuel and disposal. Estimates show that nuclear plants cost only 33-50% of a coal plant and 20-25% of a gas combined-cycle plant.
- **Reliable and Continuous Power:** Nuclear energy can provide reliable and continuous base load power. **Unlike solar and wind energy, which are intermittent and dependent on weather conditions, nuclear power plants can operate continuously,** which can contribute to a stable and resilient energy supply.
- **Achieving Net Zero:** To achieve **Net Zero by 2070, India needs to scale up nuclear energy to a couple of thousand GWe** as suggested by a study conducted by Vivekananda International Foundation with analytical support from IIT-Bombay.
- **Economic Growth and Job Creation:** Meeting high energy demands is often linked to economic development. India's high per capita energy consumption is a factor for achieving a high human development index. The nuclear energy sector can also create jobs and foster innovation, leading to economic growth.
- **Availability of Thorium:** India has **abundant thorium resources, which can be utilized as nuclear fuel. Thorium is considered a safer and more**

efficient alternative to uranium, and India has developed indigenous technology for its utilization. This positions India well for future nuclear energy expansion.

- India has consciously proceeded to explore the possibility of tapping nuclear energy for the purpose of power generation. In this direction a **three-stage nuclear power programme** was formulated by Homi Bhabha in the 1950s.

What are the Challenges before India's Nuclear Energy?

- **Capital Intensive:** Nuclear power plants are capital intensive and recent nuclear builds have suffered major cost overruns.
- **Insufficient Nuclear Installed Capacity:** In 2008, the Atomic Energy Commission projected that India would have 650GW of installed capacity by 2050; the current installed capacity is only 6.78 GW.
- **Nuclear Liability:** India's **Civil Liability for Nuclear Damage Act, 2010**, has been a contentious issue for foreign suppliers, who fear being held liable for accidents beyond their control.
- **Nuclear Safety**: Disposal of radioactive material and danger of nuclear accidents makes it further prohibitive. Risks and costs of nuclear energy are overwhelmingly borne by the poor. There is always a lot of resistance from local communities against reactors.
- **Nuclear Fuel Cycle:** India considers a closed nuclear fuel cycle of crucial importance for implementation of its **three-stage nuclear power programme,** the third stage being the long-term objective of tapping vast energy available in thorium resources in India.
    - However, this requires advanced technologies and expertise that are not readily available.
- **International Cooperation**: India's dependence on imported energy resources and the inconsistent reform of the energy sector are challenges to satisfying rising demand. India also faces diplomatic hurdles in securing membership of the **NSG,** which would enable it to access more nuclear technology and fuel.

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