Strengthening India’s Nuclear Supply Chain

For Prelims: Nuclear Sector, Small Modular Reactors, Prototype Fast Breeder Reactor, Light Water Reactors (LWRs), Pressurised Heavy Water Reactor, Atomic Energy Regulatory Board (AERB), Nuclear Power Corporation of India Limited (NPCIL).

For Mains: Importance of nuclear energy for India's development and key challenges in modernisation of India’s nuclear sector. Measures required to modernise India’s nuclear sector.

Source: IE

Why in News?

India is planning to introduce **legal reforms in its civil** nuclear sector to allow controlled **private and foreign investment**, address **supplier liability,** and align with **global norms**—focusing on expanding low-carbon nuclear capacity through LWRs and SMRs.

Nuclear Energy

- **About:** It is a form of **energy released from the nucleus, the core** of atoms, made up of protons and neutrons.
  - This source of energy can be produced in **two ways: fission** – when nuclei of atoms split into several parts – **or fusion** – when nuclei fuse together.
  - It is a **low-carbon, high-density energy source** providing **base-load power** and contributing to **energy security** and **sustainable development**.
- **Status in India:** India’s current **nuclear power capacity** stands at **8.18 GW**, with plans to expand to **22.48 GW by 2031-32** and an ambitious target of **100 GW by 2047**.
  - Currently, India operates more than **20 nuclear reactors**, all managed by **Nuclear Power Corporation of India Limited (NPCIL)**, with over a dozen new projects planned.
  - Key developments, such as the **Prototype Fast Breeder Reactor at Kalpakkam**, showcase India’s expanding **nuclear capabilities**.
- **Government Support:** The **Union Budget 2025-26** allocated **Rs. 20,000 crore** to the **Nuclear Energy Mission**, targeting the deployment of **five** Bharat Small Reactors (BSRs) by **2033** to diversify **energy infrastructure**.

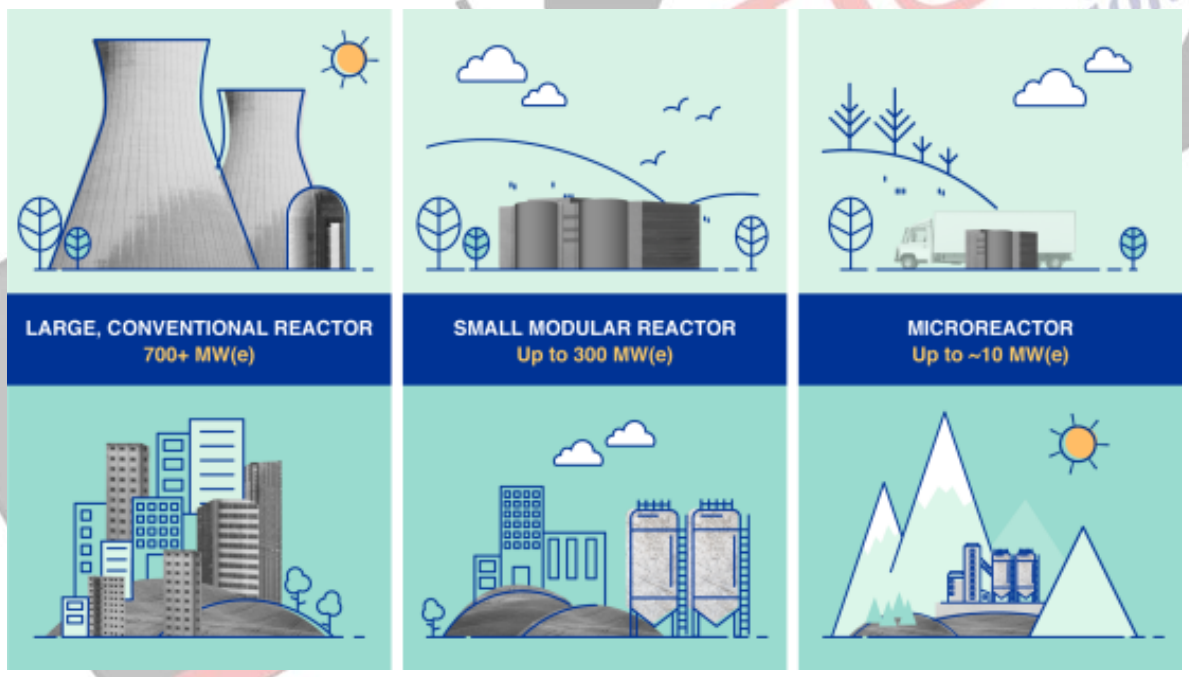
What is the Significance of Nuclear Energy for India?

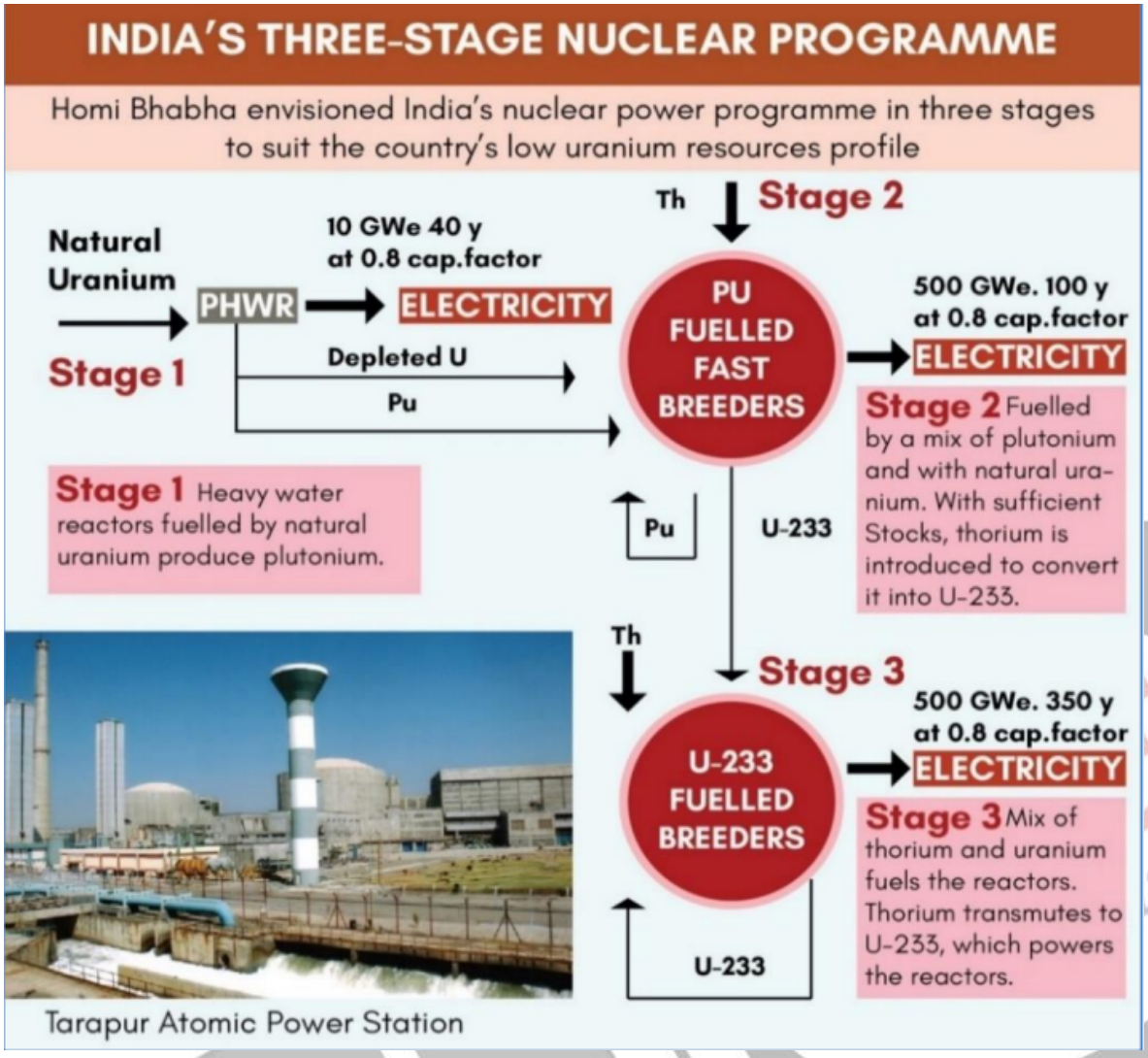
- **Ensuring Reliable Energy Supply:** Nuclear power can play a pivotal role in meeting India’s rapidly growing energy demand by providing **continuous, 24/7 electricity**.
  - **Small Modular Reactors (SMRs)** and microreactors can deliver **clean energy to remote locations** without dependence on the conventional grid.

    - Nuclear plants provide a **stable power supply even during natural disasters or geopolitical disruptions**, offering a reliable alternative when conventional grids are compromised.
- **Achieving Net-Zero Goals:** Nuclear energy plays a pivotal role in India's strategy to reduce dependency on fossil fuels and meet its **net-zero emissions target by 2070.**
- **Boosting Industrial Development:** Nuclear energy can support **high-capacity, energy-intensive sectors** such as **steel, cement, and data centers** that require stable power.
    - SMRs can further enable **remote industrial operations, hydrogen production, and large-scale desalination projects**.
- **Strengthening Strategic Position:** Indigenous technological achievements, such as the **Prototype Fast Breeder Reactor (Kalpakkam)**, demonstrate India's **technological self-reliance**, reduce strategic vulnerabilities, and enhance the country's **negotiating power in global energy and technology partnerships**.

Small Modular Reactors

- **About: SMRs** are next-generation nuclear reactors with a **power output of up to 300 MW(e) per unit**, roughly one-third that of conventional nuclear reactors.
- **Features:** They are defined by **three key features**:
    - **Small:** Much smaller than traditional nuclear power reactors, making them suitable for limited-space installations.
    - **Modular: Designed for factory-assembly and transport, systems and components** can be **pre-assembled** and moved as a **complete unit** to the **installation site**.
    - **Reactors: Harnessing nuclear fission** to generate **heat** for producing **energy**.





What are the Major Challenges Associated with Modernisation of India's Nuclear Sector?

- **Supply Chain and Quality Control Challenges: The mid- and lower-tier supplier base lacks quality standards, modern processes, and capacity, causing gaps in supporting advanced technologies like** Light Water Reactors (LWRs) **and SMRs, and reliance on a single foreign company for specialized systems.**
  - **Quality assurance (QA) issues** and **outdated expertise** lead to **project delays** and **production stoppages** due to a shortage of **qualified QA professionals**.
- **Cybersecurity Challenges: Global vendors warn of weak** cybersecurity **in India's nuclear sector, risking loss of critical plant data and vulnerability to cyber-attacks and ransomware.**
- **Regulatory Hurdles:** The **Atomic Energy Regulatory Board (AERB)** oversees **design certification**, while **NPCIL** manages **quality control**, leading to **coordination challenges** across the **supply chain**.
- **Capacity Challenges:** For critical areas like **control and instrumentation**, **indigenisation efforts are heavily dependent** on a single **public sector enterprise** like **Electronics Corporation of India Ltd** whose **capacity** was recorded as **"limited"**.
- **Laps in Legal Framework:** The **Atomic Energy Act, 1962** restricts **private participation** in India's **nuclear projects**, limiting **investment, technology development**, and slowing progress.
  - **Foreign and domestic suppliers** fear **unlimited liability** because of **unclear**

insurance rules, ambiguous definitions of **"nuclear damage"**, and the risk of **civil suits**.

What Measures are Required to Modernise India's Nuclear Sector?

- **Strengthening Supply Chain:** Implement a **National Quality Upgradation Programme** to train **mid- and lower-tier nuclear suppliers** on **manufacturing processes** and **quality standards** for **LWRs** and **SMRs**.
    - Simultaneously, **develop and certify new vendors** for **core equipment** and **specialised systems** to expand domestic **capacity**.
- **Enhance Quality Control:** Increase **manpower** by deploying **qualified QA professionals** for **24/7 coverage**, use **Third-Party Inspection (TPI)** to support in-house **QA**, and station **full-time QA teams** at all critical **supplier sites**.
- **Address Cybersecurity Gaps:** Implement a **state-of-the-art cybersecurity framework** across the **nuclear ecosystem**, covering **plant operators** and **suppliers**, to safeguard **control systems** and **critical data** from **cyber attacks**.
- **Modernise Legislative Framework:** Prioritise passing **policy and legal reforms**, including major amendments to the **Electricity Act**, the **Atomic Energy Act**, and the **Civil Liability for Nuclear Damage Act**, to align with **global standards**, address **investor concerns**, and encourage **foreign collaboration and investment.**
- **Strategic Development and Competitiveness: Execute the SMR strategy** by advancing **indigenous SMR development** with clear **timelines** for **prototype demonstrations** to ensure **technology readiness**.
    - **Facilitate global exports** for qualified **Indian suppliers** to boost **capacity, competitiveness, and quality**.

Conclusion

Modernising India's nuclear sector is crucial for **energy security**, **industrial growth**, and **strategic autonomy**. Strengthening the **supplier base**, enforcing **quality standards**, enhancing **cybersecurity**, and advancing **indigenous SMRs** will boost **reliability**, **competitiveness**, and **resilience**, ensuring **sustainable, low-carbon energy** and a robust **industrial ecosystem**.

Drishti Mains Question:

Q. What are the key challenges in modernising India's nuclear sector and how can they be addressed?

UPSC Civil Services Examination, Previous Year Question (PYQ)

Prelims

Q. In India, why are some nuclear reactors kept under "IAEA safeguards" while others are not? (2020)

(a) Some use uranium and others use thorium
(b) Some use imported uranium and others use domestic supplies
(c) Some are operated by foreign enterprises and others are operated by domestic enterprises
(d) Some are State-owned and others are privately owned

Ans: (b)

Q. Consider the following statements: (2017)

1. The Nuclear Security Summits are periodically held under the aegis of the United Nations.
2. The International Panel on Fissile Materials is an organ of the International Atomic Energy Agency.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Ans: (d)

Mains

Q. With growing energy needs should India keep on expanding its nuclear energy programme? Discuss the facts and fears associated with nuclear energy. (2018)

Q. Give an account of the growth and development of nuclear science and technology in India. What is the advantage of the fast breeder reactor programme in India? (2017)