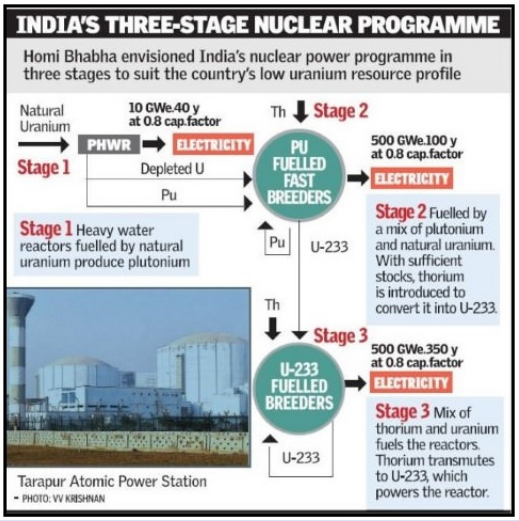
Stage II of India’s 3-stage nuclear programme

Why in news?

Prime Minister Narendra Modi witnessed the core-loading of the indigenous prototype fast breeder reactor (PFBR) at Kalpakkam, Tamil Nadu marking a significant step in India's nuclear power program.

3 stages of India’s nuclear program

• **Formulation-** By Homi Bhabha who is credited as “father of India’s nuclear program”.
• **Launch year-** 1954
• **Aim-** To achieve complete self-sufficiency in nuclear energy by leveraging India's significant thorium resources.
• The ultimate goal was to capitalize on India’s vase thorium reserves while accounting for its low uranium reserves.
• India has only about 2% of the global uranium reserves but 25% of the world’s thorium reserves which is found in the *monazite sands of coastal regions of South India*.



• **Closed fuel cycle-** The three stages feed into each other in such a way that the spent fuel generated from one stage of the cycle is reprocessed and used in the next stage of the cycle to produce power.
• The closed fuel cycle helps to breed fuel and minimise the nuclear waste.
• **Thorium-** It is viewed as the fuel of the future, Stage-III aims at using thorium as fuel for power generation on a commercial scale.

Stages	Types of nuclear reactor	By-Product
Stage-I	Pressurized Heavy Water Reactors (PHWRs)	Plutonium-239
Stage-II	Fast Breeder Reactor	Energy,Uranium-233 and Plutonium-239
Stage-III	Advanced Heavy Water Reactors (AHWR)	Energy and Uranium- 233

What is PFBR?

- **Developed by**- Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVANI).
- **Design**- Indira Gandhi Centre for Atomic Research (IGCAR).
- **Location**- Kalpakkam, Tamil Nadu.
- **Nuclear Fuel Complex**- It is entrusted with the responsibility of fabrication of core subassemblies for Fast Breeder Test Reactor (FBTR) and 500 MWe PFBR.
- **BARC**- Bhabha Atomic Research Centre contributes to the research & development and manufacture of fuels for fast reactors, technology for reprocessing of fuels, waste management and health and safety of the work force.
- **Expansion**- The Department of Atomic Energy (DAE) proposed building 4 more FBRs with a capacity of 600 MWe each.
- **Fissile material-** Mixed oxide of Uranium and Plutonium-239 (By-product from stage-I).

- **Coolant- *Liquid sodium***, a highly reactive substance used in 2 circuits to transfer heat and produce electricity.
- **Breeder reactor-** It generates more Pu-239 than it consumes.

To know about the history of India's nuclear program click here

Why PFBR delayed?

- **Impact of sanction-** Sanctions following *India's 'Smiling Buddha' nuclear test* led to the use of mixed carbide fuel instead of enriched uranium, affecting power output and operating conditions.
- **Loss of expertise**-Many experts involved with the Fast Breeder Test Reactor (FBTR) were retiring by the time PFBR was approved in 2003, leading to a loss of expertise.
- **Fund deficit**- The project faced *cost overruns*, and the need for additional funds and extensions contributed to delays.
- **Procurement Delays**- An audit revealed that BHAVINI's dependency on the Nuclear Power Corporation of India resulted in significant delays in component procurement.
- **Operational challenges**- The experts expected that the reactor vessel could be preheated to 150°C in about a month based on theoretical calculations and tests with a mock-up, but the process took more than a year in reality.
- **Technical difficulties**- The coolant liquid sodium is highly reactive, it requires careful handling due to leaks, blockages or temperature fluctuations.
- **Fukushima Daiichi disaster 2011**- It shifted global public opinion against nuclear power, affecting new facility construction.

Small Modular Reactor- An innovative approach to nuclear reactor
• **Capacity**-SMRs have a maximum capacity of up to 300 MW. • **Fuel compatibility**- SMRs can operate using low-enriched uranium. • **Eco-friendly-** They require less land compared to conventional nuclear reactors. • **Safety**- SMRs can accommodate more safety features. • **Global trends**- Several countries are developing SMRs as a complement to existing facilities. • **Cost-effective-**SMRs can be installed at reduced cost and time by repurposing infrastructure in brownfield sites. • India can potentially import this uranium from the U.S. through the 123 Agreement. • **Increase SMR procurement**-To increase SMRs' contribution, India would need to make amendments to the Atomic Energy Act (1962). • It would allow private sector participation under the oversight of the Atomic Energy Regulatory Board (AERB).

What are the challenges with PFBR?

- **Safety concerns**- Fast Breeder Reactors (FBRs) are known to be more challenging to handle than other reactor types, raising safety concerns.
- **Regulatory dependency-** The Atomic Energy Regulatory Body (AERB) has faced criticism for lacking independence, there have been calls for an independent statutory atomic regulator to enhance safety oversight.
- **Public reaction-** The Department of Atomic Energy (DAE) has faced public skepticism and concerns about its handling of safety issues.

- **Radioactive by-products**- The thorium fuel cycle, while promising for its abundance, produces radioactive byproducts (*caesium-137, actinium-227, radium-224, radium-228, and thorium-230*) that require careful handling and storage.

What lies ahead?

- Nuclear power is seen as a strategic component in India's energy mix, providing a reliable and continuous source of electricity while supporting national goals related to energy security and sustainability.
- The proposed expansion of FBRs indicates a commitment to advancing nuclear technology in India despite challenges.
- Nuclear Power Corporation of India Limited announced plans to commission a nuclear power reactor every year suggest a proactive approach to meeting energy demands and contributing to the country's energy transition.

Quick facts

BHAVINI
• **Launch year-** 2003 • **Administrative control-** *Department of Atomic Energy.* • **About-** It is a ***Special Purpose Vehicle***, for implementing India's first prototype 500 MW Fast Breeder Reactor project. • **Location-** Chennai, Tamil Nadu. • **Objective-** - To construct and commission the first 500 MWe Fast Breeder Reactor (FBR) at Kalpakkam in Tamilnadu - To pursue construction, commissioning, operation and maintenance of subsequent Fast Breeder Reactors for generation of electricity in pursuance of the schemes and programmes of Government of India under the provisions of the Atomic Energy Act,1962

Reference

1. The Hindu- PFBR stage II nuclear program
2. DAE- Annual report 2022-23