Q16

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

UPSC Civil Services Mains 2017 · GS III · 15 marks · Indian Economy

Indian Economy and issues relating to planning, mobilization of resources, growth, development and employment.

Core demand of the question

- Narrate the growth of nuclear science and technology in India from AEC to the civil nuclear deal
- Explain the three-stage programme
- State the advantages of the fast breeder reactor programme

Revision summary

India's nuclear programme runs from the 1948 Atomic Energy Act and BARC through indigenous PHWRs, 1974 and 1998 tests, and the 2008 NSG waiver.

The three-stage plan uses PHWRs, then fast breeders, then thorium because uranium is scarce and thorium is not.

IGCAR's Fast Breeder Test Reactor trained the sodium-cooled line; PFBR is the commercial prototype.

FBRs stretch fuel, open the thorium stage, and can ease some waste burdens.

They are a strategic energy bet, not a quick cheap plant.

Introduction

- **India built** nuclear science **as a State project from the late 1940s: energy, isotopes, and later weapons**. The civilian spine is the **Department of Atomic Energy**, **pressurised heavy water reactors**, and a **three-stage** plan toward **thorium**, because India has little **uranium** and a lot of **thorium** in beach sands. The **fast breeder reactor (FBR)** is the bridge of that plan.

Body

Growth and development

- **1948 Atomic Energy Act** and the **Atomic Energy Commission**, with **Homi Bhabha**, set research as a sovereign goal. **Department of Atomic Energy (1954)** and **Bhabha Atomic Research Centre** (Trombay) became the core.
- **Apsara (1956)** was Asia's early research reactor. **Cirus** and later **Dhruva** trained people and made isotopes.
- **Power: Tarapur** boiling-water reactors with the United States (late 1960s), then **Rajasthan** (Canadian CANDU lineage) and an indigenous **pressurised heavy water reactor (PHWR)** line under **Nuclear Power Corporation of India Limited** - Kakrapar, Narora, Kaiga, and others.

• **1974** peaceful nuclear explosion and **1998** tests brought **sanctions** and a long dual-use isolation: limited imported fuel and technology, so self-reliance in PHWR, fuel fabrication, and heavy water was forced, not chosen.

• **Indira Gandhi Centre for Atomic Research**, Kalpakkam, ran the **Fast Breeder Test Reactor** (1985, sodium-cooled) as the school for breeders.

• **Applications beyond power: radiation** in food and medicine, **isotope** diagnosis, and strategic propulsion research - the DAE umbrella is wider than electricity.

• **2005 Indo-US civil nuclear agreement**, **2008 Nuclear Suppliers Group waiver**, and IAEA safeguards on separated civilian plants reopened imported uranium and reactor offers (**Kudankulam** VVER with Russia; talks on other light-water units).

• Liability law, local protest (Kudankulam, Jaitapur), and project delays remain the political half of the technology story.

Three-stage programme (Bhabha)

• **Stage 1:** PHWRs on **natural uranium**; spent fuel yields **plutonium**.

• **Stage 2: FBRs** burn plutonium and **breed** more fissile material from **uranium-238**, multiplying a scarce uranium base.

• **Stage 3: thorium-uranium-233** cycles in advanced reactors, using India's large **monazite / thorium** resource.

• Without stage 2, stage 3 stays a paper option.

Advantages of the FBR programme

• **Fuel security:** breeds more fissile atoms than it consumes (with a blanket); stretches domestic and imported uranium.

• **Path to thorium:** produces the inventory and the operating skill for U-233 systems.

• **Waste:** can burn some long-lived actinides relative to a once-through thermal cycle (design-dependent), reducing the high-level waste burden in principle.

• **Base-load, low-carbon** power once commercial - a complement to coal and to variable renewables.

• **Indigenous learning:** sodium technology, fuel fabrication, and safety culture stay inside Indian labs rather than as a perpetual import.

• **Caution:** FBRs are **complex** (sodium fire risk, cost, delays). The **Prototype Fast Breeder Reactor** at Kalpakkam has been a long construction. Advantage is **strategic**, not a cheap kilowatt-hour in the first unit.

Flow diagram

Stage 1 PHWR natural U -> Plutonium

Plutonium -> Stage 2 FBR

Stage 2 FBR -> Breed more fissile

Stage 2 FBR -> Stage 3 thorium U-233

India thorium sands -> Stage 3 thorium U-233

NSG waiver imported U -> Stage 1 PHWR natural U

Conclusion

Indian nuclear science grew from Bhabha's AEC and Apsara through PHWRs, isolation after 1974 and 1998, IGCAR's breeder school, and a partial reopening after the civil nuclear deal. The FBR programme's advantage is to multiply scarce uranium, open the thorium third stage, and keep a low-carbon base-load option under national control - if safety and project delivery catch up with the physics.

Facts & figures

AEC / DAE

Atomic Energy Commission (from 1948) and Department of Atomic Energy (1954): the civilian nuclear State.

Apsara 1956

India's first research reactor at Trombay; the start of an indigenous operator culture.

Three-stage programme

PHWR (natural uranium), FBR (plutonium breeding), then thorium-U-233 systems.

FBTR / PFBR

Fast Breeder Test Reactor (Kalpakkam, 1985) and Prototype Fast Breeder Reactor: the Indian FBR line.

NSG waiver 2008

Nuclear Suppliers Group exception after the Indo-US civil nuclear deal, allowing civilian fuel and reactor trade under safeguards.