4. Thorium Power 2047 Mission - Science & Technology

India's thorium reserves provide a unique strategic opportunity to achieve long-term energy security through its indigenously designed three-stage nuclear programme. With limited uranium but abundant thorium, India aims to transition toward a sustainable nuclear fuel cycle.

1.India's Thorium Reserves

1. India possesses one of the largest thorium reserves globally, primarily found in monazite sands along coastal regions.
2. States like Kerala and Odisha together account for over 70% of the country's thorium deposits.
3. These reserves are located mainly in beach sands and riverine deposits, making extraction technically challenging.
4. Thorium availability gives India a comparative advantage over uranium-deficient countries.

2.Need for Thorium Utilisation

1. Reduce reliance on uranium imports
    1. India's nuclear power expansion currently depends on imported uranium.
    2. Domestic uranium reserves are low-grade and costly to mine.
    3. Thorium offers a long-term indigenous alternative to reduce import dependence.
2. Sustainability of global uranium resources
    1. Global nuclear capacity is expected to rise from about 380 GWe to nearly 1,400 GWe.
    2. Known uranium reserves (~8 million tonnes) may last only about 30 years under once-through fuel cycles.
    3. Thorium-based fuel cycles can significantly extend nuclear fuel availability.
3. Long-term energy security
    1. Thorium enables a closed fuel cycle with better resource efficiency.
    2. Supports India's goal of achieving high nuclear capacity sustainably.

3.Significance of Thorium for India

1. Resource advantage
    1. India has limited uranium but abundant thorium reserves.
    2. This aligns with a strategy of utilising domestic resources for energy independence.
2. Nuclear behaviour
    1. Thorium-232 is a fertile material, not directly fissile.
    2. It absorbs neutrons to convert into uranium-233, which is fissile.
    3. Uranium-233 can sustain nuclear chain reactions efficiently.
3. Strategic fit
    1. Thorium is central to the third stage of India's nuclear programme.
    2. Enables a transition from uranium dependence to a thorium-based cycle.

4.India's Three-Stage Nuclear Programme

Institutional Evolution

1. India established the Atomic Energy Commission in 1948 to guide nuclear policy.
2. The first research reactor Apsara was commissioned at Bhabha Atomic Research Centre in 1956.
3. India's first nuclear power plant was set up at Tarapur Atomic Power Station in 1969.
4. The programme was conceptualised by Homi J. Bhabha.

Stage I – Pressurized Heavy Water Reactors (PHWRs)

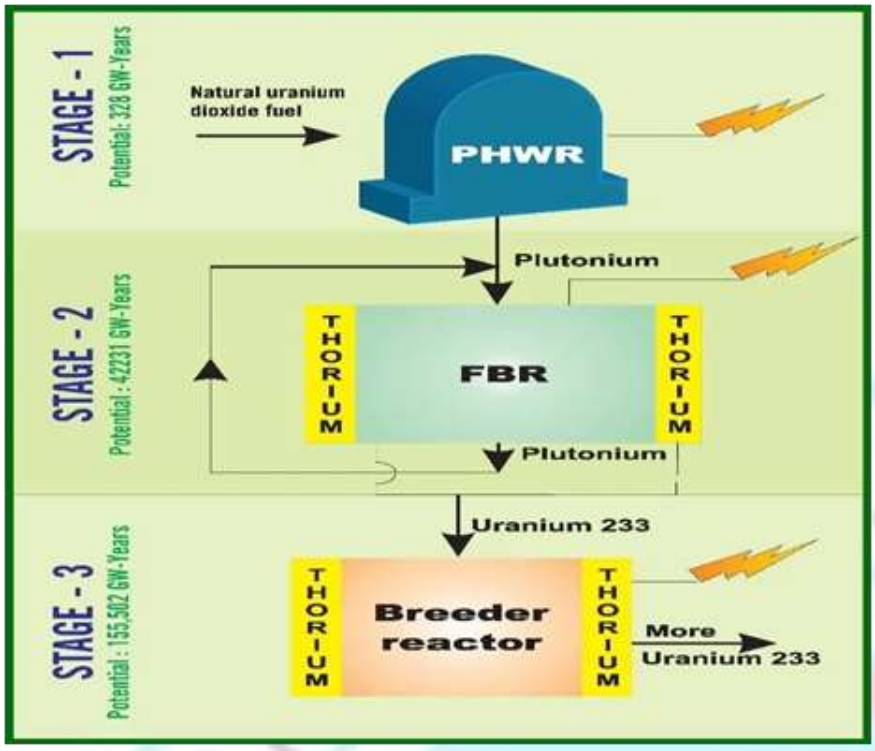
1. Uses natural uranium (U-238 with small U-235 content) as fuel.
2. Employs heavy water as moderator and coolant.
3. Generates energy and produces plutonium-239 as a byproduct.
4. Objective is to build a plutonium inventory for the next stage.

Stage II – Fast Breeder Reactors (FBRs)

1. Utilises plutonium-239 obtained from Stage I as fuel.
2. Uses fast neutrons to breed more fissile material than consumed.
3. Converts U-238 into additional plutonium and produces uranium-233.
4. Enhances fuel efficiency and multiplies fissile material availability.

Stage III – Advanced Heavy Water Reactors (AHWRs)

1. Uses thorium-232 along with plutonium-239 as fuel.
2. Thorium converts into uranium-233, which sustains fission.
3. Designed to fully exploit India's thorium reserves.
4. Represents the final transition to a thorium-based nuclear economy.



5.Challenges in Thorium Utilisation

1. Technological constraints
    1. Requires advanced reactor designs such as AHWRs and FBRs.
    2. Handling uranium-233 involves radiation and safety challenges.
2. High extraction and processing costs
    1. Thorium extraction from monazite is energy-intensive.

    2. Generates radioactive waste requiring safe disposal.
3. Economic viability
    1. High initial capital costs for advanced reactors.
    2. Thorium fuel cycle is not yet commercially mature.
4. Infrastructure and research gaps
    1. Limited operational experience with thorium reactors.
    2. Requires sustained R&D and policy support.

Conclusion

India's thorium reserves provide a long-term strategic pathway for achieving sustainable and secure nuclear energy. However, realising this potential requires overcoming technological and economic barriers through sustained investment, innovation, and policy support within the three-stage nuclear framework.

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