A Strategic Roadmap for Nuclear Energy Expansion

This editorial is based on **"India needs to go nuclear"** which was published in The Hindu on 09/10/2023. It argues that India needs to go nuclear to achieve its developmental aspirations and to address the climate change challenge. It proposes a six-pronged national strategy for a rapid scale-up of nuclear energy in India.

For Prelims: Nuclear energy, Nuclear Fission, Nuclear Fusion, Status of Nuclear Energy in India, Small Modular Reactors (SMRs), Civil Liability for Nuclear Damage Act, 2010

For Mains: Need of Nuclear Energy, Challenges and Way Forward

India's economy is growing rapidly. It is expected to surpass Germany and Japan and move up from number five to number three position before the end of this decade. **Economic growth triggers demand for energy.** One would thus expect significant growth in our primary energy consumption which is already the third-highest globally. Most of this is based on fossil energy.

To achieve a **Human Development Index** comparable to advanced countries, India needs at least 2,400 kilogram oil equivalent (kgoe) energy consumption per capita per year, which could improve to around 1,400 kgoe with expected improvements in energy use efficiency. However, **to support a developed India, clean energy requirements would be around 25,000-30,000 terawatt-hours per year (TWh/yr), more than four times the present energy consumption.** Deployment of **renewable energy** alone won't enable India to become an advanced country.

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.

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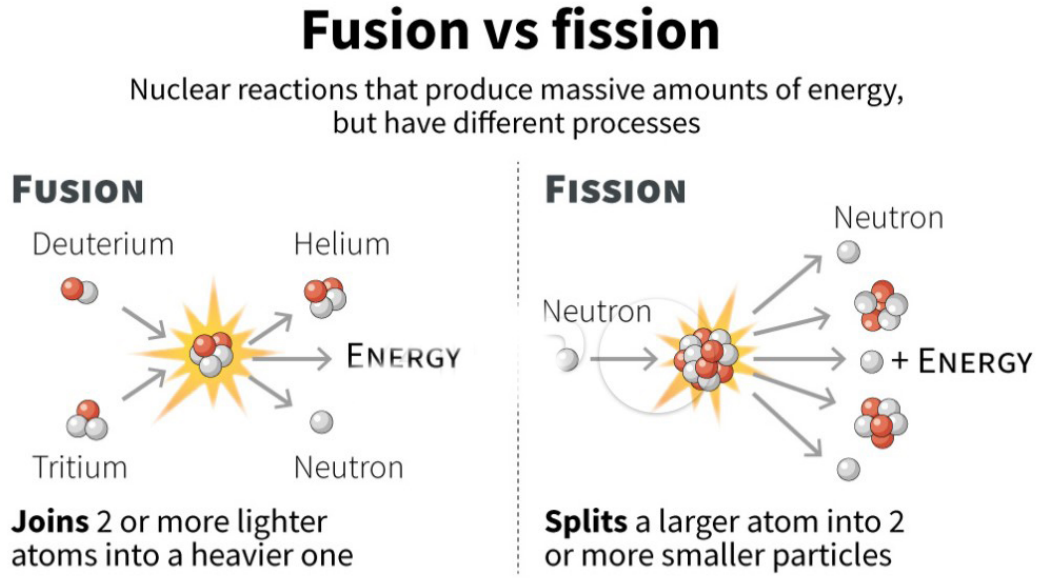

What is the Status of Nuclear Energy in India?

- 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.

What is a National strategy for a Rapid Scale-up of Nuclear Energy?

- **PHWR Expansion:** The Indigenous 700 MWe **PHWR**, with the first unit already in commercial operation, should be the primary source for adding base load electrical capacity.
    - Fifteen more units are currently under construction in fleet mode.
    - Implementing multiple fleets with the involvement of various PSUs in addition to NPCIL should be considered.
- **SMRs and Coal Plant Replacement:** Build indigenous **Small Modular Reactors (SMRs)** at a large number of sites that would be vacated by retiring coal plants in the coming decades.
    - Importing these units would make electricity production unaffordable.
    - NTPC, being the owner of the largest number of coal plants in the country, is a natural partner in this process. More industrial partners could be involved.
- **Captive Units for Industries:** The 220 MWe **PHWR** units can be offered as partially owned

captive units for electricity and hydrogen for energy-intensive industries such as metals, chemicals, and fertilizers. **The Advanced Heavy Water Reactor (AHWR300-LEU) developed by BARC can also be offered for this role after demonstrating a prototype.**

- **High-Temperature Reactor for Hydrogen Production:** Develop a high temperature reactor for direct hydrogen production without resorting to electrolysis. This would enable cheaper green hydrogen production and reduce pressure on excessive electrification of the energy system in the country, which otherwise appears inevitable.
- **Thorium Energy Development:** Speed up second and third stage nuclear-power programme development to **unleash thorium energy potential in accordance with the pre-existing plans** for long-term sustainable energy supply.
    - Bhabha Atomic Research Centre has the requisite capability.
- **International Cooperation:** India's PHWRs are globally competitive in terms of performance and capital cost, making them well-suited to meet these requirements. The use of Thorium-HALEU fuel in PHWRs can further enhance their attractiveness in terms of economics, safety, waste management, and proliferation resistance.
    - India should seize this opportunity by piloting major international cooperation to tackle climate change challenges on a global scale.

Drishti Mains Question:

Examine the potential of nuclear energy as a cornerstone for India's energy security, economic growth, and climate objectives. Discuss the challenges faced and propose a comprehensive strategy to accelerate the expansion of nuclear energy in the country.

UPSC Civil Services Examination, Previous Year Questions (PYQs)

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)

Explanation:

- The nuclear facilities are kept under International Atomic Energy Agency (IAEA) safeguards if the source of Uranium, which is the fissile material for a nuclear reactor is from outside the territory of India or if the new reactor plants are established with foreign collaboration.
- This is to ensure that imported uranium was not diverted for military use and assure that the imported uranium is used to generate nuclear energy for civilian purposes.
- There are at present 22 operational reactors, of which 14 are under the International Atomic Energy Agency (IAEA) safeguards as these use imported fuel.
- Under safeguards agreement, the International Atomic Energy Agency (IAEA) has the right and obligation to ensure that safeguards are applied on all nuclear material in the territory, jurisdiction or control of the State for the exclusive purpose.
- **Therefore, option (b) is the correct answer**

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)**