Dr. Homi Bhaba devised India's three-stage nuclear power program in the 1954. It was formulate to provide energy security to India. The main aim 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.** Thorium itself is not a fissile material, and thus cannot undergo fission to produce energy. Instead, it must be transmuted to uranium-233 in a reactor fueled by other fissile materials. The first two stages, natural uranium-fueled heavy water reactors and plutonium-fueled fast breeder reactors, are intended to generate sufficient fissile material from India's limited uranium resources, so that all its vast thorium reserves can be fully utilised in the third stage of thermal breeder reactors. The first generation of atomic power stations based on natural uranium can only be used to start off an atomic power programm. **The plutonium produced by the first generation power stations can be used in a second generation of power stations designed to produce electric power and convert thorium into U-233, or depleted uranium into more plutonium with breeding again.** The second generation of power stations may be regarded as an intermediate step for the breeder power stations of the third generation all of which **would produce more U-233 than they burn in the course of producing power**.

The three stages are:

- Natural uranium fuelled Pressurized Heavy Water Reactors **(PWHR)**
- Fast Breeder Reactors **(FBRs)** utilizing plutonium based fuel
- Advanced nuclear power systems for utilization of thorium

Stage 1

The first stage involved using **natural uranium to fuel Pressurized Heavy Water Reactors to produce electricity and producing plutonium-239** as a byproduct. Using Pressurized Heavy Water Reactors rather than Light Water Reactors was the best choice for India given its infrastructure. While Pressurized Heavy Water Reactors used unenriched uranium, Light Water Reactors required enriched uranium. Also, the components of PWHR could be domestically manufactured in India, as opposed to LWRs, which would need some components to be imported. Furthermore the by product plutonium-293 would be used in the second stage**. Natural uranium contains only 0.7% of the fissile isotope uranium-235. Most of the remaining 99.3% is uranium-238 which is not fissile but can be converted in a reactor to the fissile isotope plutonium-239. Heavy water (deuterium oxide, D 2O) is used as moderator and coolant.** Known reserves of natural uranium in the country permit only about 10 GW of capacity to be built through indigenously fueled PHWRs. The three-stage programme explicitly incorporates this limit as the upper cut off of the first stage, beyond which PHWRs are not planned to be built.

Almost the entire existing base of Indian nuclear power (4780 MW) is composed of first stage PHWRs, with the exception of the two Boiling Water Reactor (BWR) units at **Tarapur**. The installed capacity of **Kaiga** station is now 880 MW, making it the third largest after Tarapur (1400 MW) and **Rawatbhata** (1180 MW). The remaining three power stations at **Kakrapar**, **Kalpakkam** and **Narora** all have 2 units of 220 MW, thus contributing 440 MW each to the grid. The 2 units of 700 MWe each (PHWRs) that are under construction at both Kakrapar and Rawatbhata, and the one planned for Banswara would also come under the first stage of the programme, totalling a further addition of 4200 MW. These additions will bring the total power capacity from the first stage PHWRs to near the total planned capacity of 10 GW called for by the three-stage power programme .

Stage 2

The second stage involves **using plutonium-239 to produce mixed-oxide fuel, which would be used in Fast Breeder Reactors. These reactors have two processes. Firstly plutonium 293 undergoes fission to produce energy, and metal oxide is reacted with enriched uranium reacts with mixed-oxide fuel to produce more plutonium-239.** Furthermore once a sufficient amount of plutonium-239 is built up, thorium will be used in the reactor, to produce Uranium-233. This uranium is crucial for the third stage. In the second stage, fast breeder reactors (FBRs) would use a mixed oxide (MOX) fuel made from plutonium-239, recovered by reprocessing spent fuel from the first stage, and natural uranium. In FBRs, plutonium-239 undergoes fission to produce energy, while the uranium-238 present in the mixed oxide fuel transmutes to additional plutonium-239. **Thus, the Stage II FBRs are designed to "breed" more fuel than they consume**. **Once the inventory of plutonium-239 is built up thorium can be introduced as a blanket material in the reactor and transmuted to uranium-233 for use in the third stage.** The surplus plutonium bred in each fast reactor can be used to set up more such reactors, and might thus grow the Indian civil nuclear power capacity till the point where the third stage reactors using thorium as fuel can be brought online, which is forecasted ***as being possible once 50 GW of nuclear power capacity has been achieved***. The design of the country's first fast breeder, called Prototype Fast Breeder Reactor (PFBR), was done by Indira Gandhi Centre for Atomic Research (IGCAR). **Bharatiya Nabhikiya Vidyut Nigam Ltd (Bhavini),** a public sector company under the Department of Atomic Energy (DAE), has been given the responsibility to build the fast breeder reactors in India. **The construction of this PFBR at Kalpakkam was due to be completed in 2012**. It is not yet complete. A start date in 2015 has been suggested.[59]

In addition, the country proposes to undertake the construction of four FBRs as part of the 12th Five Year Plan spanning 2012–17, thus targeting 2500 MW from the five reactors

Doubling time

Doubling time refers to the time required to extract as output, double the amount of fissile fuel, which was fed as input into the breeder reactors.[a] This metric is critical for understanding the time durations that are unavoidable while transitioning from the second stage to the third stage of Bhabha's plan, because building up a sufficiently large fissile stock is essential to the large deployment of the third stage. In Bhabha's 1958 papers on role of thorium, he pictured a doubling time of 5–6 years for breeding U-233 in the Th–U233 cycle. This estimate has now been revised to 70 years due to technical difficulties that were unforeseen at the time. Despite such setbacks, according to publications done by DAE scientists, the doubling time of fissile material in the fast breeder reactors can be brought down to about 10 years by choosing appropriate technologies with short doubling time

Stage 3

The main purpose of stage-3 is to achieve a sustainable nuclear fuel cycle. **The advance nuclear system would be used a combination of Uranium-233 and Thorium**. Thus India's vast thorium would be exploited, **using a thermal breeder reactor**. A Stage III reactor or an Advanced nuclear power system involves a self-sustaining series of thorium-232-uranium-233 fuelled reactors. This would be a thermal breeder reactor, which in principle can be refuelled after its initial fuel charge using only naturally occurring thorium. According to the three-stage programme, Indian nuclear energy could grow to about 10 GW through PHWRs fueled by domestic uranium, and the growth above that would have to come from FBRs till about 50GW. The third stage is to be deployed only after this capacity has been achieved.

As there is a long delay before direct thorium utilisation in the three-stage programme, the country is now looking at reactor designs that allow more direct use of thorium in parallel with the sequential three-stage programme. Three options under consideration are the Accelerator Driven Systems (ADS), Advanced Heavy Water Reactor (AHWR) and Compact High Temperature Reactor

Current State

Currently India has 21 reactors that produce 5780 MW, 6 under construction aimed to produce 4300 MW and 33 planned aimed to produce 33000 MW. Currently India's installed capacity of energy is 230,000 MW so nuclear energy could form a significant portion of India's energy output.

Uranium supply imbalance in the 2000s

In spite of the overall adequacy of its uranium reserves, Indian power plants could not get the necessary amount of uranium to function at full capacity in the late 2000s, primarily due to inadequate investments made in the uranium mining and milling capacity resulting from fiscal austerity in the early 1990s. Hence India cannot produce sufficient fuel for both its nuclear weapons programme and its projected civil nuclear programme. India's current uranium production of less than 300 tons/year can meet at most, two-thirds of its needs for civil and military nuclear fuel. This can be resolved with requisite investments in India's uranium milling infrastructure.

It was estimated that after attaining 21 GW from nuclear power by 2020, further growth might require imported uranium. The estimated stagnation of the nuclear power at about 21GW by 2020 is likely due to the fact that even the short "doubling time" of the breeder reactors is quite slow, on the order of 10–15 years. Implementing the three-stage programme (Which requires 50 GW before the third stage can set in) using the domestic uranium resources alone is feasible, but requires several decades to come to fruition. Imports of fissile material from outside would considerably speed up the programme. The best way to get access to the requisite fissile material would be through uranium imports, which was not possible without ending India's nuclear isolation by U.S. and the NSG.