CHAPTER 3

Development of Nuclear Energy in India

This chapter discusses how India’s nuclear energy has been developed as a part of energy security in the realization of strategic national objective. Furthermore, India’s independence in 1947 coincided with the dawn of the ‘Atomic age’. Mahatma Gandhi offered a scathing critique of the atomic bomb as having deadened the finest feeling that has sustained mankind for ages, and concluded that the moral to be legitimately drawn from supreme tragedy of the bomb is that it will not be destroyed by the counter-bombs even as violence cannot be countered by violence.\(^1\) India’s approach to nuclear power came to be defined by this duality: a moral opposition to the bomb coupled with its belief that atomic energy could be harnessed for ‘humanitarian purposes’.\(^2\)

Therefore, some people across the world including India still view atomic energy as rather esoteric science. Its technology is considered too arcane and the exclusive province of elitist order which is insulated from the rest of the society. But, India has gathered long experience in the field of nuclear science. She started its nuclear program even before independence and now there are a plethora of institutions, research centers dedicated to the peaceful development of nuclear energy. The 500MW prototype fast breeder project at Kalappakam which is nearing completion is one such example a narrative to the realization of India’s third stage of nuclear program using thorium as fuel.

For Jawaharlal Nehru, the first Prime Minister of India, ‘the scientific approach \(\text{and temper}\)’ represented the temper of a free man.\(^3\) He implored the scientists to strive

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\(^2\) Ibid. P.74.

\(^3\) Nehru, Jawaharlal, *The Discovery of India*, New Delhi: Oxford University Press, 1946.
for the benefit of the community instead of their individual quest for scientific truths.\textsuperscript{4} His prioritisation of atomic energy is best manifested in his speech titled ‘\textit{The Necessity of Atomic Research in India}’ delivered after laying the foundation-stone of the National Physical Laboratory (NPL) in New Delhi in January 1947, seven months prior to Independence. Here, he stated: “\textit{Atomic energy is going to play a vast and dominating part, I suppose, in the future shape of things, it will make power mobile, and this mobility of power can make industry develop anywhere. We will not be tied up by the accidents of geography. Atomic energy will help cottage industry.}”\textsuperscript{5}

India started on its tryst with the atom on the very morrow of its independence, braced by foresight and commitment to advanced scientific quests of an abiding and dedicated scientist. Dr. HomiBhabha a Professor at Indian Institute of Science at Bangalore. He had a visionary mind and dynamic leadership and managerial qualities. Scion of a wealthy Parsifamiy, Bhabha combined tastes and attitudes with a nationalistic determination to raise India’s rank in the world. Bhabha earned his Ph.D. from in physics from Cambridge University in 1935, writing on cosmic rays physics. Before returning to India in 1939, Bhabha visited the institutes and laboratories of some of Europe’s greatest physicists. There he met, among others Neils Bohr, James Frank, and Enrico Fermi who played important role in the U.S. Manhattan Project. Bhabha took the post of Reader in Theoretical Physics at Indian Institute of Bangalore. He was promoted to Professor of cosmic rays in 1941. At the young age of 31, he was elected a fellow of Royal Society. Further, in a letter on 22 March, 1944 to Late J.R.D. Tata and sought financial support of the Dorabji Trust for creating an institute for fundamental research in areas in which he described as the ‘\textit{frontiers of knowledge}’ in physics, particularly nuclear physics, cosmic rays, high energy physics and mathematics. Bhabha revealed his ambition to establish himself and India as a source of world-class science.

In 1946, \textit{The Atomic energy Research Committee} was formed under the chairmanship of Bhabha. It aimed to promote education in nuclear physics in Indian


\textsuperscript{5}Extracts from Jawaharlal Nehru’s speech after laying the foundation-stone of the National Physical Laboratory in New Delhi, \textit{The Necessity of Atomic Research in India}, New Delhi : January 4, 1947, NMML Archives,.
colleges and universities. By 1948 its work had grown to such an extent that it was moved to 35,000 sq. ft. hired space elsewhere. TIFR’s to Indian Atomic Programme was man power Scientists who grew up in the creative activity of the Institute and later spread out to other nuclear projects, universities and even nuclear industrial units which had to be built to provide indigenous sustenance to India’s nuclear program. This way the institute became take-off point for India’s Atomic Energy Establishment at Trombay, primarily working in areas such as reactor physics, electronic instrumentation and fuel fabrication. These were the three pillars that had to be erected for India’s nuclear program to go forward. In 1948, United Nations grapple with U.S.-inspired attempt to establish control over fissile materials and facilities that could mine, process and utilize them, both for peaceful and military purposes. The Baruch Plan had been proposed in 1946. The proposal to create an international Atomic Development Authority to own and operate all materials, technologies and facilities with potential nuclear weapon application caused significant consternation for newly independent India.6

Indian delegate to the UN discussion on the plan, Mrs. Vijay Laxmi Pandit, insisted that international ownership of fissile ores such as thorium would deprive the country of an important economic asset in the future. India had signed a nuclear cooperation agreement with France in 1951, and in 1952 Nehru unveiled a four-year plan to begin developing India’s nuclear-capability, starting with surveying of atomic materials and processing monazite to obtain thorium.7 Application of atomic energy in medicine and biology were also announced. India had to stop its exports of thorium nitrate a material useful as a potential nuclear fuel, to China, as per mutual Defence Assistance Act of 1951- required that United States deny any form of military, economic or financial assistance to a country trading such material to Soviet Union or its Satellites. The thorium-nitrate episode exacerbated already-strained Indo-American relations.8

In this period, no field of science and technology appeared more prestigious and promising than atomic energy. Proponents of nuclear power believed that electricity from

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7 Ibid, P.40.
atomic reactors held the key to economic development. Many scientists saw atomic energy as the best or only source of rapid increase in energy supply in countries not endowed with other sources of fuel. One of the earliest acts of AEC was to set up Rare Earth Mineral Survey Unit in 1950 under D.N., probably the most famous geologist India has produced. Wadia was responsible for locating the uranium deposits in Jaduguda in 1952 and in Narwapahar in 1963.\textsuperscript{9} The earlier concrete achievement of the AEC was establishment of \textit{Indian Rare Earth Limited} (IREL) in 1952.

Nehru was followed by three parliamentarians who emphasized the importance of pursuing atomic energy only for peaceful purposes and who evinced concern about India’s wherewithal to fund such research. They were, DR. B. Pattabhi Sitaramayya, Dr. S.V. Krishnamurthy Rao and Prof. Sibban Lal Saksena.\textsuperscript{10} Meanwhile, Professor Shibban Lal Saksena asked for the floor and wearing the mantle of a hardened realist, evocatively criticized the naïveté of the forging debate by saying, “\textit{Science is a power both for good or evil. If we have not got the knowledge and the ability to use this power, there is no virtue in our saying that we shall not use it for destructive purposes and the other people should not use it. Until we have the capacity to use atomic energy for destructive warfare it will have no meaning for us to say that we shall not use atomic energy for peaceful purposes.”}\textsuperscript{11}

Nehru stepped forward in the debate with curiosity. He did not challenge Saksena instead he acknowledged that the nuclear project in India, as in the United States and Great Britain, was potential source of military as well as economic power. In formulating our strategy for nuclear power development, we had to take into account that while our uranium reserves are rather limited, our thorium reserves are amongst the largest in the world. Nehru stated: “\textit{We chalked out a model for development of atomic energy tailored on our conditions. There is just one aspect to which I should like again to draw the attention of the House. Somehow we cannot help associating atomic energy with war. Nevertheless, the important thing today is that atomic energy is vast source of power. It is in that hope that we should develop this. Of course, if we are compelled as

\textsuperscript{9}Wadia , D.N., \textit{Atomic Energy in India}, New Delhi: Govt. of India, DAE, 1998, P.238.
\textsuperscript{10}Constituent Assembly of India ,\textit{Legislative Debate}, 2\textsuperscript{nd} Session, Vol. 5, April 6, 1948, P. 3315.
\textsuperscript{11}Ibid, PP.3332-3333.
a nation to use it for other purposes, possibly no pious sentiments of any of us will stop
the nation from using it that way.”

During 1953 and 1954, the U.S.-Indian ‘dialogue’ on international control of
atomic energy and disarmament intensified. On December 8, 1953 President Eisenhower
delivered his famous Atoms for Peace speech before the UN General Assembly.
Highlighting the dangers of the dangers of nuclear war and arms racing, he urged world
community instead to harvest the power of atomic fission and fusion for peaceful
purposes. Eisenhower proposed an Atomic Energy Agency that would Act as a bank to
receive deposits of fissionable materials. The vision of a fissile material bank was much
more modest than the Baruch Plan’s Atomic Development Authority. Nehru’s reaction to
Atoms for Peace was highlighted in an important speech in Lok Sabha on May 10, 1954.
Nehru began by stating the imperative of controlling and eventually eliminating nuclear
weapons. But he quickly acknowledged that they cannot be controlled by a mere desire or
demand for banning them.

Initially, three member commission comprising H.J. Bhabha, as the Chairman,
and Dr. S.S. Bhatnagar and Dr. K.S Krishnan as the other two members, a full-fledged
Department of Atomic Energy was created on August 03, 1954 under the direct
chairmanship of Prime Minister—which ensured the complete effectiveness as well as
complete autonomy for the department in all its operations and Dr. Homi. J. Bhabha was
assigned as the first Secretary of Department of Atomic Energy (DAE). This was a
departure from prevailing bureaucratic structure that permeated the working of India’s
nuclear institutions and projects and went a long way in cutting red tape and bureaucratic
practices in formulating and developing India’s Nuclear Program.

It was Bhabha who carved out this role of scientific and administrative leadership
with great distinction in the formative years—1948 to 1966—till his untimely death over
Mount Blanc in Switzerland. The mantle fell on Sarabhai in May 1966 and he remained

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12 Ibid, PP. 3333-3334.
at the helm of AEC and DAE till Dec. 30,1971. Sarabhai was a space scientist of great
distinction, guided with considerable capability, the entire program-atomic space and
electronics—since AEC was then an umbrella organization of all the three disciplines,
there after it was split into three commissions. AEC was set up to act as a scientific leader
with pre-eminence for scientists but reinforced by DAE with organizational capability for
meeting the formidable challenges. TIFR played a big role in India’s nuclear journey.
Initially a joint Endeavour of the Dorabji Tata Trust and then government of Bombay,
which was formally inaugurated in Dec 1945 in Kenilworth, which was Bhabah’s
ancestral home, with 6000 sq. ft.

Nuclear Power Corporation of India Limited is a Public Sector Enterprise Under
the administrative control of the Department of Atomic Energy (DAE), Government of
India. The Company was registered as a Public Limited Company under the Companies
Act, 1956 in September 1987 with the objective of operating atomic power stations and
implementing the atomic power projects for generation of electricity in pursuance of the
schemes and program of the Government of India. Along with NPCIL the Atomic Energy
Act, 1962 also has the equity participation in BHAVINI\textsuperscript{15}.

An organization formed for implementation for Fast Breeder Reactors (FBR)
program in the country. NPCIL is responsible for design, construction, commissioning
and operation of nuclear power reactors. NPCIL is a MOU signing, profit making and
dividend paying company with the highest level of credit rating (AAA rating by CRISIL
and CARE). NPCIL is presently operating 21 nuclear power reactors with an installed
capacity of 5780 MW. The reactor fleet comprises of two Boiling Water Reactors
(BWRs) and eighteen Pressurized Heavy Water Reactors (PHWRs) and includes RAPS-
1(100 MW) owned by DAE, Government of India. Currently it has four reactors under
various stages of construction totaling 3400 MW capacity and 1400 MW (RAPP-7&8) is
being prepared to be in construction with first pour of concrete planned mid-2011.

Pre-project activities at the sites, accorded in principle approval by the
Government in October, 2009 have been taken up aggressively so as to enable early

launch of projects at these sites. NPCIL completed its units namely TAPS-3&4 and KGS-3 with gestation periods matching international level achievements in construction of nuclear power plants.\textsuperscript{16} India’s upcoming nuclear institutions were permeated with unique upswing, the product of scientific innovation welded with patriotism, the outflow of newly won independence. The Trombay Atomic Energy Establishment renamed Bhabha Atomic Research Centre after great scientist’s sudden end amidst a somewhat mysterious air crash. Soon its research activity took over that of ITFR. It became the hub of Indian nuclear program related activity and in the subsequent years the world’s collection of scientific laboratories under a single roof that sprang up further various aspects of Indian nuclear program. It should be specially mentioned that both in the domain of peaceful application and exercise of India’s weapons option, BARC has played a key role. Speaking in scientific language India was on its way to acquire capability along the entire fuel cycle.\textsuperscript{17}

There was also a fourth area of action for laying the base of Indian nuclear program search for uranium quite a stupendous task both in magnitude and basic import of atomic energy. Countrywide surveys were launched for locating deposits of uranium and other atomic minerals under the care of Rare Minerals Survey unit in 1949. This unit was reconstituted as the Atomic Mineral Division under Atomic Energy Commission in 1950, to prospect for naturally occurring minerals. Later, the Division was renamed as Atomic Minerals Directorate for Exploration and Research Uranium deposits were found at Jaduguda (about 7000 tones) and Narwapahar (about 12000 tones)—both in Singbhum thrust belt of Bihar, now in Jharkhand—were taken up for mining. In subsequent years, rich deposits have been established at Domiasiat, Meghalaya. BY 1995, the available reserves have been established at 86,000 tones. In India uranium mining facilities in Jaduguda and Meghalaya have been targets of public opposition due to lack of adequate mitigation measures in the past. The inefficiency in managing radiation issues often turns into protests against nuclear establishment and its facilities.\textsuperscript{18} The government needs to address these challenges by strengthening radiation prevention and nuclear waste

\textsuperscript{17}http://www.barc.gov.in/reactor/index.html. Accessed on 20 August, 2013-14
management measures. Without proactive steps by the government, the domestic challenges will continue to be a serious concern for nuclear industry development. If India intends to increase nuclear power production capacity, it is critically important to make improvement at domestic front.\(^{19}\)

An eminent metallurgist, Dr Brahmp Parkash, one of the architects of Mishra Dhatu Nigam entered the scene as a uranium man for India. Appointed as the first chairman of the uranium corporation of India, he along with Tej Bhan Malhotra, the first Managing Director of UCIL, and Fareeduddin, BARC’s designated specialist for taking the mined uranium ore through chemical processing to final stage of use of reactors—laid the foundation of large-scale commercial processing of uranium. The corporation went on to commercial production in May, 1968, and the first consignment of yellow cake—magnesium diuranate - was sent to Trombay in September, 1968.

Further, the most important component part of Indian nuclear miracle is scientific manpower engaged in research and development, based on whom rose the nuclear infrastructure needed for great edifice. Dhruva high flux research reactor—among BARC’s pride creations-- built during early eighties entirely through indigenous efforts by a team of prominent scientists and engineers, notable among them were Dr. Anil Kakodkar and Dr. Sundaram. This has been possible that despite the fact that after 1974, the West erected a sort of cordon sanitaire round India’s nuclear program making imports of even minor nuclear-related items virtually impossible. The complex project was built painstakingly, along the scientific path of enquiry, testing and cross-checking. Dhruva an advanced research reactor demonstrated India’s climb in nuclear capability between 1974 and 1982, the difficult years.\(^{20}\) But this marked an important stage in Indian nuclear capability acquisition. Now it had to meet the growing requirements of radioisotopes to support research in build-up of India’s nuclear power program, equally important was Dhruva’s function as a link between the power program and the Indian weapons option. This technological breakthrough was achieved in 1964. These technological advances, notably breakthrough in reprocessing nuclear spent fuel


\(^{20}\)Ibid
technology and building advanced chain such as Dhurva, and further on Purnima chain, laid the strong base for India’s nuclear program and elevated India’s status in the global nuclear community. A reflection over various phases of Indian nuclear technology acquisition shows that it could absorb advanced know-how and nuclear material from the West as well as the shocks of blockade and denial of scientific cooperation because of the base of self-reliance on which it rested. This base comprised not only of innovative, indigenous technology acquisition but also fundamental research. The continuing build-up of dynamic nuclear infrastructure along with centers of research and development is a feature that lends strength to Indian nuclear program.21

TIFR and BARC embodied both these facets that sustain India’s nuclear edifice. Later, other centers of research and development were added to create a chain of scientific research as well as technology development ‘frontiers of knowledge’. This included Reactor Research Centre renamed as Indira Gandhi Center for Atomic Research (IGCAR), at Kalapakkam and Centre for Advanced Technology (CAT) at Indore.22 In January 1966, Bhabha died in an air crash. Then, on 25 May 1970 Sarabhai announced a ten-year plan for development of nuclear energy, later it was termed as Sarabhai Profile. In 1954 and again in1965, plans had called for the Atomic Energy Commission to have 600 megawatts of power on line by 1970-71. Yet in 1970 only two US supplied reactors were operating, and their combined output was only 420 megawatts. Bomb advocates blamed these failures on the lack of leadership since Bhabha days.

The published version of Sarabhai’s plans for 1970 to 1980 began by looking at problem of developing atomic energy and space capabilities within broader context of Indian industrial, management and organizational resources. Sarabhai argued that the shortcomings of Atomic Energy Commission stemmed from the inadequacies of surrounding political economy on which it depended for manufacturing and human resources.23 He also invoked the importance of atomic energy and space research for national defence and security and not merely development.24

22Ibid, P. 41.
24Ibid. P.5.
envisioned providing 8,000 MWs of electricity in 1980-81, the new plan called for 2,700 MWs installed capacity by the same time. Thus, India’s Atomic Energy program was still guided by Bhabha’s premature and unachievable vision of speedy transition to plutonium-then-thorium fuel cycle. The ten-year plan called for expenditures of Rs, 12,500 million, or approximately $1.67 billion at the exchange rate of the time.\textsuperscript{25} This was slightly more than the annual defence budget of India.

The Department of Atomic Energy’s 1970 profile also presented the first major plans for space research. The first task had been to develop a cadre of scientists and engineer to develop space research in India. Much of the early technological work has been done through foreign cooperation, primarily with P-4 (excluding China), a space launching facility was established near Trivendrum. In 1969 a separate organization – the \textit{Indian Space Research Organization} (ISRO)—was created within DAE. The new Department of Space was created in 1972. This arrangement was done to avoid controversy of correlating the AEC’s developing nuclear explosive capabilities and rockets.\textsuperscript{26}

The 1970 profile emphasized three objectives for space research: to develop and deploy satellites for communication, particularly television broadcasting; to develop and utilize meteorological satellites to predict weather, particularly monsoons; to apply remote sensing technology to detect crop and forest disease, measure snow coverage in Himalayas to anticipate drought and flood conditions and so forth.\textsuperscript{27} Sarabhai clearly intended for the space organization to be a vehicle for India’s economic and technological developments. On the contrary Sarabhai believed that the DAEs activities simply do not provide enough direct benefit to the citizenry or the economy to warrant a major sustained budget increase.

\textsuperscript{25} This Included Natural Uranium Fuel Fabrication Facilities, Heavy Water Production Facilities, Plutonium Reprocessing and Waste Treatment Plants, and Uranium Enrichment.

\textsuperscript{26} \textit{Home Sethna Interviewed by George Perkovich}, Mumbai: February, 26, 1997.

\textsuperscript{27} Government of India, Atomic Energy Commission, \textit{A Profile For The Decade, 1970-80}, P. 29.
In July 1970, Sarabhai asserted that India was capable of conducting underground nuclear explosion and was internationally entitled to do so as a nonparty to NPT. On August 31, Prime Minister informed the Parliament that the government was studying the economic and technical issues surrounding peaceful nuclear explosives. Indian leadership had decided to develop nuclear explosive capability. The Director of Terminal Ballistics Laboratory, Chandigarh, Sampooran Singh, provided the most sophisticated case for nuclear weapons program in *India and Nuclear Bomb*. He wrote, “so long as nuclear power and political power are correlated elements in world politics it is necessary that India take close hard look as its defence posture on long term basis, and view nuclear power as an integral part of its defence and deterrence system.” India has limited reserves of uranium but its thorium reserves are very large. In view of this resource position, India has chalked out a three-stage programme which aims at the development of nuclear energy sector in India.

**India’s Nuclear Edifice—Strong R&D Base:** There have been three broad phases in evolution of India’s nuclear policy in the last 70 years since 1945. In the first phase India’s pursuit of nuclear idealism is clear. The country was led by Nehru, whose abhorrence of nuclear weapons reflected his international idealism. On one hand Nehru became the first leader to sign the Partial Test Ban Treaty of 1963, while he was equally driven by scientific temper and was appreciative of potential of atomic energy for India’s development and economic growth. Developing the technical base for the nuclear option has been the priority both for Indian leadership and the scientific community. Nuclear power is a manifold term. It describes the production of electricity as well as a state possessing nuclear weapons. India wanted it’s all the prestige, status and the economic benefits associated with being a nuclear power, including the option of building the bomb if necessary. It was evident that, the capacity to master the atom represented modernity,

potential propensity, transcendence of colonial past, individual and national prowess and international leverage.

Typically it is said that Nehru between strategic attributes of the country and nuclear imperatives had appreciated early the connection between great-power status and modern military wherewithal and intended, for India to use nuclear technology and know-how exclusively for peaceful purposes. He also understood that if India was to realize its ambition, it had to have capabilities to construct a nuclear weapon and had made the connection. In the words of T.T. Poulose, “There was no guile in his nuclear policy as it originated from a mind imbued in idealism, deep sense of history and a world view and always a vision of strong and modern India. Nehru’s nuclear decisions were not outcome of any national debate but deeply rooted in his scientific temper, abhorrence of nuclear weapons and nuclear allergy after supreme tragedy at Hiroshima and Nagasaki.”32 Thus, the close scrutiny reveals, that Nehru also accepted, albeit reticently and ambivalently, the potential military deterrent and international power embodied in a nuclear weapon capability.

Further, he said in a speech in 1946 at Bombay: “As long as the world is constituted as it is, every country will have to devise the use of latest scientific devices for its protection. I have no doubt that India will develop her scientific researches and I hope Indian scientists will use the atomic force for constructive purposes. But if India is threatened she will inevitably try to defend herself by all means at her disposal. I hope India in common with other countries will prevent the use of atomic bombs”.33

Nehru’s strategic thinking regarding a nuclear program, was a result of the influence on him, ironically, of three Englishmen, Field Marshal Claucde Auchinleck, the former commander-in-chief of allied Middle Eastern Command in initial years of Second World War before Winston Churchill posted him as commander-in-chief, in India; Lieutenant General Francis Tuker, who commanded the famed 4th division in North African campaign and returned to India’s Eastern Army. The last British Officer to do so. Nehru advised by his old friend Prof. P.M.S. Blackett from Cambridge, the 1948 Nobel

32Poulose, T.T., Perspectives of India’s Nuclear Policy, New Delhi :Radiant , P.102.
33Perkovich, George, op.cit., P. 14.
laureate in physics, recommended a giant network of laboratories under the CSIR.\textsuperscript{34} Blackett’s sympathetic treatment of India’s economic plight and his political orientation towards the atom seemed to be in sync with that of leading scientists in India, who regarded nuclear power as an energy lifeline. A holistic paradigm was needed to pull in these various strands and it was provided by Blackett. By the time Bhabha has achieved fame and was elected President of Scientific Advisory Committee to the UN.

The new dynamism and self-confidence in Indian nuclear technology carries the assurance that target of 20,000 MWe nuclear power capacity will be realized in time. The transformation is the India’s strong nuclear edifice and organizational structure. The core foundation of the nuclear organizational structure is the chain of R&D centers and the system of innovative science round which these R&D centers have been built.\textsuperscript{35} At the apex of Indian nuclear scientific edifice are two scientific bodies- the Atomic Energy Commission and Atomic Energy Regulatory Board – one seeking relentless, dynamic advance towards nuclear projects, specific areas and technologies, and other applying safety factors without any concession or compromise, exercising vigilance that Indian units strictly to international norms of safety and environmental protection. The executive instrument for implementation of the nuclear program is the \textit{Department of Atomic Energy} (DAE). The realization of India’s nuclear dreams rests on DAE’s performance.\textsuperscript{36}

Bhabha structured the nuclear program around the nuclear complex in suburb of Mumbai, called Trombay which after his death in 1966, was renamed as Bhabha Atomic Research Centre. BARC today has some 4,000 scientists, five research reactors of various types, and ‘\textit{Dhurva}’—a 100 megawatt weapon-grade plutonium producer then went critical in 1985. A second nuclear complex in Kalpakkam, near Madras, later christened as \textit{Indira Gandhi Centre for Atomic Research} (IGCAR) came in 1970s, housing some of the most sensitive projects, the up scaled 500 MW prototype fast breeder reactor under construction the thorium fuelled ‘\textit{Kamini}’ including the 40 MW breeder test reactor, and

\textsuperscript{34}Wadia, D.N., \textit{op.cit.}, P.238.  \textsuperscript{35}Sabherwal ,O.P., \textit{op.cit.}, P. 142.  \textsuperscript{36}\textit{Ibid},P.143.
the test bed for miniaturized enriched uranium run power plant for the indigenous nuclear powered submarine project.\textsuperscript{37}

However, only Canada offered technology transfer under Colombo Plan\textsuperscript{38}. India’s progress compared to European Nations was slow, but thorium plant at Trombay went into production in 1955. In 1956, the Chinese announced the construction of experiment reactors outside Beijing. India’s First nuclear reactor, Apsra, was commissioned by Nehru in January 1957. India has become aware that CENTO treaty signed by Pakistan could well result in nuclear weapons being based in that country. As a consequence of this in 1956 Nehru announced in Parliament that if adequate resources were diverted, the India bomb could be made in three to four years.\textsuperscript{39} On 10 May 1956, China announced the start of its nuclear weapons program.

Eventually India’s perception of its own strengths vis-à-vis China, which was that of equal in 1947, slipped to an acknowledged position of inferiority. The nuclear asymmetry certainly contributed to this self-generalized decline, and in the annals of international diplomacy, the Chinese gains against India with in span of fifteen years are a classic instance of the use of power of realpolitik.\textsuperscript{40} The progress on Cirus has peaked in 1959 amid the murmurs in the press that a weapons option should not be foreclosed. India has imported 20 tons of heavy water from US with the help of which Cirus went critical. Nehru also announced the conclusion of the agreement with the US to set up a power plant at Tarapur.

Homi Sethna was permitted to start a plutonium plant at Trombay, the project called Phoenix, in 1958. It was to reprocess the 20 tons of fuel reprocessed by Cirus to produce about 10 kg of plutonium a year. This Nuclear Fuel Cycle has been envisioned by Bhabha. Since uranium sources at Jaduguda and Narwapahar were limited, India would need to reprocess spent fuel in fast-breeder reactors. Once this cycle was started, India could then experiment with its vast thorium reserves to power the nuclear program.

\textsuperscript{38} Perkovich, George, \textit{op.cit.}, P. 226.  
\textsuperscript{40} Menon, Raja, \textit{A Nuclear Strategy for India}, New Delhi: Sage Publications, 2001, P.70.
In 1961, Zerlina reactor went critical. The first quantities of plutonium were produced in 1964.\textsuperscript{41}

The Chinese invasion changed many stances in Indian ways of thinking. Offers of military, economic and technological aid poured in from around the globe. The Indian Air Force acquired MIG-21s. In November 1963 India launched its two-stage rocket from Thumba in Thiruanthapuram which bore remarkable similarities to an earlier American rocket. In December 1963, India and the US signed the agreement on Tarapur atomic power plant. In early 1964 the US exported to India CDC-3600-140A computer which could be used to simulate nuclear fission. The Chinese exploded the first bomb at Lop Nor on 16\textsuperscript{th} October 1964.

**Nuclear Establishments, Infrastructure, Installations and Institutions:**

The *Department of Atomic Energy* (DAE) was set-up on August 3, 1954 under the direct charge of the Prime Minister through a Presidential order.\textsuperscript{42} The vision of the Department of Atomic Energy is to empower India through technology, creation of more wealth and providing better quality of life to its citizen. This is to be achieved by making India energy independent, contributing to provision of sufficient, safe and nutritious food and better health care to our people through development and deployment of nuclear and radiation technologies and their applications.

DAE is engaged in the design, construction and operation of nuclear power/research reactors and the supporting nuclear fuel cycle technologies covering exploration, mining and processing of nuclear minerals, production of heavy water, nuclear fuel fabrication, fuel reprocessing and nuclear waste management. It is also developing advanced technologies that contribute to the national prosperity. The spin-off technologies, human resource developed and technical services being rendered by the Department have been greatly helping the Indian industry. The Department is also developing better crop varieties, techniques for control/eradication of insects thus protecting the crops, radiation based post-harvest technologies, radiation based

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\textsuperscript{41}\textit{Ibid.} P.70.

\textsuperscript{42}http://dae.nic.in/?q=node/77. Accessed on 12 June 2014.
techniques for diagnosis and therapy of disease particularly cancer, technologies for safe drinking water, better environment and robust industry.
Main Target Areas of Work in DAE:\(^{43}\):

- Increasing share of nuclear power through deployment of indigenous and other proven technologies, along with development of fast breeder reactors and thorium reactors with associated fuel cycle facilities.
- Building and operation of research reactors for production of radioisotopes and carrying out radiation technology applications in the field of medicine, agriculture and industry.
- Developing advanced technologies such as accelerators, lasers, supercomputers, advanced materials and instrumentation, and encouraging transfer of technology to industry.
- Support to basic research in nuclear energy and related frontier areas of science, interaction with universities and academic institutions, support to research and development projects having a bearing in DAE’s programs and international cooperation in related advanced areas of research and
- Contribution to national security.

Industries and Mining Sector of DAE

Various departments work in the Industries and mining sector of DAE. These institutions had laid down a strong infrastructure which is the essential requirement for augmentation of nuclear energy program in India, described as under:

Nuclear Fuel Complex:

It was established in 1971 as a major industrial unit of Department of Atomic Energy, for the supply of nuclear fuel bundles and reactor core components. It is the sole supplier of fuel to the country’s nuclear power plants, has firmed up plans to establish two major fuel fabrication facilities to meet the expected jump in nuclear power

production. NFC symbolizes the strong emphasis on self-reliance in the Indian Nuclear Power Program.

Natural uranium, mined at Jaduguda Uranium Mine in the Singhbhum area of Jharkhand state, is converted into nuclear fuel assemblies. A 220 MW PHWR fuel bundle contains 15.2 kg of natural uranium dioxide. Uranium dioxide pellets, which generate heat while undergoing fission, also generate fission products. The fission products, which are radioactive should be contained and not allowed to mix with coolant water. Hence the UO2, pellets are contained in zirconium alloy tubes with both ends hermetically sealed. NFC is planning to establish two major fuel fabrication facilities to meet the expected jump in nuclear power production.

**Heavy Water Board:**

The research in Heavy Water production was initiated by the Chemical Engineering division of *Bhabha Atomic Research Centre* (BARC) in the 60s and was continued by the Heavy Water Division of the Centre where a Pilot Plant was operated for studying the H2S-H2O exchange process. While these studies were in progress, a Heavy Water Plant at Nangal in Punjab was set up and commissioned in August, 1962. Further, to have a share of at least 10% of the national power demand by 2000 A.D., Department of Atomic Energy embarked on an ambitious program of producing nuclear power of 10,000 MWe which required setting up a number of heavy water plants. This was also the time when the need for a separate organisation to oversee the planning and setting up of Heavy Water Plants was strongly felt. Accordingly an organisation known as the Heavy Water Projects was set up on May 1, 1969.

India is one of the largest manufacturers of heavy water in the world and is meeting the heavy water requirements of the Indian Nuclear Power Program. The plants based on Ammonia-Hydrogen (NH3-H2) exchange process are linked to the ammonia fertilizer plants for synthesis gas feed supply while H2S-H2O based plants are independent in this respect.

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Heavy Water Plant at Baroda: It is the first plant set up in the country for the production of heavy water by employing Monothermal Ammonia-Hydrogen exchange process. This facility also has a Potassium metal plant for supply of Potassium metal for preparing catalyst solution for all Monothermal Ammonia-Hydrogen exchange plants. The plant is located 8 km north from Baroda railway station along the national highway No. 8, adjacent to the Gujarat State Fertilizers & Chemicals Ltd. (GSFC). This plant was originally integrated with three stream ammonia plants of M/S GSFC. Plant was
receiving synthesis gas from ammonia plants of GSFC and returning the depleted synthesis gas back to GSFC after extraction of deuterium from the gas.

- **Heavy Water Plant at Kota:** It is a solely indigenous effort and is based on the Bithermal H2O-H2S exchange process. The plant is located at a distance of 65 KM from Kota Railway Station, adjacent to *Rajasthan Atomic Power Plant* (RAPP). The Heavy Water Plant is integrated with RAPP for its supply of power and steam.

- **Heavy Water Plant at Hazira:** It is also known as *Hazira Ammonia Extension Plant*—(HAEP), which employs the ammonia-hydrogen exchange mono-thermal process. The plant is located at a distance of about 16 km from Surat city. Work on HWP (Hazira) commenced in August 1986 and the plant was commissioned in January 1991.

- **Heavy Water Plant Thal:** It is the first of second-generation plants in India and is made completely with indigenous efforts. The vast technical resources available with Heavy Water Board with the experience gained by commissioning and sustained operation of the earlier plants were utilized for setting up of the plant. It is located at Thal-Vaishet village in Raigad district of Maharashtra and is about 100 kms south of Mumbai on National Highway No.17 It is about 20 kms away from Pen railway station of Panvel - Roha section.

- **Heavy Water Board (HWB):** It is a constituent unit of Industries and Minerals Sector under Department of Atomic Energy, is primarily responsible for production of Heavy Water (Deuterium Oxide-D2O) which is used as a 'moderator' and 'Coolant' in the nuclear power as well as research reactors. HWB has mastered the complex production technology using two chemical exchange processes viz. H2S-H2O bithermal process and NH3-H2 monothermal process.

- **The Heavy Water Plant at Manuguru, Andhra Pradesh:** It is based on the Bithermal Hydrogen Sulphide-Water (H2S-H2O) Exchange Process. This plant with a capacity of 185 Metric Tones per Year is the second in India based on this process. The first one located at Kota, Rajasthan had complete technology developed indigenously with the close interaction between Bhabha Atomic Research Centre and the Heavy Water Board.

- **Heavy Water Plant at Tuticorin:** It is a constituent unit of Heavy Water Board, Mumbai under Department of Atomic Energy, Government of India. It employs the ammonia-hydrogen exchange process (mono-thermal). The plant is located at a distance
of about 14 km from Tuticorin Railway Station. Work on HWP Tuticorin was commenced in September 1971 and the plant was commissioned in July 1978. Board of Radiation and Isotope Technology

BOARD OF RADIATION AND ISOTOPE TECHNOLOGY:  

It is having a BRIT Board setup by the Department of Atomic Energy on March 1, 1989. It was headquarters in Navi Mumbai. It supplies a vast array of high quality radioisotope products for medical and industrial use. Setting up of radiation processing plants in the private sector is one of the important activities along with isotope application services. It is involved in production, development, and supply of radioisotope based products and provision of isotope applications, radiation processing, radioanalytical services, etc. It has regional centres at Rawatbhatta-Kota in Rajasthan, Bengaluru in Karnataka, Delhi, Hyderabad in Andhra Pradesh, Kolkata in West Bengal and Dirugarh in Assam.

Public Sector Undertakings:

Uranium Corporation of India Limited:

It was incorporated on 4th October 1967. Uranium Corporation of India Limited is a Public Sector Enterprise under the Department of Atomic Energy. UCIL is at the forefront of the Nuclear Power cycle. UCIL plays a very significant role in India’s nuclear power generation program. It has adopted the latest state of the art technology for its mines and process plant. It had an annual turnover of about Rs. 304 Crores in the financial year 2007-08. The Company is having its mining operations at Bagjata, Jaduguda, Bhatin, Narwapahar, Turamdih underground mines and Banduhurang opencast mines and upcoming mining projects at Mohuldih in East Singhbhum district of Jharkhand and at Tummalapalle mining project in Andhra Pradesh and Gogi mining project at Karnataka.

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46 http://www.britatom.gov.in/htmldocs
Electronics Corporation and India Limited:

It was setup under the Department of Atomic Energy on 11th April, 1967 with a view to generate a strong indigenous capability in the field of professional grade electronics. The initial accent was on total self-reliance and ECIL was engaged in the Design, Development, Manufacture and Marketing of several products with emphasis on three technology lines viz. Computers, Control Systems and Communications. The company played a very significant role in the training and growth of high caliber technical and managerial manpower especially in the fields of Computers and Information Technology. The Company has developed various products to cater to the needs of Defence, Civil Aviation, Information & Broadcasting, Telecommunications, Insurance, Banking, Police, and Para-Military Forces, Oil & Gas, Power, Space Education, Health, Agriculture, Steel and Coal sectors and various user departments in the Government domain.

Indian Rare Earths Limited:

It was incorporated as a private limited company on August 18, 1950. It is jointly owned by the Government of India and Government of Travancore, Cochin with the primary intention of taking up commercial scale processing of monazite sand at its first unit namely Rare Earths Division (RED), Aluva, Kerala for the recovery of thorium. In 1963 it came under the administrative control of Department of Atomic Energy (DAE), IREL took over a number of private companies engaged in mining and separation of beach sand minerals in southern part of the country and established two more Divisions one at Chavara, Kerala and the other at Manavalakurichi (MK), Tamil Nadu. In 1983 IREL commissioned its largest Division called Orissa Sand Complex (OSCOM) at Chatrapur, Orissa. Today IREL operates these four units with Corporate Office in Mumbai and produces/sells six heavy minerals namely ilmenite, rutile, zircon, monazite, sillimanite and garnet as well as various value added products.

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48 http://www.irel.gov.in/scripts.
## Table: Nuclear Power Stations and Their Capacity

<table>
<thead>
<tr>
<th>Power Station</th>
<th>Operator</th>
<th>State</th>
<th>Type</th>
<th>Units</th>
<th>Total Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiga</td>
<td>NPCIL</td>
<td>Karnataka</td>
<td>PHWR</td>
<td>220 x 4</td>
<td>880</td>
</tr>
<tr>
<td>Kakrapar</td>
<td>NPCIL</td>
<td>Gujarat</td>
<td>PHWR</td>
<td>220 x 2</td>
<td>440</td>
</tr>
<tr>
<td>Madras</td>
<td>NPCIL</td>
<td>Tamil Nadu</td>
<td>PHWR</td>
<td>220 x 2</td>
<td>440</td>
</tr>
<tr>
<td>Narora</td>
<td>NPCIL</td>
<td>Uttar Pradesh</td>
<td>PHWR</td>
<td>220 x 2</td>
<td>440</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>NPCIL</td>
<td>Kota Rajasthan</td>
<td>PHWR</td>
<td>100 x 1, 200 x 1, 220 x 4</td>
<td>1180</td>
</tr>
<tr>
<td>Tarapur</td>
<td>NPCIL</td>
<td>Maharashtra</td>
<td>BWR PHWR</td>
<td>160 x 2, 540 x 2</td>
<td>1440</td>
</tr>
<tr>
<td>Kudankulam</td>
<td>NPCIL</td>
<td>Tamil Nadu</td>
<td>VVER-1000</td>
<td>1000 x 1</td>
<td>1000[^66]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Total 21</strong></td>
</tr>
</tbody>
</table>

(Source: www.britatom.gov.in)

### Future Nuclear Power Generation in India:

**Nuclear Power Corporation of India Limited**: NPCIL is a Public Sector Enterprise under the administrative control of the Department of Atomic Energy (DAE), Government of India.\(^{49}\) The Company was registered as a Public Limited Company under the Companies Act, 1956 in September 1987 with the objectives of operating atomic power stations and implementing the atomic power projects for generation of electricity in pursuance of the schemes and program of the Government of India under the atomic energy act of 1962. NPCIL is responsible for design, construction, commissioning and operation of nuclear power reactors. NPCIL is a MoU signing, profit making and dividend paying company with the highest level of credit rating (AAA rating by CRISIL and CARE).

**Bharatiya Nabhikiya Vidyut Nigam Limited**: BHAVINI is a wholly owned Enterprise of Government of India under the administrative control of the Department of Atomic Energy (DAE) incorporated on 22nd October 2003 as Public Limited Company with the objective of constructing and commissioning the first 500 MWe Fast Breeder Reactor (FBR) at Kalpakkam in Tamilnadu and to pursue construction, commissioning, operation

and maintenance of subsequent Fast Breeder Reactors for generation of electricity in pursuance of the schemes and programs of Government of India under the provisions of the Atomic Energy Act, 1962. The 500MWe Prototype Fast Breeder Reactor is in the advanced stage of construction. Despite technological challenges of first of its type sodium cooled fast reactor, the construction work has progressed well and almost all major reactor equipment’s are in place.  

Both Dr. R. Chidambaram and Dr. Anil Kakodkar were associated with the first successful Peaceful Nuclear Explosion Experiment conducted by India on March 18, 1974 at Pokhran. Both played a key role in a series of five successful nuclear tests carried out during May 1998 again at Pokhran. Dr. Anil Kakodkar, immediately after taking over as the Chairman, AEC, identified the following six ‘Key Drivers’ for further development and implementation of the Indian Atomic Energy Program.

**The Atomic Energy Regulatory Board**[^51] (AERB): It was constituted on November 15, 1983 by the President of India by exercising the powers conferred by the Atomic Energy Act to carry out certain regulatory and safety functions under the Act. The regulatory authority of AERB is derived from the rules and notifications Promulgated under the Atomic Energy Act and the Environment (Protection) Act, 1986. It is responsible for the regulation and licensing of all nuclear facilities and their safety and carries authority conferred by the Atomic Energy Act for radiation safety and by the Factories Act for industrial safety in nuclear plants. However, it is not an independent statutory authority, and its 1995 report on a safety assessment of DAE's plants and facilities was reportedly shelved by the AEC. In April 2011 the government announced that it would legislate to set up a new independent and autonomous Nuclear Regulatory Authority of India that will subsume the AERB, and that previous safety assessments of Indian plants would be made public.

**Nuclear Safety Regulatory Authority** (NSRA): It was established for regulation of radiation safety or nuclear safety and achieving highest standards of such safety based on scientific approach, operating experience and best practices followed by nuclear

[^50]: http://www.bhavini.nic.in/project.asp (Accessed on October 05, 2013)
[^51]: http://www.aerb.gov.in/AERBPortal/pages/English/t/annrpt/2013/chapter2.pdf
industry and to ensure that the use of radiation and atomic energy in all its applications is safe for the health of the radiation workers, members of the public and the environment and also to establish a Council of Nuclear Safety to oversee and review the policies relating to radiation safety and nuclear safety and to provide for matters connected therewith or incidental there to.\textsuperscript{52}

Minister of State in the Prime Minister's Office V. Narayanasamy, introducing the Nuclear Safety Regulatory Authority Bill, 2011, said, the Bill was aimed at achieving the highest standards of nuclear safety based on scientific approach, operating experience and best practices followed by the nuclear industry. It will enable establishment of a \textit{Council of Nuclear Safety} (CNS), under the Prime Minister's chairmanship, to oversee and review the policies relating to radiation/nuclear safety.\textsuperscript{53}

Prime Minister Manmohan Singh in his inaugural address in an international seminar\textsuperscript{54} at IDSA (New Delhi) said that India wants to enhance international nuclear security but it also maintain the objective of promoting safe and secure expansion of nuclear energy and other developmental benefits that nuclear science and technology offers us. Manmohan Singh, (Inaugural Address), ‘A Nuclear Weapon-Free World: From Conception to Reality’. He said we are targeting an expansion of our nuclear energy generation capacity to more than 62,000 megawatts by 2032.

\textbf{Thorium Based Reactors:} In reply to Question of Smt. Annu Tandon whether India is actively pursuing a research program for developing thorium-based reactors for generation of power and the vast reserves of thorium in Kerala is being considered as a national resource and adequately protected Minister of state Public Grievances and Pensions Sh. Narayan Swami replied: “\textit{Thorium plays a pivotal role in Indian Nuclear power program}”.\textsuperscript{55} Right from the inception of Indian nuclear power program, work has been carried out on various aspects of thorium utilization-mining and extraction of thorium, fuel fabrication, and irradiation in reactors, reprocessing and prefabrication. In

\textsuperscript{52}http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/India/
\textsuperscript{53}\textit{The Hindu}, New Delhi, September 08, 2011
\textsuperscript{55}\textit{LOK SABHA Debate}, UNSTARRED QUESTION NO.634, 20 Dec., 2013.
addition, studies have been carried out regarding use of thorium in different types of reactors.

**Details of Research Program:**

(i) Thorium fuel fabrication through powder pellet route has been well established. Few tons of fuel has been made for CIRUS and Dhruva, *Pressurized Heavy Water Reactor* (PHWR) and for blanket assemblies for *Fast Breeder Test Reactor* (FBTR). Few pins have been fabricated using mixed oxides of (Th-Pu) for irradiation in research reactors.

(ii) Thoria bundles are used in the initial cores of PHWR. The irradiation experience of thoria fuel in the research reactors CIRUS and Dhruva, PHWR and test irradiations are satisfactory.

(iii) The thoria pins of CIRUS have been reprocessed to obtain U233. The recovered U233 has been fabricated as fuel for KAMINI reactor at Kalpakkam. The Post Irradiation Examination of one of the thoria bundle irradiated in PHWR has also been carried out for validation of theoretical analyses.

(iv) Studies have been carried out regarding use of thorium in different types of reactors with respect to fuel management, reactor control and fuel utilization.

(v) A Critical Facility for Advanced Heavy Water Reactor has been commissioned in 2008 and is used for carrying out experiments to further validate the physics design features of Advanced Heavy Water Reactor.

(vi) A small research reactor KAMINI with 30 kWth capacity which utilises nuclear fuel based on Uranium-233 derived from irradiation of thorium, has been in operation at *Indira Gandhi Centre for Atomic Research*56 (IGCAR), Kalpakkam for Generation of power from Thorium:

- While it is true that Thorium can be used to produce nuclear energy, it should be noted that Thorium cannot be used directly. Thorium does not contain any fissile isotope, hence it cannot be used in a reactor alone. It can be used with added fissile material that

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56 *Annual Report, IGCAR, Department of Atomic Energy, Government of India, New Delhi, 2013-14.*
can be either enriched Uranium, Plutonium or Uranium-233 (obtained after irradiation of Thorium).

- Thorium absorbs the neutrons, which can more efficiently produce more Plutonium in Fast Breeder Reactor for a faster growth. Therefore, using Thorium in the first, ore in early part of second stage of nuclear power program will adversely affect the rate of growth of nuclear power generation capacity in the initial periods.

Due to these reasons, large scale deployment of Thorium is to be postponed till the later part of the second stage. Thorium is to be introduced only at an optimal point during operation of Fast Breeder Reactors in the second stage. Thorium, for power generation is to be used mainly in the third stage. The time taken for large scale thorium deployment is around 3 - 4 decades after the commercial operation of Fast Breeder Reactors with short doubling time. All efforts towards technology development and demonstration are made, so that a mature technology is available in time. The third stage of Indian nuclear power program contemplates making use of Uranium-233 to fuel Uranium-233 – Thorium based reactors, which can provide energy independence to the country for several centuries.

To accelerate thorium utilization, BARC has designed an **Advanced Heavy Water Reactor** (AHWR) to serve as a technology demonstrator. The 300 MW research reactor specially meant for demonstration of large scale commercial utilization of thorium, generating nearly 70 percent of its power from in-situ burn up of thorium. The design of all nuclear systems of the reactor has been completed and associated confirmatory R&D is in a very advanced stage. Detailed engineering is being carried out in consultancy mode.

Hence, Thorium a naturally occurring radioactive chemical element may play a pivotal role in Indian Nuclear power program. The Government has notified Thorium as Prescribed Substance under the Atomic Energy Act 1962. The Government has also notified Atomic Energy (Working of the Mines, Minerals and Handling of Prescribed Substances) Rules 1984 under which no person shall mine, mill, process and/or handle any ore mineral or other material from which any one or more of the Prescribed Substances can be extracted, without obtaining a license and except in accordance with the terms and conditions of such license.
**Nuclear Energy Expansion Plans:** The July 2005 Indo-U.S. Civil Nuclear Energy Statement was simply a statement of intent and accordingly, did not create any binding obligation on either of the two countries. It nevertheless, laid the framework for future negotiations.

**Map**

(Source: http://www.world-nuclear.org/info-country-profiles.)
Kundakulam Nuclear Power Plant (TamilNadu)

Jaitapur Nuclear Power Plant (Maharashtra)
The Statement, at least, made it sufficiently clear to India as to what would be the nature of its obligations if it wishes to end its ‘nuclear isolation’. In that sense the July 2005 Statement could be regarded as a signpost and a ‘soft’ legal instrument articulating certain intent expressed in terms of written commitments\(^{57}\). This document had only limited legal effects. Some of these intended obligations were the Separation Plan, Safeguards Agreement with IAEA, modalities concerning the reprocessing of spent fuel and implications arising out of testing of nuclear devices required reciprocal initiatives, though some were specific and definitive to India.

Now it is recognized that the civilian nuclear technology is well established in India and the primary issue in front of the government is to scale up the nuclear energy and increase the amount of electricity generated by the nuclear reactors. This has to be done by running the existing power at full capacity and building new reactors to increase the overall electricity generation. This calls for construction of newer power plants and for securing uninterrupted supply of nuclear fuel for the reactors.

To increase the nuclear power generation capacity, many international vendors have also started investing in India subsequent to the culmination of the Indo–U.S. Civilian Nuclear Agreement. For instance, Russia’s Atoms troy has agreed to build six more light water pressurized reactors in Kundakulam by 2017 and four in Haripura after 2017. Areva has signed a memorandum of understanding with NPCIL to build a total of the six *European Pressurised Reactors* (EPR). GE Hitachi Nuclear Energy has signed agreements with NPCIL and *Bharat Heavy Electricals* (BHEL) to build a multi–unit power plant using 1350 MWe *Advanced Boiling Water Reactors* (ABWR). Many other companies such as Atomic Energy of Canada Ltd. and Korean Electric Power Co. have also signed similar agreements with India regarding servicing India’s existing 10PHWRs.\(^{58}\)


As per the Department of Atomic Energy (DAE) targets, India is expected to generate 29,460 MWe by 2022. This target is too ambitious. That being said, the DAE sounds confident about achieving the target of 20,000 MWe. As per the DAE, “The target set by DAE of installing 20 GWe nuclear power by the year 2020 will be achieved. This target includes 2.5 GWe of Oxide fuelled FBRs [fast breeder reactors] and 8 GWe of LWRs (Light Water Reactors). R&D for using metal fuel in FBRs will be completed by the year 2020. Corresponding fuel cycle technologies will also be developed. Industrial capability to construct required numbers of FBRs of 1 GWe rating will be in place by the year 2021 and this capacity will be expanded subsequently.” It is noted by the DAE that if only the already negotiated 2 GWe LWRs are imported then the installed capacity in 2052 will be 208 GWe instead of 275 GWe.  

As on June 2014 India’s total installed electricity generation capacity is 2,22,541.71 MW. The share of nuclear power was 4780 MW, which with the linking of Kudankulam-1, VVER-1000, has gone up to 5,780 MW, which is less than three percent. Currently there are 21 reactors in operations in India. India has ambitious plan to raise the nuclear power generation capacity to 29 GWe by 2020, 63GWe by 2032 and 275GWe by2052.According to World Nuclear Association, 18 reactors are planned for expansion and about 39 energy parks are proposed. The Government of India has revised the nuclear energy targets as follows: the installed capacity of 10,080 Mw will be achieve by 2017 and 27480 will be achieved. This information was given to Indian Lok Sabha by Shri. V. Narayanswamy, Ministry of State in Ministry of Personnel, PG &Pensions, and PMO Office, Government of India, on August 9, 2012.

During the Twelfth Plan (2012-17) NPCIL has planned to initiate the development of several nuclear projects. These are: Eight indigenous PHWRs of

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700MWe each – Gorakhpur 1 and 2 (Haryana); Chutka 1 and 2 (Madhya Pradesh); Mahi Banswara 1 and 2 (Rajasthan); Kaiga 5 and 6 (Karnataka) and Eight Light Water Reactors, each of 1000MW or more with international cooperation—Kudankulam 3 and 4 (Tamil Nadu); Kovvada 1 and 2 (Andhra Pradesh); Jaitapur 1 and 2 (Maharashtra) and Chaya Mithi Virdi 1 and 2 (Gujarat). Two fast breeder reactors of 500 MW each – Kalpakam 1 and 2 (Tamil Nadu) and one advanced heavy water reactor of 300MW\textsuperscript{65}.

**Foreign Investment in India's Nuclear Energy Program:** India’s civilian nuclear program was largely indigenous for many years, but the government is now beckoning foreign investment. It intends to set up ‘nuclear parks’ supplied by foreign companies and operated - for now - by the NPCIL, a government-owned company. These ‘parks’ are planned to have installed generated capacity of 8,000-10,000 MW at a single site\textsuperscript{66}. As of now TAPS has the greatest installed capacity at one site is currently only 1,400 MW.

Russian company Atomstroyexport, a government subsidiary, has reached a deal to build sixteen nuclear reactors in India. From the two of these units, of 1000 MW each, one is operational and the other is currently under construction in Kundankulam, Tamil Nadu. French company AREVA NP (a joint venture between AREVA and Seimens) have agreed to construct six 1650 MW reactors in Jaitapur, Maharashtra. The European pressurised reactors, an untested type of reactor, will have a collective capacity of 9900 MW, making the Jaitapur nuclear power plant the largest in the world.

Apart from importing nuclear reactors with international cooperation, NPCIL is to develop nuclear reactors through joint venture companies with National Thermal Corporation Limited, The Indian Oil Corporation Limited and National Aluminum Company India. French company AREVA NP (a joint venture between AREVA and Seimens) have agreed to construct six 1650 MW reactors in Jaitapur, Maharashtra. The


European pressurised reactors, an untested type of reactor, will have a collective capacity of 9900 MW, making the Jaitapur nuclear power plant the largest in the world.

The DAE is closely working with the nuclear industry to develop an indigenous manufacturing base for nuclear components and equipment’s. These developmental plans are facing some challenges such as: issue of land acquisition; public non-acceptance; inadequate industrial capacity and capability.

One VVER-1000 MW at Kudankulam the power reactor has been connected with the Southern Grid, but still there are protests from the local population. Six (1,600x6 MW) European Pressurized Reactor (EPR) design reactors that are to be imported from France and are located to be in Jaitapur (Maharashtra) are still the targets of anti-nuclear protests. The high targets set by the government are sought to be achieved by indigenous technological development and by pursuing a three stage nuclear development plan and international nuclear cooperation, including the import of nuclear reactors. India needs to get a crucial technological breakthrough for the success of three-stage nuclear development program.

The technological progress in nuclear reactor construction and the advanced safety measures have made the nuclear power industry more attractive. The generation III and IV reactors offer better safety mechanisms than the older generation reactors. This would obliviously contribute the development of nuclear sector worldwide. In the coming years the advanced technology and its potential to offer is much safer operation of nuclear facilities. This is going to be a key factor in India’s industrial growth.

India’s technological advancement in the nuclear arena would determine its status as an advanced nuclear supplier state from that of a nuclear recipient state. The program is bold initiative by all standards as no country has experimented with it. Skepticism is always expressed about India’s Breeder program, because it has very little experience. India has been pioneering in the Thorium fuel cycle. Since there is hardly any country

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67 Ibid, P.94.
with such experience, so the question of international collaboration at this stage does not arise.

For the success of breeder reactors the fuel conversion ratio at present is higher than one. The breakeven occurs when the conversion ratio is exactly one. In commonly used Light Water Reactors the conversion ratio is approximately 0.6 and in Heavy Water reactor the ratio is 0.8. There is reluctance on the part of other countries to collaborate with India’s nuclear program, because of non-proliferation concerns. This is despite the conclusion of Indo-US civilian nuclear cooperation deal and the subsequent NSG waiver in October 2008.

Department of Atomic Energy and other entities such as NPCIL, are making renewed efforts to formulate an impressive plan for the development of nuclear energy in India. They are taking measures to inject transparency into the nuclear program so as to enhance mutual trust within the country and outside, which could lead to collaboration with other countries. The indigenous nuclear industry is facing some technological problems.

The government policy measures encouraging public-private participation in nuclear engineering would give desired boost to the nascent private nuclear engineering industry. Some Private players such Larson and Tubro, Walchand Industries Limited, Godrej and Avsaral Technologies Ltd. are already providing core components for the nuclear reactors. The further advancement on nuclear engineering and nuclear reactor manufacturing sector would enhance India’s international profile as a supplier of nuclear design, construction, operation, safety and related nuclear services. The DAE has plans for importing reactors from various advanced countries in addition to indigenous construction of new nuclear power plants. There are obstacles before DAE to achieve these high targets. The opposition from civil society, the technological hitches, safety and security of nuclear reactors are major constraints and these will be discussed in the last chapter of the thesis.

Nuclear power for civil use is well established in India and has been a priority since independence in 1947. In 1948 the Atomic Energy Act was passed, and the Atomic
energy Commission set up. Under it, the Department of Atomic Energy was created in 1954, when the country’s 3-stage plan for establishing nuclear power was first outlined. This plan first employs Pressurized Heavy-Water Reactors (PHWR) fuelled by natural uranium to generate electricity and produce plutonium as a by-product. Stage 2 uses fast breeder reactors burning the plutonium to breed U-233 from thorium. Stage 3 is to develop this and produce a surplus of fissile material.

India's civil nuclear strategy has been directed towards complete independence in the nuclear fuel cycle, necessary because it is excluded from the 1970 Nuclear Non-Proliferation Treaty (NPT) due to it acquiring nuclear weapons capability after 1970, five countries doing so before 1970 were accorded the status of Nuclear Weapons States under the NPT.

In May 1974 when India exploded its first nuclear device only 94 states had signed the NPT and fewer (79) had ratified it. This number of ratifying states has now gone to 190. After 1974 India was denied nuclear technology by the Western world. Post 1974, India has been considered a nuclear weapons-capable state – though its military nuclear program proceeded slowly in the ensuing years and only came fully out of the closet in 1998 when India conducted several nuclear explosive tests. The rationale for this isolation was largely coercive, to encourage signature of the NPT by India and the other 80+ states that were non-signatories in 1974. However, political support within India for its nuclear weapons program has been strong across the political spectrum, due to distrust of its neighbors China and Pakistan in particular, and this precluded any move to sign the NPT as a Non-Nuclear Weapons State – the only option open from NPT perspective.

The self-sufficiency engendered by this isolation extends from uranium exploration and mining through fuel fabrication, heavy water production, reactor design and construction, to reprocessing used fuel, and waste management. It has a small fast breeder reactor and is commissioning a much larger one. It is also developing technology to utilise its abundant resources of thorium as a nuclear fuel. It has 18 small and two mid-sized nuclear power reactors in commercial operation, plus one large on now operating. Five large reactors are under construction, and more are planned. In 2013 nuclear power
contributed 30 billion kWh of electricity – 3.4 Percent of total, and capacity had reached 5.3 GWe.

Now India have plans to install almost 15 GWe of nuclear capacity operating by 2020, and 25 percent nuclear contribution is foreseen by 2050. Led by the USA, India has entered in agreements with more than ten countries in bilateral nuclear agreements, which now allows it to import nuclear power plants, technology and uranium fuel. India has also become a partner in international nuclear commerce and has put itself under the international safeguards regime without having to sign the non-proliferation. These developments in various fields will certainly help India in increasing share of nuclear energy which will further help it ensuring energy security.