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    REVIEW OF LITERATURE
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    HYPOTHESES
    RESEARCH METHODOLOGY
    RESULTS & DISCUSSION
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ROLE OF NUCLEAR ENERGY IN INDIAN ECONOMY

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ABSTRACT

India has had a long commitment to nuclear energy since the establishment of the Atomic Energy Commission in 1948 and the Department of Atomic Energy in 1954. India was one of the few countries to achieve the complete fuel cycle – from uranium exploration, mining, fuel fabrication and electricity generation, to reprocessing and waste management – by the 1970s. (Sethna, 1979). The country's nuclear industry is viewed with strong pride and considered an instrument to achieve "energy independence," "fossil fuel frees future" or "self-sufficiency" (Kalam, 2011; Sethna, 1979). However, India's nuclear power capacity remains small despite continuous commitment and advances in indigenous technology. India's current nuclear generation capacity is 4.8 GW and ranks 13th in the world, which account for only 1.2% of global nuclear capacity (WNA, 2012). The share of nuclear was 1% in India's total energy mix in 2009 and 2% in electricity generation capacity in 2012 (Figure 31). This is the result of India's long isolation from the global nuclear energy regime and its emphasis on a thorium-based nuclear development programmer. Nuclear energy could play a critical role in addressing India's energy challenges, meeting massive energy demand potentials, mitigating carbon emissions and enhancing energy security through the reduction of dependence on foreign energy sources. This is why India remains devoted to nuclear power even after the Fukushima-Daiichi accident in 2011 (PMO, 2012). This chapter discusses India's policy framework for the nuclear sector, provides an overview of nuclear capacity and prospects and key issues.

KEYWORDS
Indian economy, nuclear energy.

INTRODUCTION

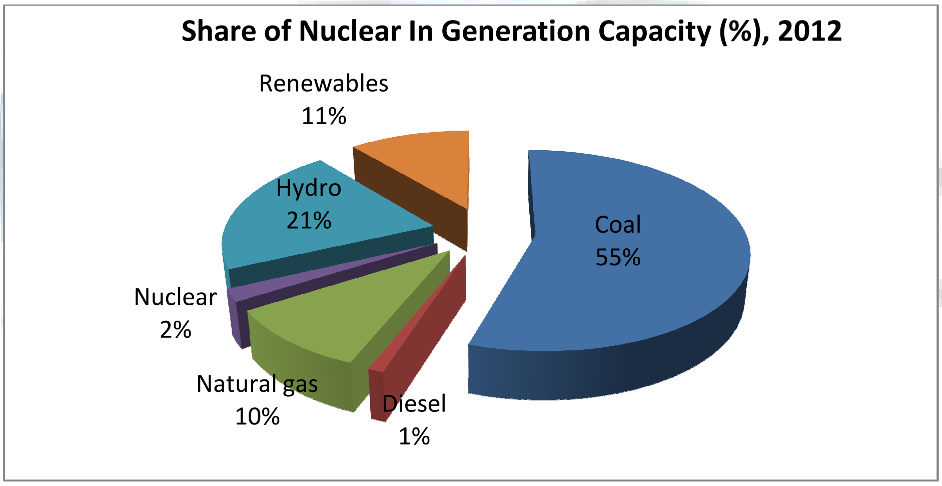
Nuclear power is the fourth-largest source of electricity in India after thermal, hydroelectric, and renewable sources of electricity. As of 2013, India has 21 nuclear reactors in operation in 7 nuclear power plants, having an installed capacity of 5780 MW and producing a total of 30,292.91 GWH of electricity while seven other reactors are under construction and are expected to generate an additional 6,100 MW.

In October 2010, India drew up "an ambitious plan to reach a nuclear power capacity of 63,000 MW in 2032",but, after the 2011 Fukushima nuclear disaster in Japan, "populations around proposed Indian NPP sites have launched protests, raising questions about atomic energy as a clean and safe alternative to fossil fuels".There have been mass protests against the French-backed 9900 MW Jaitapur nuclear power project in Maharashtra and the Russian-backed 2000 MW kudankulam nuclear power plant in Tamil Nadu. The state government of West Bengal state has also refused permission to a proposed 6000 MW facility near the town of Haripur that intended to host six Russian reactors. A Public Interest Litigation (PIL) has also been filed against the government's civil nuclear program me at the Supreme Court. Despite this opposition, the capacity factor of Indian reactors was at 79% in the year 2011-12 compared to 71% in 2010-11. Nine out of twenty Indian reactors recorded an unprecedented 97% capacity factor during 2011-12. With the imported uranium from France, the 220 MW Kakrapar 2 PHWR reactors recorded 99% capacity factor during 2011-12. The Availability factor for the year 2011-12 was at 89%.

India has been making advances in the field of thorium -based fuels, working to design and develop a prototype for an atomic reactor using thorium and low-enriched uranium, a key part of India's three stage nuclear power program me. The country has also recently re-initiated its involvement in the LENR research activities, in addition to supporting work done in the fusion power area through the ITER initiative.

India's and Asia's first nuclear reactor was the Apsara research reactor. Designed and built in India, with assistance and fuel from the United Kingdom, Apsara reached criticality on August 4, 1956 and was inaugurated on January 20, 1957. A further research nuclear reactor and its first nuclear power plant were built with assistance from Canada. The 40 MW research reactor agreements were signed in 1956, and achieved first criticality in 1960. This reactor was supplied to India on the assurance that it would not be used for military purposes, but without effective safeguards against such use. The agreement for India's first nuclear power plant at Rajasthan, RAPP-1, was signed in 1963, followed by RAPP-2 in 1966. These reactors contained rigid safeguards to ensure they would not be used for a military programmer. The 200 MWe RAPP-1 reactors were based on the reactor at Douglas point and began operation in 1972. Due to technical problems the reactor had to be downrated from 200 MW to 100 MW.[] The technical and design information were given free of charge by to India. The United States and Canada terminated their assistance after the detonation of India's first nuclear explosion in 1974.

DIAGRAM NO. 1



THREE-STAGE NUCLEAR POWER PROGRAMMED

India's three-stage nuclear programmer was approved by parliament in 1958 and developed by Dr. Homi Bhabha, the first Chairman of the Atomic Energy Commission, who is widely known as the father of India's nuclear programmer (Suryanarayan, 2010). The three-stage strategy aimed to utilize India's vast thorium reserves, an approach that is still valid today (NPCIL, 2008):

First stage: Pressurized Heavy Water Reactors (PHWRs), fuelled by natural uranium.

Second stage: Fast Breeder Reactors (FBRs) backed by reprocessing plants and plutonium based fuel fabrication plants, fuelled by mixed oxide of Uranium-238 and Plutonium-239. With sufficient inventory of plutonium, thorium can be converted to fissile isotope U-233.

Third stage: Thorium generated U-233 cycle using Advanced Heavy Water Reactor (AHWR), which generates a large amount of energy.

India has so far reached the commercial maturity of the first stage and is moving into the second stage (NPCIL, 2008). The country's first-of-its-kind 500 MWe prototype Fast Breeder Reactor (PFBR), which was scheduled for completion in 2011, is under construction at Kalpakkam, Tamil Nadu and expected to start operation by early 2013 (Raj, 2009; DAE, 2012a; ET, 2012c). Nuclear capacity is envisioned to reach 20 GW by 2020. India also aims to develop a thorium-based demonstration plant and a full prototype before 2050.

INDIA'S ENERGY DEMAND OUTLOOK

The demand for energy increases with increase in population base, and change in livelihood and lifestyle needs. In India, the energy demand has increased over six fold over the last five 4 decades, whereas the population has increased by 2.7 times. Table 1 provides the energy demand met by different energy sources (Planning Commission, 2012). While total energydemand registered an average annual growth rate of 3.67% between 1990–91 and 2011–12, the commercial energy demand grew at the rate of 4.93% indicating of a declining growth rate for noncommercial energy sources. The share of oil has remained around one-third of the commercial fuel since 1970. The share of natural gas has increased from 1% in 1970–1 to 8.8% in 2011–12 while that of other renewable sources like solar, wind, small hydro, hydrogen, geothermal forms is below 1% of the total primary energy demand.

TABLE 1: PRIMARY ENERGY DEMAND IN INDIA (MTOE)

Type of carriers	1960-61	1970-71	1980-81	1990-91	2000-01	2006-07	2011-12
Coala	35.7 (79.9)	37.3 (62.3)	58.2 (60.2)	97.7 (55.9)	138.0 (49.1)	208.7 (53.3)	283 (51.8)
Oila	8.3 (18.6)	19.1 (32.0)	32.3 (33.4)	57.8 (33.1)	107.0 (38.1)	132.8 (33.9)	186 (34.1)
Natural gasa	0.0 (0.0)	0.6 (1.0)	1.41 (1.5)	11.5 (6.6)	25.1 (8.9)	34.6 (8.8)	48 (8.8)
Hydroa	0.7 (1.5)	2.2 (3.6)	4.0 (4.1)	6.2 (3.6)	6.4 (2.3)	9.8 (2.5)	12 (2.2)
Nucleara	0.0 (0.0)	0.6 (1.1)	0.8 (0.8)	1.6 (0.9)	4.41 (1.6)	4.86 (1.2)	17 (3.1)
Total Commercialb	42.8 (36.5)	60.3 (41.0)	99.8 (47.9)	181.1 (59.7)	296.1 (68.4)	391.5 (72.6)	546 (76.4)
Non-Commercialb	74.4 (63.5)	86.7 (59.0)	108.5 (52.1)	122.1 (40.3)	136.7 (31.6)	147.6 (27.4)	169 (23.6)
Total	117.2	147.1	208.3	303.2	432.8	539.1	715

Source: Planning Commission (2012)

Notes: a The number in the bracket shows the percentage with respect to total commercial fuels

b The number in the bracket shows the percentage with respect to total fuels

NUCLEAR POWER GROWTH IN INDIA

India now envisages increasing the contribution of nuclear power to overall electricity generation capacity from 2.8% to 9% within 25 years. By 2020, India's installed nuclear power generation capacity will increase to 20,000 MW (2.0×1010 Watts, which is 20 GW). As of 2009, India stands 9th in the world in terms of number of operational nuclear power reactors. Indigenous atomic reactors include TAPS-3, and -4, both of which are 540 MW reactors. India's US$717 million fast breeder reactor project is expected to be operational by 2012–13.

The Indian nuclear power industry is expected to undergo a significant expansion in the coming years, in part due to the passing of the U.S. India Civil Nuclear Agreement is agreement will allow India to carry out trade of nuclear fuel and technologies with other countries and significantly enhance its power generation capacity. When the agreement goes through, India is expected to generate an additional 25,000 MW of nuclear power by 2020, bringing total estimated nuclear power generation to 45,000 MW.

Risks related to nuclear power generation and prompted Indian legislators to enact the 2010Nuclear Liability Act which stipulates that nuclear suppliers, contractors and operators must bear financial responsibility in case of an accident. The legislation addresses key issues such as nuclear radiation and safety regulations, operational control and maintenance management of nuclear power plants, compensation in the event of a radiation-leak accident, disaster clean-up costs, operator responsibility and supplier liability. A nuclear accident like the 2011 Fukushima Daiichi nuclear disaster would have dire economic consequences in heavily populated India as did the 1984 Union Carbide Bhopal disaster, the world's worst industrial disaster, covered extensively in Dominique Lapierre's 2009 prize winning book *Five Past Midnight in Bhopal*.

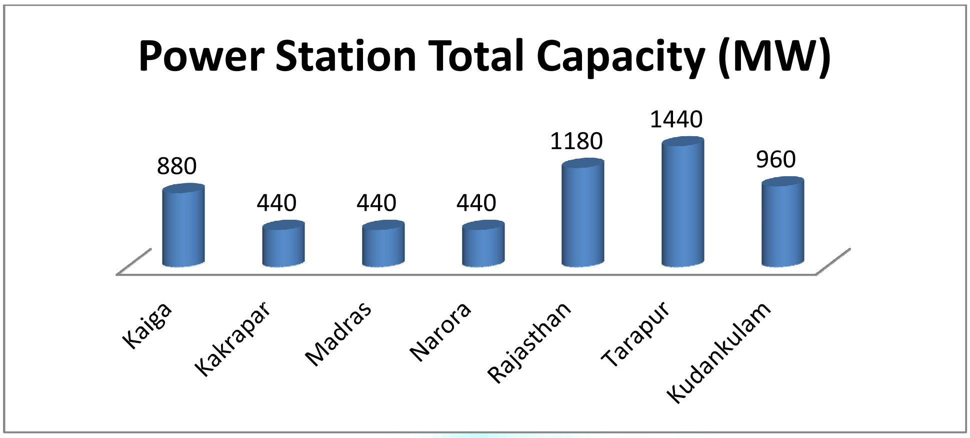
India has already been using imported enriched uranium for light-water reactors that are currently under IAEA safeguards, but it has developed other aspects of the nuclear fuel cycle to support its reactors. Development of select technologies has been strongly affected by limited imports. Use of heavy water reactors has been particularly attractive for the nation because it allows Uranium to be burnt with little to no enrichment capabilities. India has also done a great amount of work in the development of a thorium centered fuel cycle. While uranium deposits in the nation are limited there are much greater reserves of thorium and it could provide hundreds of times the energy with the same mass of fuel. The fact that thorium can theoretically be utilised in heavy water reactors has tied the development of the two. A prototype reactor that would burn Uranium-Plutonium fuel while irradiating a thorium blanket is under construction at Kalpakkam by BHAVINI - another public sector enterprise like NPCIL

Uranium used for the weapons programmer has been separated from the power programmer, using uranium from indigenous reserves. This domestic reserve of 80,000 to 112,000 tons of uranium (approx 1% of global uranium reserves) is large enough to supply all of India's commercial and military reactors as well as supply all the needs of India's nuclear weapons arsenal. Currently, India's nuclear power reactors consume, at most, 478 tones of uranium per year. Even if India were quadruple its nuclear power output (and reactor base) to 20 GW by 2020, nuclear power generation would only consume 2000 tones of uranium per annum. Based on India's known commercially viable reserves of 80,000 to 112,000 tons of uranium, this represents a 40–50 years uranium supply for India's nuclear power reactors (note with reprocessing and breeder reactor technology, this supply could be stretched out many times over). Furthermore, the uranium requirements of India's Nuclear Arsenal are only a fifteenth (1/15) of that required for power generation (approx. 32 tonnes), meaning that India's domestic fissile material supply is more than enough to meet all needs for it strategic nuclear arsenal. Therefore, India has sufficient uranium resources to meet its strategic and power requirements for the foreseeable future.

Former Indian President A.P.J.Abdul Kalam, stated while he was in office, that "energy independence is India's first and highest priority. India has to go for nuclear power generation in a big way using thorium based reactors. Thorium, a non fissile material is available in abundance in our country." India has vast thorium reserves and quite limited uranium reserves.

The long-term goal of India's nuclear program has been to develop an advanced heavy water thorium cycle. The first stage of this employs the pressurized heavy water reactors (PHWR) fueled by natural uranium and light water reactors, which produce plutonium incidentally to their prime purpose of electricity generation. The second stage uses fast neutron reactors burning the plutonium with the blanket around the core having uranium as well as thorium, so that further plutonium (ideally high-fissile Pu) is produced as well as U-233. The Atomic and Molecular Data Unit (AMD) has identified almost 12 million tonnes of monazite resources (typically with 6-7% thorium). In stage 3, Advanced Heavy Water Reactors (AHWR) would burn thorium-plutonium fuels in such a manner that breeds U-233 which can eventually be used as a self-sustaining fissile driver for a fleet of breeding AHWRs. An alternative stage 3 is molten salt breeder reactors (MSBR), which are believed to be another possible option for eventual large-scale deployment. On 7 June 2014, Kudankulam-1 became the single largest power generating unit in India (1000 MWe). Currently, twenty-one nuclear power reactors have a total install capacity of 5,780.00 MW (3.5% of total installed base).

DIAGRAM NO. 2

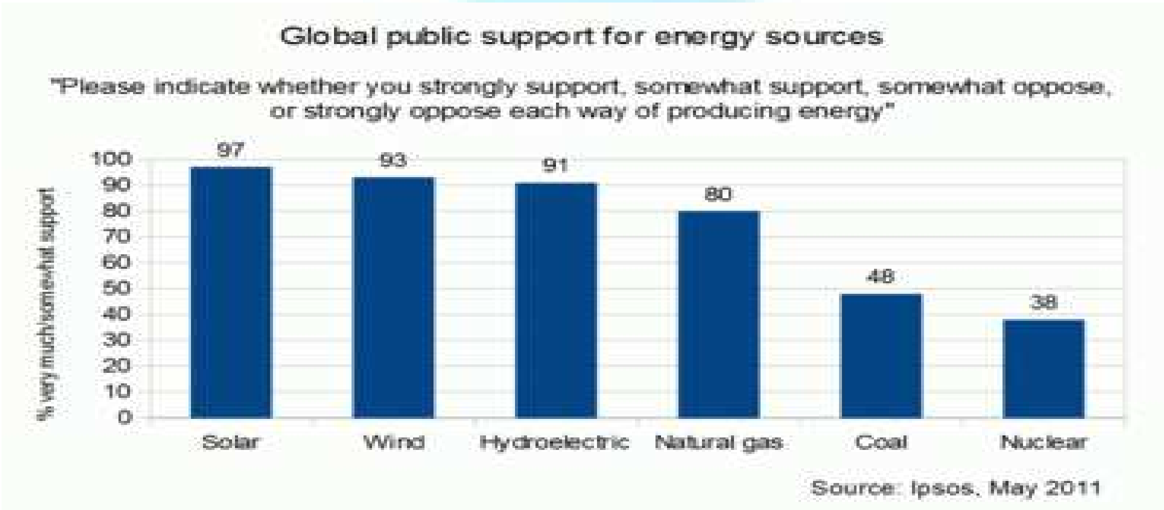


The details of the nuclear power generation capacity in the country are given below

TABLE NO. 1

Year	Total nuclear electricity generation	Capacity factor
2008–09	14,921GW.h	50%
2009–10	18,798GW·h	61%
2010–11	26,472GW·h	71%
2011–12	32,455GW·h	79%
2012–13	32,863GW·h	80%
2013-14	35333 GW-h	83%

DIAGRAM NO. 3



Following the March 2011 Fukushima nuclear disaster in Japan, populations around proposed Indian NPP sites have launched protests that had found resonance around the country. There have been mass protests against the French-backed 9900 MW Jaitapur Nuclear Power Project in Maharashtra and the Russian-backed 2000 MW Koodankulam Nuclear Power Plant in Tamil Nadu. The Government of West Bengal refused permission to a proposed 6000 MW facility near the town of Haripur that intended to host 6 Russian reactors. But that now is disputed: it's possible for Bengal to have its first nuclear power plant at Haripur despite resistance. A Public Interest litigation (PIL) has also been filed against the government's civil nuclear programme at theSupreme Court. The PIL specifically asks for the "staying of all proposed nuclear power plants till satisfactory safety measures and cost-benefit analyses are completed by independent agencies". But the Supreme Court said it was not an expert in the nuclear field to issue a direction to the government on the nuclear liability issue.

Nuclear power is already economically competitive with coal-thermal away from coal pitheads. But with increase in unit-capacity size, reduction in project gestation periods and safe and higher operation levels, it is our end eavour to make it competitive with coal-thermal even at coal pithead. This will open new business avenues at new locations for NPCIL. It also implies that nuclear power will emerge as one of the cheapest sources of electricity in the regions, which are away from coal-belts. The uniqueness of this programme is derived from the concept of the 3-stage nuclear power programme propounded by Dr. Bhabha...... Utilisation of abundant thorium resources in combination with moderate uranium resources through a 3-stage nuclear power programme for India was also outlined. The 3-stage nuclear power programme essentially links the fuel cycles of each stage in a manner that multiplies the potential of nuclear fuel several-hundred folds. A major challenge before the nuclear establishment in India in the early days was to develop an indigenous industry capable of meeting the requirements of the nuclear power industry.

CONCLUSIONS

Nuclear power is already economically competitive with coal-thermal away from coal pitheads. But with increase in unit-capacity size, reduction in project gestation periods and safe and higher operation levels, it is our Endeavour to make it competitive with coal-thermal even at coal pithead. This will open new business avenues at new locations for NPCIL. It also implies that nuclear power will emerge as one of the cheapest sources of electricity in the regions, which are away from coal-belts. The uniqueness of this programmer is derived from the concept of the 3-stage nuclear power programmer propounded by Dr. Bhabha...... Utilization of abundant thorium resources in combination with moderate uranium resources through a 3-stage nuclear power programmer for India was also outlined. The 3-stage nuclear power programmer essentially links the fuel cycles of each stage in a manner that multiplies the potential of nuclear fuel several-hundred folds. A major challenge before the nuclear establishment in India in the early days was to develop an indigenous industry capable of meeting the requirements of the nuclear power industry. Under the climate regime India's energy sector faces a difficult challenge. On one hand, the country needs to expand its energy base to sustain growth, make energy reach the deprived, while, on the other hand, energy course needs to follow an efficient and low-carbon path. In this paper, we tried to map these twin objectives through a sustainable development strategy. We have forecast future demand for different energy carriers under two scenarios: baseline and low carbon future (LC). The important factors influencing energy demand are GDP, population, urbanization, resource availability, and diversification of energy supply, efficiencies in generation, transmission and utilization, growth of vehicles and appliances, and modal shift in transportation. Through a mathematical model, the growth rates for different energy carriers are estimated and the demand projections are made. The diversification of India's current energy mix, which is dominated by coal, is necessary if India is to increase its economic growth rate and at the same time constructively contribute towards reducing climate change. Therefore, it becomes necessary for India to reduce its coal and other fossil fuel consumption and consider other alternatives that do not emit as much greenhouse gases as do fossil fuels. At the same time, India needs to make sure that it employs sustainable energy sources which do not jeopardise its energy supply and therefore its economic growth. The country finds itself in a position where it has to constantly negotiate between sustained economic growth and reducing its carbon emission. Therefore, nuclear energy proves to be a viable option as it is a tried and tested technology and India has developed nuclear technology over the years and has a matured nuclear industry. Nuclear energy is therefore a sustainable source of energy and would significantly reduce total carbon emissions from India. Another reason why nuclear energy proves to be a viable option for India is because India will continue to develop its civilian nuclear industry with indigenous efforts and from foreign investments made possible by the Indo–U.S. Civilian Nuclear Agreement. While significant contribution from nuclear energy towards the total energy needs of India in the short term (within the next decade) is suspect, it holds good promise in the long run, once the construction of the reactors is complete and they become operational. In sum, prospects of nuclear energy in India are bright, but that is in the long run. The benefits of the nuclear deal coupled with a mature and well established nuclear sector in India suggests that nuclear energy has the potential to be a major source of electricity in future. India must continue to develop its fast breeder reactors regardless of the US nuclear deal to be at the forefront of technology development and to safeguard the country's strategic interests. Fast breeder reactors have the capability to produce more fuel by reprocessing spent fuel. This provides a multiplier effect which increases the amount of fuel available, and hence provides more fuel for the same amount of money spent. The fuel increases by a certain breeding rate each year. As per the DAE, the breeding rate is 8.1 per cent a year. Research and Development (R&D) activities in the area of thorium-uranium-233 cycle must be pursued as not only is thorium a clean source of energy, but it is also found in abundance in India, which would make India resource independent. Nuclear energy can be used to run water desalination plants which can convert sea water into potable drinking water. This would help in increasing the supply of drinking water. Desalination plants can be used to pump in fresh water to replenish the ground water table which can have healthy ecological implications. In the long term, India will benefit by employing nuclear energy as a source of electricity generation. Increasing environmental pressures will make it difficult for India to continue with the use of fossil fuels at existing levels in the future. While domestic nuclear ore is of low grade, and hence expensive to utilise, the Indo–U.S. Civilian Nuclear Agreement helps India to import nuclear fuel which would reduce fuel costs and hence the cost of nuclear power generation. The three-stage nuclear programme was set up which ultimately aims at developing technology which will enable India to utilise its thorium resources to generate energy. Thorium has the prospects of being a significant source of energy in the long term (perhaps 2050 and beyond).

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