Nuclear Power –An alternative

Dr. S.K.Jain
Chairman & Managing Director
Nuclear Power Corporation of India Limited
&
Bharatiya Nabhikiya Vidyut Nigam Limited

Promotion of scientific environment in India

This year happens to be the centenary of Dr. Homi Jehangir Bhabha, .the founder of Atomic energy programme in India, who drew the road map of nuclear power programme which brought the country in the elite club of nations possessing advanced nuclear technology. Thus, this is an appropriate time to look back on the evolution of nuclear power in the country and assess its current status, future opportunities and associated challenges. It is also the time to remember the contributions of great personalities like JRD Tata who scripted the scientific destiny of the country.

The JRD Tata unparalleled contribution to the Indian industry and thus the country cannot be undermined. Apart from setting up many industries, hospitals, centres for arts etc., the Tatas' contributed in a big way in developing a scientific temper with a spirit of enquiry in the country by establishing institutions for science, education and research, starting with the Institute of Science, set up at Bangalore.

It was JRD Tata, in response to Dr. Bhabha's communication expressing his desire "to stay in one's own country and build up schools comparable to those in other lands" advised him to approach the Sir Dorab Tata Trust. On JRD's advise Dr Bhabha wrote to the Sir Dorab Trust in this regard in 1944 and the rest, is history. The Tata Institute of Fundamental Research was set up with the funds provided by Sir Dorab Trust.

Genesis of Atomic Energy in India

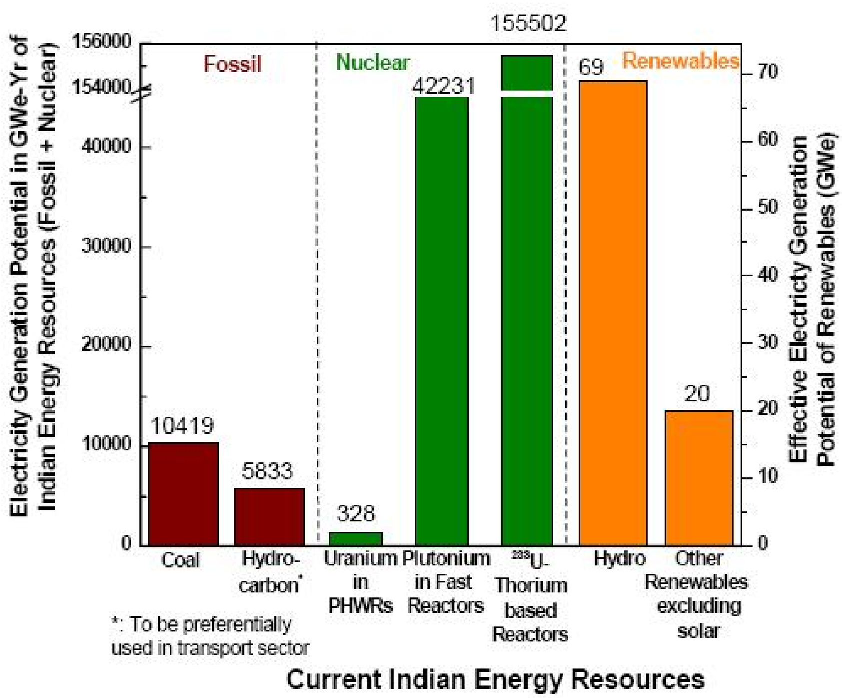
After India attained independence, in 1947, the Atomic Energy Commission was set up in 1948 for framing policies in respect of development of atomic energy in the country. The Department of Atomic Energy was established in 1954 with Dr. Bhabha as Secretary to implement the policies framed by the Atomic Energy Commission. Sir J.R.D Tata was one of the longest serving members in the Atomic Energy Commission and played a significant role in shaping the policies related to atomic energy program in the country.

The atomic energy program, which was initiated in a modest manner initially, has now grown as a wide spectrum, multi dimensional multidisciplinary with 63 organizations under DAE. The spectrum of these significant activities include R&D in Nuclear Sciences and Engineering, Exploration & Mining of Radioisotopes, Nuclear energy development and implementation, application of Nuclear Energy, Bio-Agricultural Research, Medical Sciences etc.

Atomic energy activities in the country are governed by the Atomic Energy Act. The commercial nuclear power program of the first stage (comprising of PHWRs and imported LWRs) is being implemented by Nuclear Power Corporation of India Limited (NPCIL), and the second stage (comprising of Fast Breeder Reactors) by Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), both companies owned fully by the union government in accordance with the provisions of the act.

In India, nuclear energy development began with the objectives of peaceful uses of atomic energy in improving the quality of life of the people and to achieve self-reliance in meeting the energy needs. The commercial Nuclear Power program, started in 1969 with the operation of TAPS 1&2 (BWR), currently shares about 3% country's installed capacity. Thus playing a complementary role in meeting the country's energy demand. However, in long term, it is expected to play a significant role in meeting the huge electricity demand of the country.

Incidentally, India is not a very energy resource rich country. Currently, the India's energy resource base status suggests the optimal mix of all the available energy resources to meet its growing demand of electricity which is projected to be about 800GWe by 2032 and 1300GWe by 2050.



Indian Nuclear Power Program

The Indian nuclear programme was conceived based on, unique sequential three-stages and associated technologies essentially to aim at optimum utilization of the indigenous nuclear resource profile of modest Uranium and abundant Thorium resources. This sequential three-stage program is based on a closed fuel cycle, where the spent fuel of one stage is reprocessed to produce fuel for the next stage. The closed fuel cycle thus multiplies manifold the energy potential of the fuel and greatly reduces the quantity of waste generated.

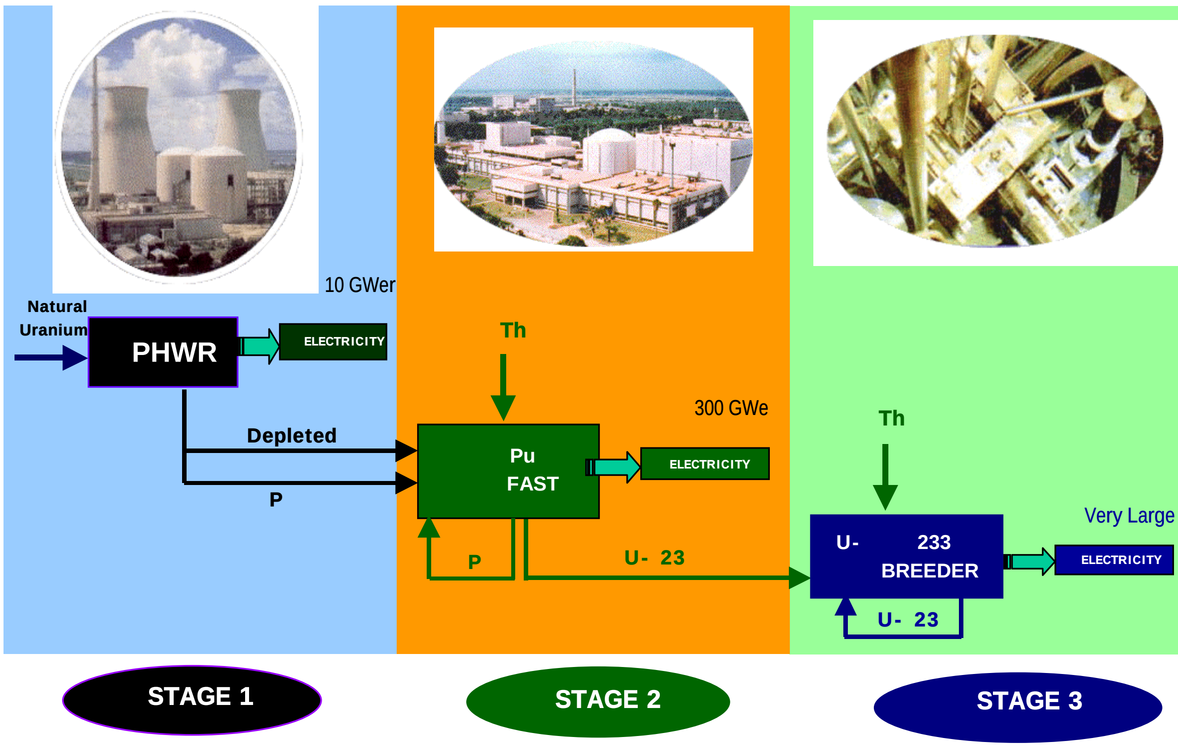
The first stage comprises of Pressurized Heavy Water Reactors fuelled by natural uranium. Natural uranium contains only 0.7% of Uranium235, which undergoes fission to release energy (200Mev/atom). The remaining 99.3% comprises Uranium238 which is not fissile however it is converted in the nuclear reactor, to fissile element Pu 239. In the fission process, among other fission products, a small quantity of Plutonium239 is formed by transmutation of Uranium238.

The second stage, comprising of Fast Breeder Reactors (FBRs) are fuelled by mixed oxide of Uranium238 and Plutonium239, recovered by reprocessing of the first stage spent fuel. In FBRs, Plutonium239 undergoes fission producing energy, and producing Plutonium239 by transmutation of Uranium238. Thus the FBRs produce energy and fuel, hence termed Breeders. FBRs produce more fuel than they consume. Over a period of time, Plutonium inventory can be built up by feeding Uranium238.

Thorium232, which constitutes world's third largest reserves in India, is not fissile therefore needs to be converted to a fissile material, Uranium233, by transmutation in a fast breeder reactor. This is to be achieved through second stage of the program, consisting of commercial operation of Fast Breeder Reactors (FBRs).

In the second stage, once sufficient inventory of Plutonium239 is built up, Thorium232 will be introduced as a blanket material to be converted to Uranium233.

Three-Stage Nuclear Power Program



Considering the sequential nature of the indigenous nuclear power program, and the lead time involved at each stage, it is expected that appreciable time will be taken for direct thorium utilization. Therefore, innovative design of reactors for direct use of thorium is also in progress in parallel to three stage program. In this context, the frontier technologies being developed include the Accelerator Driven Systems (ADS) and Advanced Heavy Water Reactor (AHWR). The ADS essentially is a sub-critical system using high-energy particles for fission. One of the significant advantages of this system is small quantity of waste production. The quantity of waste in this system is greatly reduced in comparison to the existing reactors as Actinides produced in ADS are `burnt' out.

The AHWR is another innovative concept, which will act as a bridge between the first and third stage essentially to advance thorium utilization without undergoing second stage of the three stage program. It uses light water as coolant and heavy water as moderator. It is fuelled by a mixture of Plutonium^{239} and Thorium^{232}, with a sizeable amount of power coming from Thorium^{232}.

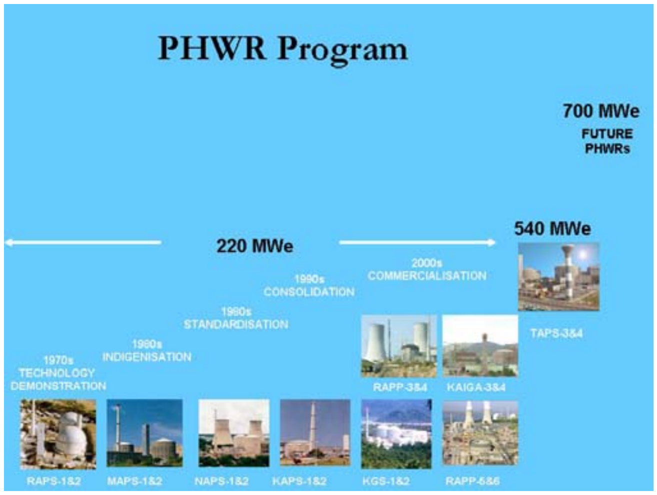
India is also an active partner in the international experimental initiative on harnessing fusion power for the future, the ITER project. India is supplying several components for this experimental reactor.

Additionalities to the Indigeneous three-stage program

For faster nuclear power capacity addition, in parallel to the indigenous three-stage program, additionalities based on imports have been introduced. Two Light Water Reactors (LWRs) of 1000 MWe each are under construction at Kudankulam in technical cooperation with the Russian Federation. As capacity addition through the indigenous route is guided by the fuel cycle linkages of the sequential three-stage program, faster capacity addition in the near term to meet the electricity needs of the country will be possible through these additionalities.

Current Status

The first stage consisting of pressurized Heavy Water Reactors (pHWR) has reached a state of commercial maturity and the second stage of Fast Breeder Reactors (FBRs) has been commercially launched with the construction of 500Mwe Fast Breeder Reactor (FBR) at Kalpakkam. The third stage systems (using U^{233} – $Thorium^{232}$ obtained from spent fuel of second stage) have been developed at pilot scale. The development of commercial technology of third stage is under way currently. However, the commercial deployment of this technology is expected to take appreciable time.



Challenges faced

Development of technology

The first stage program went through stages of technology demonstration, indigenization, standardization, consolidation and finally commercialization.

While the first stage began with 220 MWe reactors supplied by AECL, Canada, the subsequent pHWRs have all been indigenous. The Canadian assistance was withdrawn in 1974, even as the second unit of Rajasthan was under construction. It brought an international technology denial regime and isolation of the country from the rest of the world. Under such difficult and challenging circumstances, the Indian scientists and engineers rose to the occasion and with their untiring and innovative efforts, not only RAPS –1 but the design, construction and commissioning of the other unit too (RAPS-2) could be successfully completed.

Subsequently, MAPS units 1&2 were designed, constructed and commissioned with indigenous efforts. The design of 220 MWe PHWRs was standardized, and NAPS 1&2 & KAPS 1&2 set up. Kaiga 1&2 and RAPS 3&4 were also set up with further improvements in design. The standard 220Mwe design was scaled up to 540 MWe and TAPP 3&4 (2x540Mwe) have been set up. The 700 MWe PHWR design, using the same core of 540MWe, has been developed and construction of eight such reactors is planned to be taken up in the XI Plan (2007-12).

The country has developed comprehensive capabilities in all aspects of nuclear power from siting, design, construction, operation of nuclear power plants. Comprehensive multidimensional R&D facilities have been set up. Capabilities have also been developed in front and back ends of the fuel cycle, from mining, fuel fabrication, storage of spent fuel, reprocessing and waste management. Infrastructure for other inputs heavy water, zirconium components, control and instrumentation etc. has been established.

Excellent Human Resource and training infrastructure has been developed for the specialized skills needed for nuclear power.

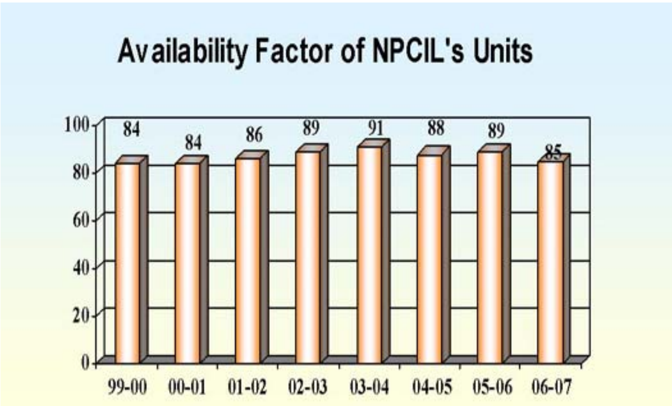
At present 17 reactors with a capacity of 4120 MWe are in operation and six with a capacity of 3160 MWe are under construction.

Development of Indian Industry.

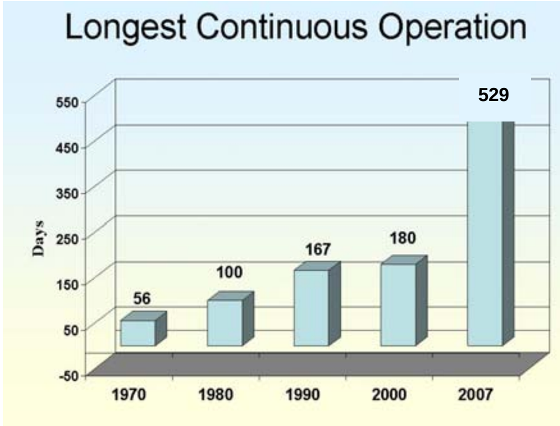
At the time of country's independence in 1947 and for several years thereafter, the industry's capability was limited to manufacturing and supply of equipment for cement and sugar industry. The Indian industry exposure, manufacturing and supply of equipment for high technology requirements was quite limited. Whereas other developed countries at that time had well established industrial infrastructure and capability to manufacture equipment for defence and aviation industry. The nuclear industry development in those countries was a spin-off of the well established industry. The Indian industry development was initiated and achieved maturity with the development of nuclear technology. Large efforts have been put by DAE and NPCIL to develop the Indian industry to achieve high standards in manufacturing of equipment for nuclear power technology. Currently, the Indian Industry capability in design, engineering and manufacturing of equipment is comparable to the international standards.

Achievements in Nuclear Power Technology

Nuclear Power plants have registered high availability factor, safety performance and longest continuous operation comparable to international standards. The performance of the operating plants is depicted in the figures below:



Availability Factors NPPs in India



Continuous Run

The Indian nuclear power plants have also performed at par with international benchmarks. Figure below depicts the performance of NPCIL units vis-à-vis others worldwide:

The performance of Indian nuclear power reactors in terms of safety has been excellent, with 282 reactor years of safe, accident free operation. The releases to the environment have been a small fraction of the limit prescribed by the Atomic Energy Regulatory Board (AERB).

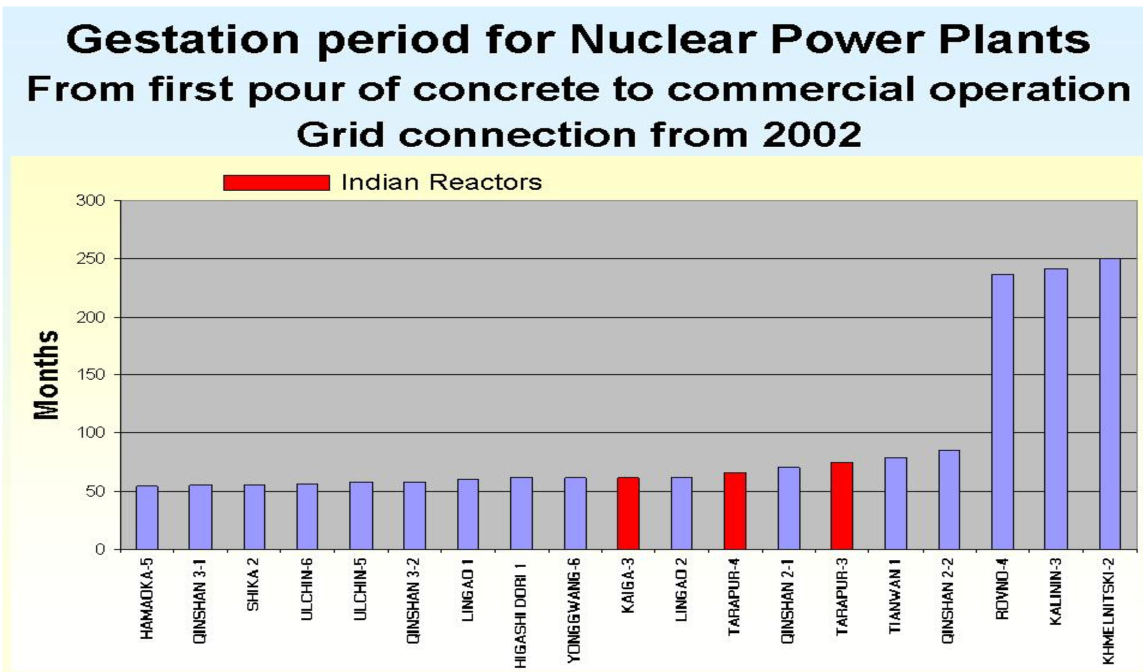
Developments in Renovation and Modernization

NPCIL has developed and carried out unique R&M activities in its stations, namely Enmasse Coolant Channel Replacement (EMCCR) which has been successfully carried out at four reactors (Rajasthan Atomic Power Station –2, Madras Atomic Power Station 1&2 & Narora Atomic Power Station -1) with indigenous technology. En masse Feeder Replacement (EMFR) was carried out for the first time in the world in a PHWR at MAPS-1. It has been carried out subsequently at Narora Atomic Power Station-1 & is presently underway at RAPS-2.

The health assessment of Tarapur Unit #1&2 has been carried out using the latest and advanced techniques. Based on these studies, the plant life has been extended by replacing the important equipment/components. This includes replacement of Secondary Steam Generators (SSGs). In addition to this, safety upgradation of the units have also been completed successfully. The Tarapur units after renovation and modernization are operating with availability Factors near 100%.

Project Execution

NPCIL has mastered and re-engineered the Nuclear Power Projects execution methodology and strategies and achieved reduction in gestation period. The construction and commissioning of TAPS 3&4 and Kaiga-3 in 5 years with substantial cost savings further endorses this. The following figure indicates the gestation time achieved in construction of nuclear power reactors in India is comparable to international standards.



Construction Performance

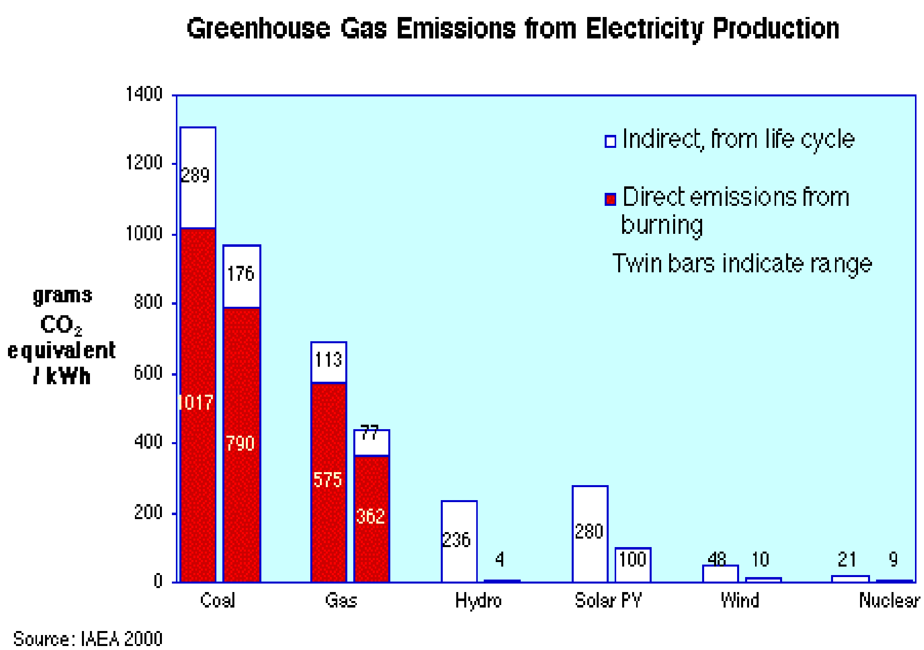
Tariffs and Costs of nuclear power

The nuclear power tariffs are competitive with those of thermal power stations located away from coal pitheads. The tariffs of one station TAPS 1&2 is 94 paise/kWh and that of three stations – MAPS, NAPS, KAPS about Rs.2. In the year 2007-08 the average tariff of nuclear power stations was Rs.2.28. The tariffs of new plants to be set up, both indigenous and imported, is expected to be about Rs. 2.50 in the year 2015 (at 2007 prices).

As far as the costs of Indian PHWRs are concerned, the overnight costs of 220 MWe reactors at 2007 prices have been in the range of Rs. 6.2 to 6.5 crore/MWe, while that of 540 MWe reactors has been about Rs. 6.0 crore/MWe at 2007 prices. The overnight cost of the 700 MWe reactors to be set up is estimated to be about of Rs. 5.4 crore/MWe (excluding finance cost and escalation), which is comparable to other reactors in the world.

Nuclear power in India has thus evolved into an economically competitive option for electricity generation.

Nuclear Power – Decarburizing the environment



Climate change arising out of Green House Gas Emissions is among the most important challenges facing the world today. The effects of climate changes are expected to be catastrophic, with crop losses, sea-level rise, extreme weather events and other losses predicted by various models. Nuclear power is environmentally benign and the life cycle Greenhouse Gas emissions of nuclear power are comparable to that of wind and solar photo-voltaic power. Nuclear power thus contribute significantly in decarburizing the power sector and arresting climatic changes.

Nuclear power, being a compact source of energy requiring lower quantities of fuel in comparison to coal based thermal power station. Therefore, the transport infrastructure needed for nuclear fuel is very small. 10,000 MWe nuclear power capacity needs only about 300-350 tons of fuel per annum, as against 35-50 million tons of coal needed for a coal fired thermal power station of the same capacity. It works to about a shipload or 20 trainloads per day. The pressure on rail, port and other infrastructure will be immense when large thermal capacity is added, apart from emissions arising out of transporting such large quantities of coal.

Future Plans

Future Plans and Projections

DAE/NPCIL vision is to achieve 20,000 MWe by the year 2020. The XI Plan proposals envisage setting up of 8 indigenously designed 700 MWe PHWRs, and 10

Light water Reactors of about 1000 MWe each, based on imports. In addition pre-project activities for setting up of 4 FBRs and an Advanced Heavy Water Reactor (AHWR) are also planned to be taken up in the XI Plan (2007-2012). The 4 FBRs will be taken up in the XII Plan (2012-2017). Larger capacity Nuclear Power Plants can be set up based on imports, subject to developments on international cooperation.

The possible nuclear power capacity beyond 2020 has been estimated by Department of Atomic Energy (DAE) is shown in the table. In energy terms, the Integrated Energy Policy of India estimates share of nuclear power in the total primary energy mix to be between 4.0 to 6.4% in various scenarios in the year 2031-32. The study by the Department of Atomic Energy (DAE), estimates the nuclear share to be about 8.6% by the year 2032 and 16.6% by the year 2052.

Year	Capacity (GWe)	
	Pessimistic	Optimistic
2030	48	63
2040	104	131
2040	208	275

Conclusions & Road Ahead

Indian Nuclear power program, visualized by Dr. Bhabha in early fifties has been developed and successfully deployed with indigenous efforts. Thus, placing the country in elite club of countries possessing advanced Nuclear technology. The evolution and development of commercial Nuclear technology in the country has passed through several technological revolutions.

While developing and implementing the nuclear power program, the Indian industry capability in manufacturing and supply of high precision and specialized equipment has also been developed comparable to international standards.

The nuclear power has come of age with comprehensive capabilities in all aspects of nuclear power and is poised for a large expansion program. The challenge is to pursue the three-stage program, develop and commercially deploy technologies for utilization of thorium and ensure the country's long term energy security.

The fruition of international cooperation will open up a plethora of opportunities in export of nuclear goods, equipment and services. The Indian nuclear power sector and industry needs to evolve faster to meet the associated challenges.

Acknowledgements

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