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WHY NUCLEAR POWER — THE INDIAN CONTEXT

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Abstract

India has made tremendous achievements in increasing electricity generating capacity since independence 50 years ago. The growth rate of electricity production has been greater than the world's average growth rate of electricity. In spite of this, the gap between demand and supply continues to exist because the population of India is large. The development of the nation is affected by this gap. Energy generating resources per capita for this large population are limited. Achieving the desired electricity generation levels is feasible only if India develops technologies to use all renewable and non-renewable resources. Nuclear power has a prominent role to play in this regard. Our resources of uranium are limited but of thorium quite large. Such a resource pattern necessitates adopting breeder technology and thorium as a fuel. This paper describes the status of resources in India and the nuclear power program adopted to use them.

1. ENERGY SCENARIO

Man's energy prior to the industrial revolution came mainly from direct sunlight, combustible material such as firewood and animal dung, personal physical reserves and the exertion of domestic animals. As development occurred, his energy needs also increased. He found different energy resources such as coal, oil, natural gas and uranium to provide for these increasing needs. In the process of development, he showed a preference for more convenient forms of energy, i.e., oil for transportation and electricity for many other applications. In 1950, not many years ago, the world consumed only 70.86 ExaJoules (Exa is 10E8) of energy whereas in 1991 energy consumption was 356.47 ExaJoules. In 1950 the world's electric power generating capacity was only 155 GWe, whereas in 1991 it was 2842 GWe, an 18-fold increase in 40 years. The share of electricity of total energy consumption in 1950 was only 13 per cent whereas in 1991, it was 32 per cent. Thus, while total energy production increased five times, electric production in the same period increased 18 times, since it is a preferred mode of consumption.

It is well known that energy consumption, especially of electricity, is an indicator of the state of national development. This fact is illustrated by the per capita energy consumption of developed and developing nations. The relative per capita energy consumption patterns amongst some countries are compared to India as reference below:

India	1
China	2
France	13
USA	25
World	5

Electricity production in India increased 62 times, from 1,336 MWe in 1947 at independence, to 85,000 MWe now. Overall energy consumption in the same period increased 15 times. Even with this tremendous increase, the impact on development has been limited due to simultaneous population growth. To reach the world average per capita energy consumption, India must develop each and every resource available, including nuclear power.

2. RESOURCES

Energy is produced from renewable and non-renewable resources. Renewable energy resources are hydro, wind, sun, sea waves, etc., and non-renewable resources are coal, oil, natural gas and uranium. Excepting hydro, use of all other forms of renewable energy are presently in their infancy in India, with many limitations on commercial production.

Development of human society the world over depends on non-renewable energy sources. These national resources in energy equivalent content in Exajoules divided by the population number, termed the R/P ratio or resources per capita, is an important parameter with which to measure the potential for development. For comparison, the status of conventional resources in India per capita *vis-à-vis* the rest of the world is given in Table I.

From the above figures it is seen that quantities of conventional resources in India are far below world values. Due to scarce non-renewable resources, India must develop nuclear power to reach a reasonable level of development. Nuclear fuel available as uranium and thorium from sources presently exploitable is given in Table II.

It is seen from the above that uranium supplies are meagre compared to total world resources but at the same time, India's thorium resources are abundant. India's nuclear power program is therefore drawn with this base of distribution.

3. INDIAN NUCLEAR POWER PROGRAM

Based on the considerations above, a three stage nuclear electric power program has been envisaged for India.

Stage I — Pressurized heavy water reactors (PHWR), using natural uranium as fuel to generate power and produce plutonium in the spent fuel.

Stage II — Fast breeder reactors (FBR) using as fuel the plutonium extracted by reprocessing the spent fuel of PHWR. These reactors would induct thorium at the appropriate time to yield additional fuel using thorium as a breeding material.

Stage III — Thorium based reactors fuelled by Uranium-233 obtained from reprocessing irradiated thorium from the FBR. These reactors would irradiate more thorium to breed nuclear fuel for subsequent nuclear power plants.

TABLE I. R/P RATIO (Joules per capita)

	India (10E9)	World (10E9)	Ratio
Solid	1445	4298	0.34
Liquid	39	1053	0.04
Gas	32	876	0.04
Hydro	293	623	0.47

TABLE II. URANIUM AND THORIUM QUANTITIES IN INDIA

	India	World
Uranium (Tonnes)	70,000	4,023,948
Thorium (Tonnes)	306,330	2,202,080

Under the first stage, a series of pressurized heavy water reactors (PHWR) are being set up using natural uranium as fuel. However, the present proven, indicated and inferred natural uranium resources in the country can sustain only about 10 to 15 GWe of PHWR. The second stage hence envisaged the utilization of PHWR plutonium in FBR, which can breed more plutonium from U-238 than they themselves use for power production. This paves the way for additional FBR to be set up using the excess plutonium. It appears technically feasible to develop the FBR electric generation capacity to as much as 350 GWe. Subsequent growth and consolidation in the third stage of the program will be accomplished through thorium resources.

It should be emphasized that the 10 to 15 GWe that can be sustained by PHWR is in fact negligible compared to the projected demand and hardly justifies substantial investment in the nuclear power program. It is only by utilizing breeders and thorium that investment in the nuclear power program in India can be justified.

4. PRESENT STATUS

In India, nuclear power was ushered in in the mid-sixties with the setting up of two boiling water reactor (BWR) units at the Tarapur Atomic Power Station (TAPS), a turnkey contract executed by the General Electric Company (GEC) of the United States (US). These reactors were built to gain operating experience in nuclear power plants.

India launched its pressurized heavy water reactor program with Rajasthan Atomic Power Station (RAPS), with the design prepared by the Atomic Energy of Canada Limited (AECL) based on the Douglas Point Reactor. Construction of the next two 220 MWe Units of Madras Atomic Power Station involving total indigenous effort started even before RAPS Plant was fully constructed and commissioned. Many design changes were incorporated in the Madras Atomic Power Station (MAPS). Narora Atomic Power Station (NAPS), where design of practically all systems has been modified relative to MAPS, demonstrated the maturity achieved in the field of PHWR design in India. Kakrapar Atomic Power Station repeated the standardized NAPS design. Four more units of this type, two at Kaiga in Karnataka and two at Kota in Rajasthan are presently in the final stages of construction. One of the guidelines in evolving the design of Narora Atomic Power Station was that this standardized design of 220 MWe PHWR would subsequently be scaled up for 500 MWe PHWR. The design work for the 500 MWe PHWR is now practically complete. The construction of the first 500 MWe is to be taken up shortly at Tarapur (TAPP-3&4).

In developing the above, India has achieved domestic capability in all the aspects of nuclear power including fuel cycle technology from uranium mining to waste management. Now, the mainstay will be the use of thorium. Work on thorium cycle has been initiated. To gain experience and perfect the technology, thorium fuel bundles are loaded in KAPS-1 and KAPS-2 reactors for initial flux flattening. Toward this accomplishment, a research reactor fuelled with Uranium-233 called KAMINI has been built and is successfully operating.

Meanwhile, to bridge the energy gap of supply and demand, two units of 1000 MWe Russian VVER type are planned for construction at Kudankulam in Tamil Nadu.

A fast breeder test reactor (FBTR) of 40 MWe was built and is successfully operating at Indira Gandhi Research Center (IGCAR), Kalpakkam. The design of the first 500 MWe prototype fast breeder reactor (PFBR) is in final stages with construction to be taken up in the next couple of years. This will mark the beginning of the second phase of the three-stage nuclear power program in India.

5. CONCLUSIONS

Development depends on energy availability. In this respect the late Dr. Homi Bhabha, father of India's nuclear energy program, said "No power is costlier than no power." His view was that development is important irrespective of its cost. Since other forms of non-renewable energy sources in India are insufficient to meet the demand targets, it must depend on nuclear power. The available resources are uranium and thorium. To utilize the vast resources of thorium, Dr. Homi Bhabha formulated the three-stage nuclear power program. Presently, the technology required for the first stage has been fully developed. For the second stage, R&D is underway and for the final stage, preliminary studies on thorium have begun.

Hence it is imperative that India pursues more vigorously than at present the three stages envisaged by Dr. Bhabha, that the 3rd stage of Th^{232} - U^{233} is reached soon so that future generations are not left helpless without electricity – the power is at the tip of the finger.

IAEA can help the developing nations realize their energy programs allowing free flow of information and having coordinated approach to development of fast breeder reactor and fuel cycles with thorium as fuel.

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