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## INDIAN EXPERIENCE IN CAPACITY BUILDING AS A PART OF DEVELOPMENT OF ATOMIC ENERGY PROGRAMME

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**Abstract.** India embarked on a programme to harness nuclear technologies for the welfare of the nation more than five decades ago and adopted an approach involving knowledge generation through research and development, disseminating the knowledge acquired to the young generation through in-house arrangement, encouraging the researchers in the university system to work on problems of interest to the nuclear industry by providing research funding, networking with the university system, collaborating with industry to upgrade their skills to take up challenging manufacturing jobs, setting up industry under the control of the Government wherever private industry was not coming forward and so on. The basic approach underlying all efforts was to tap the ‘knowledge’ wherever available and to upgrade the ‘knowledge’ by R&D. For developing new technologies and for problem solving, ‘bottoms up approach’ implying study of scientific basis of all issues beginning from fundamentals was used and shortcuts were avoided. This has enabled the country to be self sufficient in all aspects of nuclear fuel cycle as well as applications of radiation technology to industry, agriculture and health care. This also enabled the industry to gain skills and use the skills gained for other sectors of economy. Now that the industry in India is much more mature and the engineering education at the post-graduate level is well developed, several changes in the approach followed have been made. These include making use of the skills and size of the industry by ordering total systems of a power plant rather than individual components and involving industry as consultants for several jobs, which were done in-house in the earlier days. The paper summarizes Indian experience of the last five decades and what is planned for the future.

### 1. INTRODUCTION

Department of Atomic Energy (DAE) in India has just completed 50 years and has pursued its activities with a focus on self-reliance. During this period, it has been possible to build a large pool of knowledgeable scientists and engineers in virtually all disciplines important to atomic energy programme. Pool of experts and knowledge base generated has enabled the Department to carry out the activities spanning the entire spectrum of research, development, demonstration and deployment of various applications of atomic energy for the welfare of the nation. Recently, we conducted a comprehensive vision exercise to examine what we have done in the past 50 years and where do we go from here. It was felt that deployment of technologies has to be accelerated and what we have achieved in terms of deployment during the past 50 years, has to be done now during the next 10 years.

Developments during the past 50 years, on close examination, reveal the following insights for this success.

- Research and development (R&D) is necessary for progress, but R&D by itself is not enough. Knowledge generated by R&D must lead to deployment of technologies and diffusion of knowledge.
- While new research is important, adaptation of known technologies for specific applications and their continued improvement is also very challenging.
- While it is necessary and desirable to build partnerships with both the university system and the private industry, the different attributes of both should be acknowledged. Private

industry is looking for profits and that too in the shortest possible period. University researchers are looking for challenging problems that can be solved through students as a part of their research degree requirements.

- To provide long-term direction for technology development, government has to step in by providing policy framework and/or by removing entry barriers for new technologies and by insulating technology development from short-term political pressures. In particular, technologies requiring long lead-time for development, or technologies where sustainability is an issue require governmental support by way of funding for R&D and for setting up demonstration units and also by way of appropriate policy framework. Energy technologies such as fast breeder technology, accelerator driven sub-critical reactor systems or fusion technology fall in this category.
- Earning technology transfer fee is less important than deploying the technologies developed with the objective of improving the level of industry and then outsource to industry what can be done by them.
- Education and research are complementary activities.
- The first degree should be as broad as possible so as to provide enough employment opportunities to the young graduates. Specialization should be acquired as a part of the second degree and specialized programmes of higher education must be followed by assured placement.
- In addition to archiving, knowledge management also includes human resource development, technology transfer and technology assessment. For implementation of all these activities, the people are the most important element and therefore, development of individuals has to be central to knowledge management.

It is interesting to observe that several of these insights have also been revealed to others when reviewing altogether different programmes [1].

This paper gives details about how implementation has proceeded in the past.

## 2. The Organization

The most important step has been the creation of an organization having comprehensive capability spanning research, development, demonstration and deployment of various applications of nuclear science and technology. The DAE, today, has a robust infrastructure consisting of research and development centers, grant-in-aid institutions pursuing basic research, agencies for extra-mural funding, industrial organizations, public sector units and service organizations (Figure 1). Bhabha Atomic Research Centre (BARC), the first research centre of DAE in India, located in Mumbai, is the mother institution of all the other research centres as well as the nuclear power programme in India. In view of the knowledge intensive nature of the nuclear technology and the state of hi-tech industrial infrastructure in India, Bhabha Atomic Research Centre (BARC) has been designed to have a composite character. It has been pursuing activities starting from basic research to technology development and deployment. BARC also has a very effective human resource development programme in place, and as a result, BARC has attributes of an institute, a research laboratory and also an industrial organization.

The composite character is confined not only to BARC, but also extends to the Department of Atomic Energy (DAE) as a whole. The fountainhead of success of the atomic energy programme in India is the fact that both the research centres, which generate knowledge and the industrial units, which generate wealth from the knowledge, are under one umbrella, that is, the DAE working under the policy framework laid by the Atomic Energy Commission.

The comprehensive organization structure enables following a ‘bottoms up approach’ implying study of all issues from fundamentals and avoiding any shortcuts. This has enabled the country to be self-sufficient in all aspects of nuclear fuel cycle as well as applications of radiation technology to industry, agriculture and health care. This has also given us the confidence to follow a path independent of others.

### 3. Partnership with industry

Pressurized Heavy Water Reactors (PHWRs), which form the mainstay of the present nuclear power programme, were selected in the late 1960s keeping in view the then industrial capability in the country. The main components of a PHWR (Calandria, end fittings, coolant channel components) are relatively simple in comparison with reactor pressure vessel and associated components of light water reactors and were within the manufacturing capability of a developing country. A very strong base was created within DAE for achieving self-sufficiency with respect to design and manufacture of fuel, pressure tubes, calandria tubes, production of heavy water, machining of precision parts such as end fittings, liner tubes and many components of fuelling machines. Simultaneously the DAE interacted with Indian Industry and helped them to adapt to the sophisticated technologies for the manufacturing processes, highest level of quality control, quality surveillance and quality assurance. First of a kind manufacturing of many components to meet the critical requirements of various design codes was done in BARC. Indian Industry was not at all familiar with design codes such as ‘ASME code for Boiler and Pressure Vessel’ and by interacting with engineers from NPCIL and BARC, they could learn a lot. NPCIL had to modify equipment design to suit the manufacturing capability available in India. Various test facilities were set up in BARC to qualify the components and equipment manufactured by Indian Industry.

This has also enabled the industry to gain skills and now that the industry in India is much more mature, several changes in the approach have been made. These include making use of the skills and size of the industry by ordering total systems of a power plant rather than individual components and involving industry as consultants for several jobs, which were done in-house in the earlier days. This partnership with industry has benefited all involved, the industry, the DAE and the country. Industry is able to use the skills for other sectors of the economy and the DAE has been able to move from 220 MWe PHWR to 540 MWe PHWR and is now contemplating to move to 700 MWe PHWRs.

Similar effort is now being made by IGCAR for the technology development of Fast Breeder Reactors. The excavation for the construction of 500 MWe Prototype Fast Breeder Reactor has already been started and the first pour of concrete is awaiting clearance from the regulatory authority.

Overall result of partnership with industry has been that India has technological self-sufficiency with respect to all aspects of setting up of a nuclear power plant. Certain raw materials and equipment are still imported in certain situations, but that is due to economic considerations. We expect a major expansion of nuclear power capacity based on fast reactors in the decades to come and economy of scale and continuously improving skill base of Indian industry can be expected to ensure that it will be economical to source everything from Indian industry.

However, for certain products, equipments, components and systems, industrial organizations were set up within the DAE and as mentioned earlier these include ECIL, HWB, NFC and UCIL. For several special materials, industrial organizations have been set up by other departments of the Government of India and examples include Midhani for special alloys, BEL for electronics components, HMT for machine tools and so on.

For strategic reasons, all activities related to the back end of the fuel cycle including reprocessing of spent fuel, fabrication of mixed oxide and mixed carbide fuel, high level

waste management have been kept within BARC directly under the control of the Government.

Many spin-offs have been generated by technology development work done by DAE and these have been transferred to private industry for a nominal fee. These are in all areas: electronics, electrical, mechanical chemical, biotechnology and others. Management scientists always emphasize the benefits that can be derived from public-private partnership and that is what we have been practicing in the Department for capacity building in the area of nuclear science and technology.

#### 4. Knowledge management

The term ‘knowledge management (KM)’ is of recent origin and has evolved from terms like ‘learning organization’. Depending on the context and need of organizations, it is being given different meanings and ‘Knowledge Management - Classic and Contemporary Works’ [2] is a very good collection of essays on the subject. Peter Senge, in the essay written by him in this collection, defines knowledge “as the capacity for effective action, clearly distinguishing it from data and information”. He makes the point that it is perhaps another term in the ongoing continuum of business management evolution. Peter’s definition of knowledge is different from the definition by Plato, who defined knowledge as “justified true belief”. However, beliefs are particular to one’s culture and as a result approaches to KM depend on culture.

KM as perceived by us comprises of human resource development, scientific information resource management, technology transfer and technology assessment. For implementation of all these activities, the people are the most important element and therefore, development of individuals has to be central to knowledge management. Therefore, human resource development has been given an important place in the DAE right from its inception.

In order to attract bright young students graduating from universities, we have adopted the principle of ‘hire and train’. This has enabled interested students to get trained in special areas related to atomic energy on the basis of an assured career to follow. The engineering education at the post-graduate level is now well developed; therefore, in recent years, we have set up a new scheme enlarging the scope of this model to include training programmes in educational institutions, which also incorporates a significant research component in areas of interest to the atomic energy programme. As a part of training, the students carry out the research work on topics of interest to DAE. The research work leads to considerable enrichment of the training programme and also forms a valuable input to the programmes of DAE. Whenever a higher education programme is associated with frontline research, both benefit. More details about human resource development programmes are given in an earlier paper [3].

Several other dimensions of knowledge management include broad-based funding for the university system, consortium approach to collaborative research between scientists in the university and DAE R&D centres, build up of skills and technologies in industry through collaborative technology development activities and setting up of captive technology centres in special areas.

The basic approach underlying all these efforts has been to sustain and enrich knowledge and skills in multiple ways and devote a part of this effort to development of human resource.

#### 5. Partnership with academia

Recognizing that nuclear science and technology is a multi-disciplinary subject and several R&D jobs can be done by universities and laboratories outside the Department, an agency named Board of Research in Nuclear Sciences (BRNS), for extra mural funding was set up by the DAE right at the beginning of the atomic energy programme. The Department provides financial support to outside agencies for R&D on problems of interest through the BRNS.

Imperatives of providing energy security to the nation based on indigenous resources demand development of technologies, which have not been developed anywhere in the world. This would require very large high caliber manpower and nationwide effort spread over several universities and national laboratories. The Department plans to further strengthen the existing mechanisms of extra-mural funding to involve the national university system to achieve its goals. A framework for involving universities to use large facilities of DAE was established in 1989 by signing an agreement with the University Grants Commission (UGC). It has now been expanded to involve university system in DAE programmes. To implement this change, an existing organization, 'Inter University Consortium of DAE Facilities' has been changed to 'UGC-DAE Consortium for Scientific Research' and several concrete steps to give effect to the intention for the change are being planned.

#### 6. New initiatives

Both the research centres and the grant-in-aid institutions of DAE carry out research and development. While the research centres focus more sharply on technology and product development, the grant-in-aid institutions concentrate relatively more on basic research. In the process, the research centres and the grant-in-aid institutions have provided high caliber technologists as well as scientists to the Department, but for which India's spectacular strides in the field of nuclear sciences and their applications would not have been possible. To further accelerate this process, the DAE has formulated a proposal to set up a virtual university linking all the research centres and the grant-in-aid institutions.

In research and development, learning is an ongoing process and particularly when we are living in a domain where technologies get obsolete very fast. Hi-tech organizations have to carry on with orientation, re-orientation and re-re-orientation. There is also a strong need for providing avenues for continuing education during the course of employment to fight obsolescence and to facilitate re-orientation.

We expect that the proposed virtual university would provide several well-structured programmes for enhancing educational qualification of the employees and would also provide an additional attraction to talented young to join DAE institutions. It would also increase synergy within the DAE system. DAE has within its fold institutions pursuing basic research as well as technology development. Increased cooperation between DAE institutions can ensure that basic research is translated into technologies very fast and this is a national need. The proposed structure of the virtual university provides for such an interaction through the medium of students, who would be working under the joint supervision of two scientists (one working in basic sciences and the other working on technology development).

#### 7. Concluding remarks

Indian Atomic Energy programme has come of age. The programme has successfully delivered a self-reliant capability for its first stage involving setting up of Pressurized Heavy Water Reactor Systems and associated fuel cycle plants. We have now launched commercial Fast Breeder Reactor technology.

A group in the Department studied available information on GDP and population growth forecasts, trends with regard to energy-GDP elasticity and electricity intensity of industries and developed a scenario for the growth of electricity in India [4]. The scenario developed indicates that per capita electricity generation would reach a modest figure of about 5300 kWh per year by the middle of the present century, when India's population would be about 1.5 billion. This would call for a total electricity generation of about 8000 billion kWh per year. This is an order of magnitude higher than the generation at present.

Scenarios have been developed by other agencies as well, though the numbers differ depending on the assumptions made for building the scenario. The message from all such exercises is the same and that is - India is a fuel resource poor country and that there is a need

to tap every fuel resource to meet India's energy needs. The contribution of nuclear energy, therefore, has to be increased at the fastest possible pace so that nuclear electricity is able to meet about a quarter of the national electricity demand after about five decades and gets poised to make still higher contribution in the subsequent years.

While the target of reaching a quarter of national electricity generation can be met by fast breeder reactor technology, a lot of work is needed to go beyond this target. Technologies to be developed for future applications include those necessary for building accelerator driven sub-critical reactor system (ADS) for thorium utilization and fusion technologies. On the basis of achievements so far and capacities that have been built in terms of pool of experts and technologies, we can feel confident that future challenge would be met.

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**THE ORGANIZATION**

