Centre for Air Power Studies

CAPS National Seminar Report

on

Nuclear Energy: The Current State of Play

(March 13, 2024, Conference Hall, Air Force Auditorium, Subroto Park, New Delhi)

The **Centre for Air Power Studies (CAPS)** has been conducting an annual national seminar on **Nuclear Power** since 2004. This has become a prominent platform for deliberating on the advancements, obstacles, and concerns pertaining to nuclear energy. This year the seminar was attended by nearly 100 serving and retired personnel from the Armed Forces, BARC, NPCIL, DAE, and members of the strategic community.

The Director General of CAPS, **Air Marshal Anil Chopra PVSM AVSM VM VSM (Retd),** highlighted the global energy security challenge arising from the Ukraine conflict, the Israel-Hamas War, and the Red Sea crisis. These have brought home the need for reliable energy sources, prompting some countries to prioritise nuclear power generation. Additionally, he highlighted that despite India's growing renewable energy potential, augmenting nuclear power capacity is imperative to attain net-zero emissions by 2070 with the active involvement of both governmental and private entities.

Shri **Vivek Bhasin**, **Director Bhabha Atomic Research Centre (BARC),** in his inaugural address explained how the current focus on *Atmanirbhar Bharat's* objective of achieving energy independence by 2047 has long been an endeavour of the nuclear establishment. India's 3-stage nuclear power programme seeks to leverage its abundant thorium reserves and get over the vulnerability of limited and poor quality uranium reserves. In fact, it was the low quality of domestic uranium that made India adopt PHWR technology and not the difficulties of developing/acquiring enrichment technology. He traced India's nuclear journey, explained the challenges, and how India had overcome them such as in the fields of reprocessing and waste disposal. He explained how the country could achieve better utilisation of U-238 in the second stage breeder reactors and then move to thorium utilisation, for which R&D was being conducted. He also highlighted other societal applications of nuclear energy, such as food security, medicine, conventional waste treatment and also in green hydrogen generation, an eco-friendly fuel for the future.

Session I: The Status of Nuclear Energy

Dr. Manpreet Sethi spoke on **Global Nuclear Energy Scan: Contemporary Drivers & Developments.** She emphasised the present positive trendline on nuclear energy at the global level. 437 reactors in 31 countries are providing 10% of the global electricity supply, with an additional 61 reactors under construction. India and China are world leaders in new build, with China building 25 reactors and India 8. The operationalization of the first-Generation IV demo reactor in China and the core loading of the PFBR in India are heartening developments of 2024.

- There is revival of interest in nuclear energy in Western countries too. The UK has announced that it would generate 24 GWe by 2050 to achieve 25% energy supply from nuclear power. The Atomic Energy Advancement Act 2024 has been enacted by the United States. The Flamanville 1600 MWe EPR is scheduled to go critical in France, along with a plan for 14 new nuclear reactors. The EU has included nuclear technologies in its Net-Zero Industry Act (NZIA) and the first Nuclear Energy Summit was scheduled in Belgium later in March 2024.
- Nuclear energy, after hydro, is the second largest low carbon energy source. During the COP28 meeting of 2023, 22 nations committed to tripling their nuclear energy capacity by 2050. The industry too pledged to securing cost-effective funding and timely, affordable project delivery. At the World Economic Forum in Davos in January 2024 the IAEA's Atoms4NetZero initiative was highlighted, with a particular emphasis on Small Modular Reactors (SMRs).
- Amongst the challenges facing nuclear energy, she highlighted the need for a predictable policy environment and a level playing field alongside the renewables. Also, to the traditional threats to security of nuclear facilities from non-state actors, new ones have been added from state actors, as seen in Zapporhizhia where the nuclear power plant has been used as a hostage by opposing factions.
- She concluded by highlighting the many things in favour of nuclear energy -- its advanced technological base, substantial operational expertise, a commendable safety record, low carbon footprint, and limited land demands. But, there is need for managing

public opinion, guaranteeing prompt and cost-effective provision of capacity, and effectively demonstrating supplementary advantages beyond electricity production.

Shri **Ranjay Sharan, Director (Projects), Nuclear Power Corporation of India Limited (NPCIL**), spoke on **Capacity Addition in India's Nuclear Programme.** Established in 1987 and wholly owned by the Government of India, the NPCIL, operates PHWR, BWR, and PWR reactor technologies. Besides emphasis on indigenous PHWRs, there are plans to build LWRs, in collaboration with foreign partners. The construction of Indian nuclear power plants has undergone substantial evolution, transitioning from manual labour to mechanisation. Technological advancements and proficient implementation have resulted in reduced time and energy requirements at construction sites.

- NPCIL is a profit making company with an outstanding safety record, having operated without any incidents for over 54 years, which is equivalent to more than 604 reactor-years. NPCIL's focus on a strong safety culture is evident in the fact that public exposure remains well below the limitations set by AERB and natural background levels.
- NPCIL has achieved significant milestones, such as successfully operating TAPS-1&2, the world's oldest reactors, for over 50 years; Kaiga 1 has established a global record by operating for 962 days in 2018; NPCIL has successfully maintained continuous operation for over a year (365 days) 46 times; it is handling multiple projects with diverse technologies, including overseeing construction of LWRs at Kudankulam.
- During construction of Tarapur 3 & 4 reactors, NPCIL first resorted to the model of using 50% government money and 50% borrowing. The construction of the plants was completed in a record five years. Since then, use of borrowings has enabled the simultaneous construction of up to 2-5 nuclear power plants.
- The corporation is investigating the export of reactors and nuclear services, the development of Small Modular Reactors (SMRs), and the production of clean hydrogen. The proposed strategies encompass the cultivation of partnerships through public-private partnerships (PPP), joint ventures, and new business models.

Prof. **RB Grover, Emeritus Professor, Homi Bhabha National Institute,** delivered a talk

on **Energy Transitions with a Focus on Development.** He highlighted that increasing energy consumption presents an existential challenge as serious as resource scarcity or ecological crises. Despite advancements in energy efficiency, worldwide energy usage remains high, with the exception of periods marked by financial crises and pandemics. Presently, there exists a pressing need to decarbonise the economy, by tackling carbon emissions from sectors such as energy, industry, land use, and agriculture. Energy should be derived from low-carbon sources such as hydro, nuclear, solar, and wind, while ensuring that any remaining emissions are controlled through Carbon Capture, Use, and Sequestration. Nevertheless, there are still obstacles to overcome in the process of reducing carbon emissions in aviation, long-distance transportation, steel manufacturing, cement manufacture, and ensuring a dependable electricity supply. Consequently, remedies such as hydrogen and energy storage are required.

- Attaining net zero without nuclear energy will be difficult. Although solar, wind, and biomass technologies have promise, they are insufficient in meeting the anticipated energy demands. India must depend on nuclear power and coal with carbon capture. But the latter technology has to be developed along with the related issues of liabilities, institutional frameworks, regulations, and economic concerns.
- Uranium is obtained from foreign sources for use in reactors, with protection provided by the IAEA. Advancement in recycling technology enables the closure of the fuel cycle. The commissioning process of the PFBR is currently underway, with continuous fuel loading, while construction is progressing on KK units 3 to 6.
- India's consumption of grey hydrogen in 2018-19 amounted for 5.5 million tonnes, primarily for the purposes of fertiliser production and crude oil refining. India has set a target of production capacity of 5 million tonnes of Green Hydrogen (GH2) by 2030, encompassing both nuclear and clean alternatives. To achieve this, 115 gigawatts of renewable energy and 50 billion litres of potable water are necessary. The optimisation of a symbiotic relationship between electricity and hydrogen necessitates system-level studies.

Session II: Nuclear Energy: Issues for the Future

Dr. Satyendra Gautam spoke on **Atoms for Societal Benefits: Efforts Towards Achieving Food, Health & Water Security.** He explained that on a global scale, around 33% of food is lost or wasted, resulting in significant economic and environmental

consequences. Europe and North America have a 20% loss in food output, whilst sub-Saharan Africa and Southeast Asia suffer a loss of over 40%. This results in significant loss of resources, besides generation of solid waste and GHG emissions, amounting to 4.4 GtCO2 eq per year.

- In this regard, use of food irradiation can be an effective solution. DAE has been raising public awareness on this through events such as on December 8, 2023, when a Kisan mela took place at KRUSHAK, Lasalgaon, where results of onion preservation trials were presented to farmers. Food irradiation, including of seafood, can be a lucrative economic opportunity for India. Besides, the use of nuclear technology can also help in development of crops that possess specific characteristics, such as early maturity, increased productivity, broader ecological adaptation, enhanced tolerance to both biotic and abiotic stressors, and improved nutritional value. DAE's work in this field encompasses multiple phases of testing prior to introduction of new varieties to farmers.
- The utilisation of radiotracers in the field of nuclear medicine also holds significant potential for the diagnosis and treatment of cancer. For more than sixty years, BARC has been at the forefront of manufacturing radioisotopes for medicinal purposes. A cost-effective method has been created to enhance the affordability of radiopharmaceuticals, especially for the diagnosis and treatment of prostate cancer.
- The MED-TVC desalination technology, created by BARC, uses steam as a means to generate potable water from seawater. It is an energy-efficient and environmentally beneficial method. BARC has acquired expertise in the field of single-stage brackish and seawater reverse osmosis membranes. These are affordable membranes priced 10-20% lower than existing alternatives.

Dr. Deb Mukopadhyay, distinguished specialist in nuclear technology and development spoke on **Development of Technologies for the Future.** He drew attention to the many technologies under development at DAE. The first of these is the development of the General-Purpose Isotope Production Reactor. Given that the global need for radioisotopes is increasing and there is a mismatch between demand and supply, and that India too is able to meet only 30% of its needs from Dhruva and imports the rest, an isotope producer is necessary to cater to the increasing needs in the medical and industrial sectors. The primary objective of the IPR being set up at Kakrapar would be to enhance India's independence in

essential radioisotopes for nuclear medicine, hence enabling cost-effective treatments for cancer and establishing India as a prominent global frontrunner.

- A second technology is the Indian Gas Cooled Reactors (GCR-5) which would integrate sophisticated safety measures including various shutdown systems and passive decay heat extracting abilities. At present, the advancements in this field primarily revolve around physics design, fuel cluster design, and thermal-hydraulic studies. Ongoing and future activities for the GCR-5 encompass crucial aspects such as fuel design, structural design, safety, and component qualification. Additionally, coolant chemistry control, reactor control, and core instrumentation are prioritized. Other tasks include setting up test facilities for design verification, shielding, dose estimation, radiation protection, health physics, environmental safety, fuel reprocessing, waste management, project planning, documentation, and civil construction with technical services.
- The utilisation of thorium for energy security is a crucial aspect of India's three-stage nuclear programme, with the Molten Salt Reactor (MSR) playing a major role. The main safety aspects of the system include negative fuel salt reactivity, subcriticality to prevent salt leakage, online refuelling with minimal excess reactivity, and passive decay heat removal. These features guarantee dependable operation and efficient utilisation of thorium on a wide scale.
- In summary, the advancement of novel reactor technology faces obstacles pertaining to compact reactor design, durability of materials, durability of core components, stability of coolants, development of specialised equipment, fabrication methods, and reprocessing of spent fuel. BARC, being a multidisciplinary centre, tackles these difficulties in order to advance reactor technologies of the next generation.

Major Points made during Discussion Session

- There is an overlap in the three phases of India's nuclear power programme. The first stage will get us to 100 years; the second stage to 300 years and the third stage will provide a long term solution.
- In order to ensure physical security of nuclear reactors from aircraft crashes, double containment with steel liner and increased thickness of inner and outer dome has been resorted to.

- The capacity factors of Indian reactors has been more than 86% in most cases.
- The Nuclear Safety Regulatory Authority bill that had been lying in the Parliament awaiting approval since 2011 stands withdrawn. AERB de jure independence will be ensured through statutory actions and not through legislative process.
- India's 220 MWe reactor can qualify as SMR if it is factory built and assembled at site. With 3-D modelling of piping, etc., its construction time can be significantly reduced. Civil construction on site can also be made modular.
- Need for research at system level of national energy sources in order to arrive at cost-efficient conclusions. The current disconnect between energy economists and social scientists is not an ideal situation.
- The increased use of irradiation for agricultural produce and food products is handicapped not by public fears, but non-availability of adequate capacity in centres being run by DAE. There is need for technology transfer to industry to enhance usage of this technology.
- Further research needs to be done on the potential of nuclear exports of technology and services from India.

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