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Reactor Regulation: An analysis of Indian nuclear laws and policies

Abstract:

India's nuclear energy program has evolved significantly since its inception, facing challenges ranging from public opposition to technological constraints and uranium supply issues. This paper provides an overview of the historical development, current challenges, and potential solutions for India's nuclear energy sector. It explores the country's journey from the establishment of the Department of Atomic Energy (DAE) to the expansion of nuclear power generation and international cooperation agreements. Despite facing challenges, India has made strides in advancing nuclear technology and regulatory frameworks. To overcome challenges, India must prioritize public engagement, advance nuclear technology, diversify fuel sources, strengthen regulatory oversight, and mobilize financing. By addressing these challenges and leveraging its nuclear expertise, India can realize the full potential of nuclear energy to meet its energy needs and contribute to global sustainability goals.

Introduction:

Nuclear energy is a form of energy which is released during nuclear reactions by either nuclear fission or nuclear fusion processes. These reactions involve the splitting (fission) or combining (fusion) of atomic nuclei, which leads to the release of vast amounts of energy in the form of heat and radiation.

Nuclear Fission: In nuclear fission the nucleus of a heavy atom like the uranium-235 or the plutonium-239 is split into smaller nuclei which releases a large amount of energy. This process

typically occurs in nuclear reactors where controlled fission reactions generate heat to produce steam which then drives turbines to generate electricity.

Nuclear Fusion: Nuclear fusion involves the combining of two lighter atomic nuclei to form a heavier nucleus, accompanied by the release of energy. This process is magnitudes more powerful than fission, however, controlled fusion has proved to be difficult. Thus, Nuclear fission is currently used as the source of nuclear energy by all the countries.

Nuclear energy is known for its high power concentration, hence a small quantity of nuclear fuel produces lots of energy. Nuclear energy is also seen as low-carbon power because there are no emissions of greenhouse gases from nuclear power plants when they generate electricity. Despite these advantages, the use of nuclear energy has some associated difficulties such as safety worries, problems related to waste control and disposal or accidents. Due to these, various different procedures, laws, and policies have been established to deal with these.

Development:

The development of Nuclear Energy in India has been a long and arduous journey. It was realized early on, post-independence that nuclear energy would be crucial to India due to it acting as a strategic tool for economic development, energy security, and technological enhancement. Over the decades India has slowly and steadily expanded its nuclear energy program while dealing with a complex web of domestic issues, international dynamics, and technological problems.

Early Years and the Establishment of the Department of Atomic Energy (DAE)

The Indian nuclear journey began in the 1940s with the establishment of the Tata Institute of Fundamental Research (TIFR) and the Atomic Energy Establishment, Trombay (AEET) under the leadership of Dr. Homi J. Bhabha. These institutions laid the foundation for India's nuclear research and development efforts. In 1954, the Department of Atomic Energy (DAE) was formed under a presidential order. The DAE was entrusted with a lot of responsibilities which included various aspects of nuclear science and technology.

Foundations of Indigenous Nuclear Capability

In the 1950s and 1960s, India focused on building indigenous nuclear capabilities which included research reactors, nuclear fuel cycle facilities, and scientific expertise. The establishment of the Atomic Energy Commission (AEC) and the Bhabha Atomic Research Centre (BARC) played pivotal roles in advancing India's nuclear research and development agenda. India's first research reactor, Apsara, went critical in 1956 which means achieved nuclear fission, thus marking the first big milestone in the development of nuclear energy in India.

The Pokhran Tests

India put its nuclear aspirations front and center with the 1974 Pokhran-I “Smiling Buddha” test, which showed that it was capable of developing an atomic bomb. Even amid international condemnation and sanctions, India took a position of nuclear ambiguity that stressed the peaceful uses of nuclear energy as well as its capacity for credible nuclear deterrence. The 1998 Pokhran-II tests confirmed India’s nuclear strength and redefined the global nuclear order putting India on the list of the few countries with access to nuclear power,

Expansion of Nuclear Power Generation

India expanded its civil nuclear energy sector very aggressively in the following years so that it could meet the increasing demands for power while working parallel to its strategic nuclear program. The commencement of the Nuclear Power Corporation of India in 1987 marked the beginning of a new phase of nuclear power development. Tarapur Atomic Power Station-3, which was India’s first indigenously designed pressurized heavy water reactor (PHWR), started its commercial operation in 2006 and showed that the country had made quite a big jump in its nuclear power capabilities.

International Cooperation and Civil Nuclear Agreements

India, as a major actor in the global nuclear sphere, has been involved in numerous treaties and agreements aimed at enhancing nuclear safety, security, non-proliferation, and peaceful use of nuclear energy. These are listed as:

1. Non-Proliferation of Nuclear Weapons Treaty (NPT)[1]:
   The NPT was not signed by India which was formed to stop the spread of nuclear weapons and disarmament campaigns. India has rejected this treaty because of its discriminatory nature and perceived lack of progress towards nuclear disarmament in the countries that possess such arms.

2. Comprehensive Nuclear-Test-Ban Treaty (CTBT):
   India has not ratified CTBT which prohibits all types of nuclear explosions for both civil and military purposes. The Indian perspective on CTBT is based on concerns regarding mechanisms of verification under this treaty, and a demand for an internationally verifiable framework for disarmament today.

3. Nuclear Suppliers Group (NSG):
   The NSG is a multilateral export control system that aims to prevent nuclear proliferation by regulating the transfer of nuclear-related materials, equipment, and technology. Despite not being an NPT member or signatory, it has sought a waiver from the NSG so as to facilitate its nuclear cooperation with member states.

4. International Atomic Energy Agency (IAEA) Safeguards Agreements[2]:
   India has committed itself to non-military use of nuclear energy and openness in carrying out nuclear activities by signing IAEA safeguards agreements for some nuclear facilities. These agreements permit the IAEA's inspections to verify that nuclear materials are not diverted for military purposes.

[1] International Atomic Energy Agency, https://www.iaea.org/sites/default/files/publications/documents/infcircs/1970/infcirc140.pdf (last visited on 13th April, 2024)
[2] International Atomic Energy Agency, https://www.iaea.org/publications/factsheets/iaea-safeguards-overview (last visited on 13th April, 2024)

5. India-United States Civil Nuclear Cooperation Agreement[3]:
   It is also known as the 123 Agreement, the India-US Civil Nuclear Cooperation Agreement was entered into in 2008 with the USA. It allowed India access to civilian nuclear technology and fuel while at the same time tackling concerns about non-proliferation and safeguards.

6. India-Russia Nuclear Cooperation Agreement:
   India has a longstanding nuclear cooperation agreement with Russia, dating back to the Soviet era. This agreement encompasses various aspects of nuclear cooperation, including the construction of nuclear power plants, the supply of nuclear fuel, and joint research and development initiatives.

7. Other agreements:
   India has agreements with various other nations like France, Japan, South Korea and Canada regarding the civil use and development of nuclear energy through civil use and research.

8. Other International Treaties on Nuclear Safety and Security:
   India is also a party to various other international treaties and conventions related to nuclear safety and security, including the Convention on Nuclear Safety, the Convention on the Physical Protection of Nuclear Material, and the International Convention for the Suppression of Acts of Nuclear Terrorism.

Legal Framework:

1. **Atomic Energy Act, 1962[4]**

[3] Department of Energy, https://www.energy.gov/nnsa/123-agreements-peaceful-cooperation (last visited in 13th April 2024)
[4] Atomic Energy Act, 1962

The Atomic Energy Act, 1962 acts as the base or foundational legislation for the governance of nuclear activities in the country. This act deals with the development, control, and use of the atomic energy for civil purposes. This act allows the Central Government to regulate and control nuclear energy. This act provides the powers and functions of the Atomic Energy Commission (AEC) which is the highest policymaking body for nuclear energy and it also provides the legal framework for the establishment of the Atomic Energy Regulatory Board (AERB) which oversees safety and regulatory matters. Section 28 of the Atomic Energy Act allows the government to make rules for the proper implementation of the act.

a. Atomic Energy Commission:

The Atomic Energy Commission (AEC) is the apex body for atomic energy in India. It acts as the core for Indian nuclear development and has the following functions:

- Promoting and guiding research and development in atomic energy and related fields.
- Ensuring the peaceful uses of atomic energy for the benefit of society.
- Regulating activities involving atomic energy, nuclear materials, and facilities to prevent their misuse.
- Advising the central government on matters related to atomic energy and its applications.

It also has various powers ranging from issuing licenses and granting permissions to control over import and export of nuclear technologies and materials to even dealing with the compensation for damages due to nuclear accidents. It also acts as an advisory body to the government.

2. Atomic Energy Regulatory Board (AERB) Act, 1983[5]

[5] Atomic Energy Regulatory Board (AERB) Act, 1983

The AERB Act, 1983 establishes it as the primary regulatory authority responsible for ensuring safety and security in the various nuclear installations and radiation facilities like nuclear power plants. This Act provides the functions, powers, and composition of the AERB. It empowers it to issue regulations, guidelines, and codes of practice for nuclear safety and radiation protection. The AERB operates independently of the Department of Atomic Energy (DAE) which AEC is a part of and is vested with statutory authority to enforce compliance with the regulatory requirements.

3. Civil Liability for Nuclear Damage Act, 2010[6]

The Nuclear Liability Act deals with liability and compensation for nuclear damage. It was made to provide for a complete legal framework and applies within the territorial limit of India, outlining the liability of operators & suppliers as well as other matters regarding accidents relating to nuclear damage. The principles aimed at protecting suppliers from direct claims include no-fault liability and channeling of liability to the operator.

This kind of structure reduces financial risks on suppliers while ensuring that victims are properly compensated thereby encouraging investments into the nuclear industry. There is also provision for assessing and paying compensation by Nuclear Damage Claims Commission under this mechanism. However, on this mechanism individuals, communities or property owners suffering from nuclear damages may be eligible for bodily injuries; wrongful death; damage to property; and economic losses among others.

Current challenges and issues:

1. Public Opposition and Environmental Concerns:

Local communities and environmental groups often resist the construction and implementation of nuclear power plants in India. Public opposition to nuclear energy

6 Civil Liability for Nuclear Damage Act, 2010

projects results from the fear of accidents, risks associated with radioactive waste, and environmental impact resulting from nuclear facilities. The Chernobyl and Fukushima disasters among other accidents have raised concerns and suspicions on the safety of atomic energy.

One key concern that anti-nuclear campaigners have is risk of accidents in densely populated areas. The catastrophic meltdowns at Chernobyl and Fukushima remain as grim reminders of the possible consequences that can occur during an atomic accident. Despite having stringent safety regulations and robust emergency preparedness measures in place, public perception of nuclear safety remains a significant issue.

Furthermore, radioactive waste produced by nuclear power plants has environmental implications for its management. Nevertheless, India's nuclear waste management still lacks adequate infrastructure for storage, transportation, and disposal albeit improvements made so far.

Thus, it is no surprise that citizens pose a huge issue to the development of nuclear energy.

2. Technological Constraints:

India's nuclear energy program is mostly based on pressurized heavy water reactors (PHWRs), with a lesser extent on pressurized water reactors (PWRs). India has benefited from these reactor technologies, however, it is becoming increasingly apparent that there should be more diversity and improvement in nuclear technology for future energy needs.

To expand the country's nuclear fleet and address its rising energy requirements, progress in reactor technology must include advanced reactors and fuel cycles. Some of the innovative designs for reactors are thorium-based reactors, fast breeder reactors (FBRs), and small modular reactors (SMRs), which can increase efficiency as well as make nuclear power generation safer and more sustainable.

However, technological and regulatory challenges hamper the advancement of advanced reactor technologies. Technical hurdles need to be overcome through accelerated research and development efforts aimed at proving the feasibility of advanced reactor concepts. Moreover, safety frameworks have to embrace new technologies while ensuring that they do not compromise their safety or security.

3. Uranium Supply:

India is faced with challenges in securing a steady supply of uranium fuel for its nuclear reactors. It faces a number of logistical and regulatory challenges in the extraction process and processing operations. Since it produces less than one-tenth of global production capacity, the country's uranium mining industry has always lagged behind global standards in terms of efficiency and productivity, thus resulting in frequent shortages and reliance on imported uranium.

The development of local uranium reserves involves substantial capital outlays in infrastructure, technology, and regulation. A dependable supply of India's nuclear reactor fuel can only be guaranteed by improving the efficiency as well as the sustainability of uranium mining activities. Diversification to other types of fuels such as thorium may facilitate reduced dependence on imports over time for India from abroad.

4. Cost and Financing:

The high costs of building nuclear reactors, which involve large capital investments and take considerable time to build contribute to overruns in construction budgets and delayed project completion. Consequently, it implies that raising funds for the same is quite difficult.

Securing financing for nuclear projects is a significant hurdle, especially given their high capital costs and long payback periods. Private investors are often reluctant to finance

nuclear projects due to uncertainties surrounding regulatory approval, project delays, and the potential for cost overruns.

In order to address economic feasibility challenges and financial barriers associated with nuclear energy development in India innovative financing mechanisms and government support are necessary. For example, public-private partnerships, export credit agencies, and multilateral financing institutions can help attract investment into nuclear power projects. Also, there can be government subsidies, loan guarantees, and tax incentives to encourage private sector participation in a country's (or states') nuclear program.

Possible solutions:

Despite the challenges, India's nuclear energy program holds significant potential for addressing the country's energy security and climate change mitigation goals. To overcome the obstacles hindering nuclear energy development, several measures can be considered:

1. **Promoting Public Participation and Awareness:** In order to gain public acceptance of nuclear projects, it is critical that the public's understanding of nuclear energy is enhanced and their concerns about safety and environmental impact are addressed. In this regard, proactive engagement with local communities, environmental groups, and stakeholders is important. Trust can be built and support for nuclear initiatives created by means of public education campaigns, community outreach programs, and transparency in decision-making processes. Moreover, promoting transparency through establishing avenues for the participation of the general public in planning, implementation as well as monitoring in nuclear projects enhances accountability hence informed decision making leading to greater public acceptance of nuclear power.

2. **Advancing Nuclear Technology:** overcoming technological constraints and improving the efficiency, safety, and sustainability of nuclear power generation are some of the reasons why investing in research and development (R&D) towards advanced nuclear

technology becomes imperative. Therefore, India should now focus its R&D efforts on areas like advanced reactor designs; fuel cycle technologies; and nuclear waste management. To expedite technological innovation in the sector through international collaborations while taking advantage of a global knowledge base, interdisciplinary research initiatives should be promoted. Similarly, creating a favorable environment for innovation and entrepreneurship.

3. **Diversifying Fuel Supply:** Reducing dependence on imported uranium and enhancing fuel security is essential for India's nuclear energy sustainability. Exploring alternative fuel sources, such as thorium, and investing in fuel cycle technologies, including reprocessing and recycling, can diversify fuel sources and mitigate supply risks. India has abundant thorium reserves, and developing indigenous thorium-based reactor technologies can leverage this resource for sustainable nuclear energy generation. Furthermore, establishing partnerships with uranium-rich countries for long-term supply agreements and exploring innovative financing mechanisms, such as joint ventures and resource-sharing agreements, can ensure a reliable and secure supply of nuclear fuel for India's reactors.

4. **Enhancing Regulatory Frameworks:** For the purpose of maintaining high safety standards, transparent licensing, and effective oversight of nuclear activities, regulatory frameworks and institutions need to be strengthened. India needs to give priority to streamlining regulation clearance processes, building up its regulatory capability, and promoting collaboration in security and safety issues across international borders. It is also possible to have more effective regulation and a higher level of public trust in nuclear power by implementing risk-informed regulatory approaches; carrying out regular safety assessments and inspections; creating an atmosphere where accountability matters; and fostering public confidence in the regulatory effectiveness.

   Additionally, developing platforms for independent oversight, public consultation opportunities, and protection against victimization can enhance transparency within regulations hence instilling confidence among ordinary citizens in agencies charged with nuclear energy concerns.

5. **Mobilizing Financing and Investment:** If the cost and financing hurdles are to be overcome, there is a need to create an environment that enables investments in nuclear energy development, which will then expedite the progress of the nuclear projects in India. Public-private partnerships, project finance, and export credit arrangements among others should be considered by India as alternative means through which private capital can be mobilized and financial risks mitigated for investors. Furthermore, offering policy incentives such as tax exemptions, grants and guarantees on loans can encourage private sector investment in atomic power thus reducing the cost of borrowing for such schemes. The country can look at international financial institutions like IFCs, ADBs, and ECAs for affordable capital resources and technical know-how on successful projects.

Conclusion:

India's nuclear power program has been on an upward trajectory since its inception, with India now being regarded as a major player in the global nuclear industry. Despite public opposition, technological limitations, uranium supply concerns, and cost as well as financing barriers; the country has shown strong commitment towards improving its nuclear power capabilities.

In order to surmount these challenges and harness nuclear energy to the fullest extent possible, India must put emphasis on encouraging public participation and awareness, promoting nuclear technology transfer, diversifying fuel sources, improving regulatory frameworks, and mobilizing financial resources for investment. Engaging with stakeholders through R & D funding for different fuel safety regulations and strengthening a conducive investment environment among others can help India address these challenges while achieving its energy security and climate change goals.

Furthermore, this means that not only could India generate electricity to satisfy its growing needs but it could also contribute significantly to international efforts to mitigate climatic changes. The nation can become a leader in the global arena of atomic energy if it capitalizes on its technical know-how base, improves safety requirements as well as cooperation regarding securing atomic materials.

In conclusion, India's nuclear energy program has the potential to play a crucial role in its energy future, provided that the country addresses the challenges and seizes the opportunities presented by nuclear energy development.