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The Role of Nuclear Energy in a Sustainable Future: Benefits and Risks in Addressing Climate Change

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Abstract

Nuclear energy is a type of energy that is emitted by an atom's nucleus, which is made up of protons and neutrons. Nuclear power plays an important role in addressing the global climate problem. It already accounts for one-third of all low-carbon power produced in the globe. Nuclear power provides a consistent, dependable source of power, and its usage can assist to minimize greenhouse gas emissions while meeting the requirements of the world's rising population, particularly in developing nations. However, the use of Nuclear Energy at a wide scale for the production of clean energy is looked at from dual lens i.e. its role in clean energy transition and the legal and disruptive risk it possesses. This research article aims to define what Nuclear Energy is, the legal frameworks governing the production, transmission and other relevant laws and treatise. Further this research paper also provides policy recommendations for strengthening the role of nuclear energy in the energy transformation taking into consideration contemporary framework regarding the nuclear energy globally.

Key words – Nuclear energy, Climate change, Sustainable development, Low-carbon energy, Energy transition, Nuclear safety, Radioactive waste, Greenhouse gas emissions, Environmental risks, Clean energy solutions

Introduction

Nuclear energy is a type of energy that is emitted by an atom's nucleus, which is made up of protons and neutrons. This type of energy may be created in two ways: fission, which occurs when atom nuclei divide into several portions, and fusion, which occurs when nuclei fuse together. Nuclear fission is the method used to generate power across the world today, whereas fusion technology is still in the research and development stage. [1]

Nuclear power plays an important role in addressing the global climate problem. It already accounts for one-third of all low-carbon power produced in the globe. Nuclear power provides a consistent, dependable source of power, and its usage can assist to minimize greenhouse gas emissions while meeting the requirements of the world's rising population, particularly in developing nations. Nuclear power facilities emit essentially no greenhouse gases or air pollutants while they operate. Emissions are extremely minimal during their whole life cycle. It is an essential complement to renewables like wind and solar power, which are intermittent sources of energy. [2] Globally, 444 nuclear power reactors with 394 gigawatts provide around 2,500 terawatt-hours of energy annually, accounting for nearly 10% of total world supply. More than 100 reactors are planned, with 50 already under construction to increase capacity by 55 gigawatts. Nuclear energy can significantly

[1] What Is Nuclear Energy? The Science of Nuclear Power, *IAEA* (May 28, 2020), https://www.iaea.org/newscenter/news/what-is-nuclear-energy-the-science-of-nuclear-power.
[2] International Atomic Energy Agency, Building a Clean Energy Future, IAEA (Mar. 3, 2023), https://www.iaea.org/bulletin/building-a-clean-energy-future.

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contribute to reducing global climate change, according to widely recognized models.[3] According to the IPCC synthesis report, the world is falling short of meeting the Paris Agreement's decarbonization targets due to slow reductions in greenhouse gas emissions. Things have become worse since then. Global emissions are likely to rise by 2030, rather than undergo the dramatic reductions hoped for. This paper will explore the legal framework regarding the control and regulation of nuclear power globally and its role in mitigating the event of climate change.

International Legal Framework

International Atomic Energy Agency (IAEA)

Article III of the NPT requires non-nuclear-weapon states to sign a comprehensive safeguards agreement with the IAEA. The IAEA must apply safeguards to all nuclear material in peaceful nuclear activities within a state's territory, jurisdiction, or control to prevent it from being diverted to nuclear weapons or explosives, as per the agreement. The IAEA has expanded its access to information and places through additional procedures based on the 1997 Model. The new protocol strengthens the IAEA's ability to ensure the peaceful use of nuclear material with full safeguards agreements. By the end of 2014, 124 states have implemented new protocols. The IAEA's mandate is to promote peace, health, and prosperity through atomic energy. Its activities include developing and transferring nuclear technologies for peaceful purposes, strengthening the global nuclear safety framework, and ensuring the security of nuclear materials and facilities.[4]

The IAEA's technical cooperation (TC) program promotes the use of nuclear science and technology to address sustainable development priorities at the national, regional, and interregional levels. The program focuses on six thematic areas: human health, agricultural productivity and food security, water resources management, environmental protection, physical and chemical applications, and sustainable energy development. It also includes a cross-cutting thematic area of safety and security to support the achievement of the Millennium Development Goals.

Treaty on the Non-Proliferation of Nuclear Weapons (NPT)

The NPT is a historic international pact aimed at preventing the spread of nuclear weapons and weapons technology, promoting cooperation in the peaceful use of nuclear energy, and advancing the goal of nuclear disarmament and universal and full disarmament. The pact is the only multilateral pact that includes a binding commitment by nuclear-armed states to the objective of disarmament. The Treaty is considered as the foundation of the worldwide nuclear non-proliferation system and a necessary step toward nuclear disarmament. It was intended to prevent the spread of nuclear weapons, to advance the goals of nuclear disarmament and universal and comprehensive disarmament, and to foster cooperation in the peaceful use of nuclear energy.[5]

[3] Bloomberg NEF, *New Energy Outlook Series*, https://about.bnef.com/new-energy-outlook-series/ .
[4] IAEA Factsheet, *2015 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons*, United Nations, www.un.org/en/conf/npt/2015/pdf/IAEA%20factsheet.pdf.
[5] United Nations Office for Disarmament Affairs, Treaty on the Non-Proliferation of Nuclear Weapons (NPT), UNODA,https://disarmament.unoda.org/wmd/nuclear/npt/#:~:text=The%20NPT%20is%20a%20landmark,and%20general%20and%20complete%20disarmament.

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Under Articles I and II of the pact, the NWS commit not to assist the NNWS in developing or acquiring nuclear weapons, and the NNWS agrees to refrain from pursuing such weapons indefinitely. Article III mandates that the International Atomic Energy Agency (IAEA) investigate the nuclear facilities of non-nuclear-weapon nations in order to verify these pledges and guarantee that nuclear materials are not transferred for military purposes. Furthermore, Article III provides safeguards for the movement of fissionable materials between NWS and NNWS.[6]

Article IV recognizes states-parties' "inalienable right" to explore, produce, and use nuclear energy for non-military reasons. It also encourages the "fullest possible exchange" of nuclear-related information and technologies between the NWS and NNWS.[7] Article IV of the NPT has two crucial elements. The first clause, included in Paragraph 1 of Article IV, is that "nothing in this Treaty shall be interpreted as affecting the inalienable right" of is Parties to utilize nuclear energy "for peaceful purposes" and "in conformity with articles I and II of the Treaty." Thus, States Parties to the Treaty agree that their nuclear activities must conform with Articles I and II of the Treaty. The second element is Paragraph 2 of Article IV, which requires all treaty parties to enable the "fullest possible exchange of equipment, materials, and scientific and technological information" on nuclear energy's peaceful use. Clearly, any right to obtain benefits under Article IV is equally subject to the Treaty's non-proliferation duties.

Paris Agreement and Climate Goals

Climate change has been described as "the defining issue of our time" by the United Nations, with the major goal of the 2015 Paris Agreement being to keep global temperature rise to far below 2 °C relative to pre-industrial levels, with the goal of limiting the rise to 1.5 °C. This is motivated by the scientific agreement that reducing the rise to 1.5 °C will greatly lessen the hazards associated with climate change. Despite this, carbon dioxide emissions from energy continue to climb, hitting a record high of 33.1 billion tons in 2018, and having increased by more than 40% since 2000.[8]

Nuclear power plants emit no greenhouse gases while in operation, and over their life cycle, nuclear produces roughly the same amount of carbon dioxide-equivalent emissions per unit of electricity as wind, and one-third of the emissions per unit of electricity when compared to solar. Experts have determined that achieving the extensive decarbonization necessary to keep the average rise in global temperatures below 1.5°C will make tackling climate change considerably more difficult without an enhanced role for nuclear. Because nuclear power is dependable and can be implemented on a massive scale, it can immediately replace fossil fuel plants, eliminating the usage of fossil fuels for energy generation.[9]

[6] Arms Control Association, *The Nuclear Non-proliferation Treaty (NPT) at a Glance*, Arms Control Association (Oct. 2022), https://www.armscontrol.org/factsheets/nuclear-nonproliferation-treaty-npt-glance.
[7] Treaty on the Non-Proliferation of Nuclear Weapons art. IV, July 1, 1968, 21 U.S.T. 483, 729 U.N.T.S. 161.
[8] International Atomic Energy Agency, *Nuclear Power and the Paris Agreement*, IAEA, https://www.iaea.org/sites/default/files/16/11/np-parisagreement.pdf.
[9] World Nuclear Association, How Can Nuclear Combat Climate Change, *World-Nuclear.org* (Oct. 18, 2024), https://world-nuclear.org/nuclear-essentials/how-can-nuclear-combat-climate-change.

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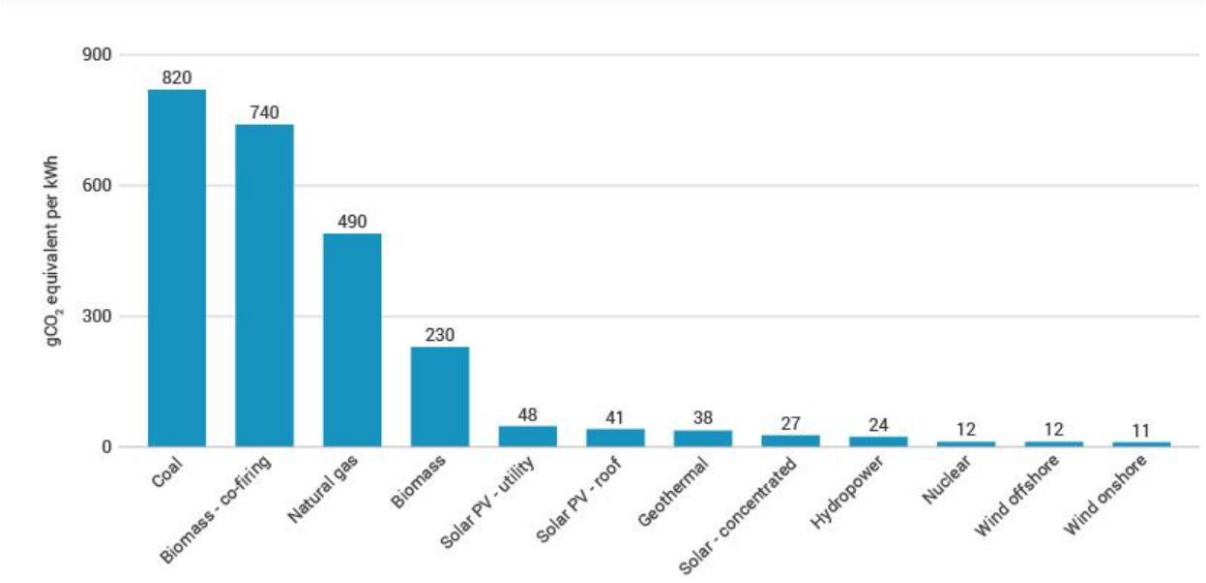

National Legal frameworks around the world

United States

The Atomic Energy Act of 1946, also known as the McMahon Act, established the US government's supervision and management of nuclear technologies produced cooperatively alongside its wartime allies, Britain and Canada. The ruling established civilian authority over nuclear weapons development and power management. It also created the United States Atomic Energy Commission for this reason. Further an act was passed in the year 1954. This Act amends the 1946 Act and establishes a program to promote industrial advancement via research and development to disseminate unclassified scientific and technical information, as well as control and declassify Restricted Data, to control the possession, use, and production of atomic energy and special nuclear material, whether owned by the government or others, to contribute to national defence and security and provide assurance of the government's commitment.[10]

By enacting the Department of Energy Organization Act of 1977, the United States government established the Department of Energy to oversee all federal energy organizations and initiatives. Energy (DoE). The Nuclear Regulatory Commission regulates nuclear energy, making it the lone exception. The DOE now oversees the Federal Energy Administration, Energy Research and Development Administration, Federal Power Commission, and elements of other organizations, including the nuclear weapons program.

European Union

The EU's member states hold a variety of viewpoints on nuclear energy. As a result, unlike with renewables, EU-level plans do not specify future nuclear technology adoption levels. The policies of EU nations with civil nuclear power plants are detailed in individual country profiles. Since 2015, the European Commission has been executing the energy union policy. The energy union intends to integrate and develop the EU's internal

[10] U.S. Dep't of Energy, Nuclear Safety Regulatory Framework (Rev. 1, 2012), https://www.energy.gov/sites/prod/files/2014/01/f7/Nuclear_Safety_Regulatory_Framework_2-22-12(Rev1-final).pdf.

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energy market, with five priorities: improving energy supply security, establishing a single integrated energy market, increasing energy efficiency, decarbonizing the economy, and promoting research and innovation. However, two initiatives are cutting across the single energy market model, both aimed at meeting crucial future demand: national capacity markets and demand response markets. France, Italy, Spain, Portugal, Italy, Greece, and Ireland all provide some kind of capacity payment, which is typically expensive, distorts the market, and runs opposite to the long-term goal of eliminating fossil fuel subsidies. In November 2016, the European Commission announced the EU Clean Energy Package, a bundle of eight legislative measures aimed at implementing the energy union plan. The legislative acts, passed in 2018-2019, establish aggressive objectives for energy efficiency, renewable energy, and carbon reductions by 2030. The plan also eliminated preferential dispatch for new renewable capacity.

In October 2023, the European Commission decided to include existing nuclear facilities in the power market reform. The accord stated that governments may use contracts for difference (CfDs) for investments targeted at extending the working lifespan of existing power plants, but they must adhere to specified "design rules" defined by the EC to avoid market distortion. The revision was part of a larger reform of the EU's energy market architecture, including a law focused on increasing the EU's protection against market manipulation.[11]

The European Parliament voted 376 to 139 in November 2023 to adopt the Net Zero Industry Act (NZIA). The NZIA targets Europe to create 40% of its yearly deployment needs in net-zero technologies by 2030, as well as 25% of the worldwide market value for these technologies. Among the ten suggested technologies are "small modular reactors, associated best-in-class fuels, and advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle.[12]

India

In 1965, India and seven other non-aligned countries proposed the Treaty to Prevent the Proliferation of nuclear weapons, which was approved by the United Nations General Assembly. The INPP has received less attention because to administrative lethargy, corruption, infighting among the scientific community, and a lack of political vision, leading to a loss of talent and opportunity. Some researchers argue that massive financing for nuclear power is insufficient to excuse poor performance and cannot be justified as investments in nuclear weapons. The atomic energy program began modestly and grew into multi-dimensional entities under DAE. Significant activities include research and development in nuclear sciences and engineering, radioisotope prospecting and mining, nuclear energy development and implementation, nuclear energy applications, bio-agricultural research, and medical sciences.[13] Despite acknowledging nuclear energy's promise since independence, India has not made significant contributions to its development. India's transition to a modern nation requires significant energy resources.

Nuclear power has the ability to provide India's energy independence beyond 2050. Nuclear energy now makes up just a small percentage of India's commercial energy use. The liability regimes for nuclear harm have two similar features: they route obligation to the operator, cap this liability, and delegate ultimate duty

[11] World Nuclear Association, Country Profile: European Union, World-Nuclear.org, https://world-nuclear.org/information-library/country-profiles/others/european-union
[12] European Parliament, Nuclear Energy, EUROPEAN PARLIAMENT, https://www.europarl.europa.eu/factsheets/en/sheet/62/nuclear-energy
[13] D.K. Paul & K.K. Singh, Seismic Design Considerations for High Rise Buildings, *38 Sādhanā* 1027, 1027-50 (2013).

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for compensating victims to the government. Following international norms and standards, India's atomic energy regulations appear to be in accordance with IAEA standards. The nuclear power in India is mainly governed by two legal frameworks which have been discussed as follows-

The Atomic Energy Act, 1948

The Atomic Energy Act of 1948, established shortly after India's independence, aims to generate and use atomic energy for peaceful reasons. The Act formalized the country's atomic energy plan. Jawahar Lal Nehru aimed to transform India into a technologically advanced nation by promoting science and technology. During the piloting of the Atomic Energy Bill in the Dominion Legislature, Nehru emphasized the importance of developing atomic energy independently of conflict. The Act was developed in a forward-looking manner. The Act is no longer suitable to address the requirements and difficulties of today's rapidly evolving world due to technological advancements and global developments. The Indian Parliament approved the Atomic Energy Act in 1962, which abolished the previous act.[14]

The Atomic Energy Act, 1962

The Atomic Energy Act of 1962 (Act, 1962) aims to produce, manage, and use atomic energy for India's benefit and peaceful purposes. The Act was expanded to cover all of India and is divided into parts. The Act has been changed three times—in 1986, 1987, and 2015. The Act defines Atomic Energy as the energy emitted from atomic nuclei during any process, including fission and fusion. Also, Radiation refers to gamma rays, X-rays, alpha particles, beta particles, neutrons, protons, and other nuclear and subatomic particles. It excludes sound, radio waves, visible, infrared, and ultraviolet light.39 non-ionizing radiations from telecommunications towers cannot ionize the materials with which they contact. The third definition of a radioactive substance or material refers to any substance that emits radiation over the levels set by the federal government.[15]

Policy Recommendation

India's energy resource base requires the use of an optimal mix of all available energy resources to fulfil its rising demand for power. Nuclear power generation is likely to meet a significant amount of this need. So long, the nuclear power industry has been solely the responsibility of the government. While this is unlikely to change in the near future, with Nuclear Power Corporation of India Ltd. (NPCIL) remaining the sole operator of NPPs, there will be private participation in the form of minority shareholders, vendors, equipment suppliers and contractors. The engagement of a wide range of stakeholders will provide new regulatory issues. The regulatory system requires a more formal legal framework. The Atomic Energy Regulatory Board (AERB) will need to evaluate its roles, duties, and resources to fulfil new needs. AERB must effectively address nuclear safety, site clearances, plant regulations, inspections, public information, sanctions for violations, emergency response mechanisms, waste management, radioactive material transport, and international obligations in new scenarios. This is crucial in gaining public trust and support for the nuclear

[14] Naveen and Prakash Sharma, Atomic Energy in India: Legal Framework, I HPNLU L. J. 165 (2020).
[15] CAG Audit Report No. 9 of 2012 - Performance Audit of Atomic Energy Regulatory Board (AERB), Comptroller & Auditor General of India (2012), https://cag.gov.in/webroot/uploads/download_audit_report/2012/Union_Performance_Atomic_Energy_Regulatory_Board_Union_Government_Atomic_Energy_Department_9_2012.pdf.

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power effort, both domestically and internationally. India must prioritize safety in all elements of nuclear power, including plant design, waste management, and radiation sources.[16]

The Indian commercial nuclear project began in 1969. Early reactors developed in the 1970s met regulatory criteria at the time. Assessing the safety of these reactors against present regulations is a tough issue. Assessing the condition of historical safety components and structures for continuing operation poses a significant problem. AERB recently reviewed and reauthorized older reactors at Tarapur (BWRs), Rajasthan, and Kalpakkam. These plants' conservative designs provide a significant safety margin. However, to fulfill modern needs, a number of upgrades were required. Some examples are as follows:

- Backfitting supplementary control room.
- Segregation of power and control cables to prevent common cause failures.
- Addition of diesel generators to enhance the reliability of emergency power supply.
- Retrofitting of high-pressure injection system into emergency core cooling system for PHWRs.
- Enhancement in fire safety.

Conclusion

Nuclear energy is considered to be one of the cornerstones of the international climate change mitigation effort because it offers reliable low-carbon electricity that can support renewable energy intermittency. Today it provides 10 percent of total global electricity and also helps curb greenhouse gases. With global emissions on the rise, nuclear energy becomes essential for meeting decarbonisation objectives, and more so with regard to the Paris Accord.

According to the IAEA and the NPT treaties, regulatory measures for the utilization of nuclear resources are well coordinated to enhance their usage for peaceful reasons. Thus, national regulations of the countries like the U.S., EU, and India to control the development of nuclear energy and ensuring safe norms.

Basically, in India, nuclear energy could provide the nation a major opportunity for attaining energy self-sufficiency by 2050. However, for this transition to happen some additional regulation and safety enhancements are required. Overcoming these challenges would mean nuclear energy can provide a scalable solution to the energy transition and secure the future.