# Initiatives to build a harmonized regulatory framework for new technologies in Brazil

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**Abstract**

One of the biggest challenges of this century will be to adapt energy production to the country's needs. This production must harmonize low cost, reduced environmental footprint, and low greenhouse effect gases release. Regarding this matter, an interesting concept is the Small Modular Reactor (SMR) which provides passive safety, low cost of operation and installation, long cycles with a duration that can reach 8 years and can help decarbonize. As in other countries, Brazil has a challenge to overcome, which is the need to rethink the licensing process and regulatory scope so as not to negatively impact commercial costs and the production schedule of innovative projects. The SMRs bring new concepts to the reactor licensing process associated with outsourcing, to the modular project´s approach, to a strong decentralization of the project activities, and the safety analysis, building, and commission offsite. The paper presents the Brazilian Nuclear Regulatory Body's initiatives to prepare safety requirements for SMRs in harmonization with the current practices as well as cooperation among regulators to provide a regulatory framework for effective oversight of nuclear power.

## INTRODUCTION

Any country in the world that aims to achieve sustainable and vigorous economic development with energy security will have to consider an adequate supply of safe and clean energy sources.

Since the beginning of the 2000s [1], a process of reconsideration of existing energy policy and structure has been established throughout the world, resulting in an active search for alternative energy sources. The solution to the problem lies in the expansion of energy sources that are capable of satisfying energy needs without political conflicts and on a sustainable basis, while at the same time satisfying contemporary requirements of industrial and environmental safety.

As in many countries, Brazil has been considering, based on the above, nuclear energy as one of the most promising and well-established energy sources, expanding its participation in the energy matrix.

The Energy Research Company - EPE, within its strategic planning and considering the guidelines for PNE 2050 [2] has been structuring actions to increase the participation of nuclear energy in the Brazilian energy matrix. These actions consider the contribution of SMRs as an option to reduce costs and increase the competitiveness of Nuclear as an energy source.

Brazil, as a member of the G20 [3] and currently president of the group, established, among others, the following thematic axis:

Tackling climate change and promoting sustainable development in its economic, social, and environmental dimensions

The working group on Energy Transitions covers the following topics:

• Acceleration of financing for energy transitions

• Social dimension of the energy transition

• Prospects for sustainable fuel innovation

Small SMR modular reactors present themselves as technologies that arouse a lot of interest and expectation mainly because they are suitable for smaller networks, require less initial capital and potentially faster construction with less construction risk. The Brazilian government has established actions to establish guidelines regarding the future implementation of SMR in Brazil on the basis established by EPE [2].

The insertion of SMRs in the Brazilian electrical system represents a significant opportunity to diversify the country's energy matrix, increasing energy security and contributing to environmental sustainability. SMRs offer distinct advantages compared to traditional large nuclear plants, such as a lower initial capital cost estimation, installation flexibility, scalability, and shorter construction time. These attributes make SMRs particularly attractive for Brazil, a country with continental dimensions, with vast energy needs and a geographical complexity that challenges energy distribution and transmission.

For the effective implementation of SMRs, it is essential to consider adaptive marketing models that align with the peculiarities of the Brazilian market. Models such as self-production, distributed generation, direct sales to the market, partnerships with electric companies, and energy service models are viable and offer different benefits and challenges. The choice between these models must be guided by a balance between energy efficiency, economic viability, social acceptance, and regulatory compliance.

Preserving the independence of government guidelines, the regulatory body has been establishing specific actions, within its scope of action, to anticipate possible future implementation scenarios.

The purpose of this paper is to present how, in response to new SMR technologies and their specificities, the Brazilian Nuclear Regulatory Body, National Nuclear Energy Commission (CNEN), has worked to prepare safety requirements and a regulatory framework to provide effective oversight of nuclear power.

## Nuclear Regulation

Nuclear Energy has proven itself throughout history to be an innovative and evolutionary technology that has been leveraging global science and technology. Not only in terms of nucleoelectric generation but also in the sophistication of nuclear medicine exams, image quality and equipment sensitivity. In recent years, applications associated with small modular reactors have been added to this set.

Another very important characteristic in this context is internationality, which guides issues of trade, property, transport, and controls, and expands discussions around international cooperation and harmonization for the drafting of nuclear legislation. [4].

State intervention in nuclear matters in all countries has followed a trajectory like that designed by the United States of America, firstly a phase of reserve and monopoly, then another in which this reserve is much smaller and takes place with industry limitations private and finally state control in the form of a monopoly in terms of possession of nuclear materials. [5]

This state intervention in general is exercised through government bodies that enjoy legal personality and both economic and financial autonomy, which are subject to governments through one of their ministers who may be the president of the industry council, economy included in a Ministry.

We will indicate that the states' mission to control nuclear energy is exercised through the granting of respective licenses and through an inspection of all areas and aspects that the application of nuclear energy can offer.

International harmonization for the drafting of nuclear regulations is a strong feature of the nuclear industry. The first nuclear programs in Europe followed parallel to those in the USA. Most of these programs had their regulations based on US regulations, each country introduced an element of differentiation. The result was that Europe had a diversity of regulatory and licensing criteria, although European regulations applied to nuclear power plants have the same scope as in the USA, which guaranteed a level of harmonization. [4].

The nuclear sector is not the only one that shares the characteristics presented above and sectors such as Civil Aviation and telecommunications are sectors with strong international collaboration and have intentionally laid the foundations from the beginning to establish harmonization and international recognition of safety standards [6]

### Nuclear Regulation in Brazil

In Brazil, state control over nuclear energy is exercised by the Brazilian regulatory body, the National Nuclear Energy Commission – CNEN, which is a government body that enjoys legal personality and autonomy. Carrying out the state's mission to control nuclear energy through the granting of licenses and authorizations and thorough inspections in all areas and aspects that the application of nuclear energy can offer [4]. With the mission of ensuring the safety and peaceful use of nuclear energy, developing, and making nuclear and related technologies available, aiming for the well-being of the population.

CNEN operates in both the energy and non-energy sectors and the energy sector covers the entire Nuclear Fuel Cycle and involves a synergistic combination of:

• Large uranium reserves

• Fuel Cycle Technologies

• PWR technology.

• Non-proliferation and Safeguards

Just like nuclear power plants in other countries around the world, in Brazil it has been installed within a legal framework. According to [4], one of the most important features of this legal framework is the provision of a continuous review and approval process for all phases of the life cycle of an NPP by the licensing authority. The regulatory framework for the nuclear energy sector in nuclear Brazil has a hierarchical structure very similar to the documents of the international agency and some other member states.

The licensing process carried out by CNEN is established by law (*Law n.º 6.189, December 16, 1974,* with the changes introduced by Decree-Law *n.º 2.464, 31/08/1988 and Law n.º 7.781, de 27/06/1989)* and covers the entire life cycle of a nuclear installation as showed in figure 1.

*FIG. 1. Chart showing the the licensing process carried out by CNEN.*

## The need to adapt the regulatory framework for licensing new technologies

The introduction of new nuclear technologies and applications establishes the need to adapt the regulatory system and regulations. Countries that experiment with the introduction of new practices pose some challenges to the regulatory framework.

Adaptation is necessary to ensure that a credible and effective licensing process is developed and implemented for new technologies.

Since the beginning of the 2000s, at a time of worldwide resurgence in interest and activity in the construction of new nuclear installations, states countries such as South Africa, China, South Korea and Pakistan, and the USA report their adaptation efforts, some in search of a harmonized system others focused on reviewing their systems. [7]

We highlight two initiatives here. In the early 2000s [8] South Africa established a process to develop licensing requirements for pebble bed modular reactor (PBMR). This process encountered the main challenges related to its internal human resources capacity to carry out the PBMR licensing review and adjustments. The licensing philosophy requires the insertion of a first-of-a-kind (FOAK) practice.

The US has developed and proposed a program for multinational project approval [9]. The MDAP (Multinational Design Approval Programme) was structured in 3 phases: the first aimed at sharing technical information to support national reviews; the second focuses on the development of more standardized reactor projects, to increase reactor safety; the third phase focused on promoting reactor safety in countries with plans to build them.

Today, SMRs bring a new wave of projects to adapt regulatory systems and the national regulatory organization in Brazil, faced with the movements established by the Government towards future implementation of SMRs, has started a process to adapt the regulatory system, and regulations.

The new wave of adaptation of regulatory systems has been led by the IAEA and is strongly focused on harmonization and international cooperation.

## Initiatives to build a harmonized regulatory framework for new technologies in Brazil

The Brazilian Nuclear Policy has been recently revised, and the Brazilian Nuclear Program Development Committee (CDPNB) was established to set guidelines and targets for developing the Brazilian Nuclear Program and to oversee its execution. The committee ensured that the Brazilian nuclear sector had a regulatory structure with the aim of regulating, licensing, authorizing, controlling, and inspecting its activities. In this context, the Ministry of Mines and Energy (MME) has requested the creation of a technical group to evaluate aspects for the selection of new nuclear sites for the construction of new plants, obtaining its reference from the National Energy Plan 2050, which estimates an expansion of 3.4 to 23.4 GW in the supply of nuclear energy over the next 30 years and the signalling of the construction of a new nuclear power plant in the Ten-Year Energy Expansion Plan 2031. The CBDPN, through Resolution CBDPN 28/12/2023, has outlined guiding principles for selecting new nuclear sites for the construction of future thermonuclear power plants in Brazil. These guidelines have been established for the government agencies involved. See Table 1 for a detailed overview of the CBDPN guidelines.

TABLE 1. CBDPN GUIDELINES FOR CHOOSING NEW NUCLEAR SITES

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| |  |  | | --- | --- | | Nº |  | | Guideline | Responsible  Body(ies) |
| 1 | Assessing the feasibility of expanding thermonuclear power plants in the Brazilian Electricity System | Ministry of Mines and Energy  with support from EPE and ENBPar/Eletronuclear |
| 2 | To establish, in due course, the National Methodological Reference for selecting sites for new nuclear power plants, the Federal Government will create a guide document based on established methodologies and determining factors. |
| 3 | Apply the National Methodological Reference to designate suitable sites for new nuclear power plants and identify potential areas in the country. |
| 4 | To assess the feasibility and extent of liberalizing the Union's monopoly on the construction and operation of nuclear reactors for the purpose of producing civilian energy. | Ministry of Mines and Energy |
| 5 | Updating and revising the regulatory framework for site identification regarding nuclear safety, radiological protection, and physical protection. | National Nuclear Energy Commission |
| 6 | Developing a regulatory framework that considers the potential technological advancements in the upcoming decades. This framework will cover the process of selecting sites for new reactor technologies, including the licensing process for small modular reactors (SMRs) currently underway in several countries. |
| 7 | Updating and revising the regulatory framework to identify sites for building new nuclear power plants, including creating preliminary guidelines for obtaining the Preliminary License as part of the environmental licensing process, within its legal jurisdiction. | Brazilian Institute for the Environment and Renewable Natural Resources |
| 8 | Establish the technical and operational criteria and parameters (technological alternatives, safety requirements, operational and design characteristics) for expanding the nuclear matrix. | Eletronuclear and Empresa Brasileira de Participações em Energia Nuclear e Binacional |
| 9 | Develop a Complementary Technical Note encompassing the implementation of Generation III+ models as well as SMRs. This should include a series of technical specifications and criteria for identifying potential new sites suitable for the installation of reactors. |

In compliance with guideline 5 and 6, CNEN is studying the development of safety requirements for SMRs to consider their characteristics in the regulatory framework and align with current practices. A three-stage work plan has been established for this purpose.

Stage 1 has already started and focuses on building knowledge about the technologies and challenges of licensing and implementing SMR and advanced reactors. CNEN is following the knowledge trail presented by the IAEA, participating in international discussions with short and long-term objectives.

Stage 2, apparently the most extensive, focuses on generating a new licensing model that addresses the new practice and that communicates with the global model of a regulatory review framework that includes safety, security and safeguards by design, in pre-licensing and that this does not conflict with the current bases.

Stage 3 is the implementation through the products of steps 1 and 2 in adapting the regulatory framework to receive new technologies, with the aim of maximizing the effectiveness of the regulatory review of the implementation of new reactor projects.

During Stage 1 development, the main focus was on education and training.

From 2022 to 2024, CNEN established a focus group in conjunction with the Research and Development Directorate and provided training to approximately 20 technicians. They were divided into specific areas as shown in Table 2.

TABLE 2. COMPETENCE TRAINING ACTIONS

|  |  |  |
| --- | --- | --- |
| Area | Number of trainings | Number of personnel undergoing training |
| Safety Assessment and Licensing | 3 | 2 |
| Regulatory Challenges | 1 | 1 |
| Infrastructure and skills training | 2 | 2 |
| Safety aspects | 1 | 1 |
| Fuel Manufacturing | 1 | 1 |
| Technical and legal aspects | 2 | 2 |
| 3 S per project | 1 | 5 |
| Instrumentation and Control and Computer Security | 1 | 1 |

The current licensing process conducted by CNEN does not adequately address certain aspects such as: (i) outsourcing of activities, (ii) modular design approach, (iii) strong decentralization of design and safety analysis activities, (iv) total capacity over time, (v) off-site construction and commissioning, (vi) loading with fuel at the manufacturer, and (vii) transportation of loaded reactors. These are all integral parts of the potential SMR's life cycle.

To address the majority of these issues in a new licensing process, it will often be necessary to modify the legal framework. These modifications are part of the discussions within the guidelines under the responsibility of the Ministry of Mines and Energy.

Other issues such as the certification of the project in modules, incremental licensing, the licensing approach in terms of safety analysis, and its coupling to the various modules are the scope of the discussions on the CNEN guidelines, more specifically in the guidelines 5 and 6, which have been guiding the development of stage 2.

In compliance with guideline number 5, a new standard for SITE APPROVAL FOR NUCLEOELECTRIC POWER PLANTS, which sets out the criteria and requirements applicable to Site Approval for Nuclear Power Plants and the content of the Site Report, expands the field of application, making it possible to implement advanced SMR-type reactors.

In accordance with guideline no. 6, the primary focus is on revising Standard 1.04. This standard outline the requirements for the licensing process of nuclear installations and applies to activities related to important regulatory milestones such as site selection (including the criteria for site selection), construction, and operation of these installations. The updated version of Standard 1.04 expands its scope to explicitly cover reactors used for power and heat generation, as well as modular reactors up to 300 MW per module. It also includes requirements for the use of a gradual approach.

CNEN is updating the current requirements and Safety Analysis Standards. During this update process, CNEN maintains open channels with interested parties and meets regularly with them to discuss pertinent issues. The Standards development process offers broad scope for stakeholder participation in addition to public consultation.

The highlights that are being incorporated into the new requirements to consider SMR are, at a minimum, reviewing safety principles and requirements:

a) Redundancy and diversity, as practicable, physical separation for safety systems to mitigate common cause failures.

b) Accounting for single failure criteria – for passive systems.

c) Define Defence at deep levels - Some levels may not be in line with the IAEA approach (5 levels) for SMRs or - Some levels may be merged with other levels for projects.

d) Availability and capacity factors, scram frequency, frequency and duration of maintenance interruptions per project.

e) Postulated Initiation Events (PIE) may differ between different SMR designs and locations (e.g. external hazards).

Amplifying the range of new CNEN Standards that are being developed, the following examples can be cited:

* New Standard about Cyber Security for Nuclear Facilities - considering that SMR can be operated remotely, it is essential to establish requirements to prevent cyber threats.
* New Standard about Probabilistic Safety Assessment to establish numerical objectives and acceptance criteria for use in the Risk informed decision making.
* New Standard about Severe Accident Management Program that considers the SMR modularity and physical separation.

## The bases of the regulatory framework in Brazil and the challenges for adaptation

Worth mentioning is Brazil's operational experience, with two operating plants and a third one under construction, all of which are pressurized water reactors (PWR). While acknowledging that new disruptive technologies have been developed, Brazil is initially more receptive to pressurized water SMRs due to the knowledge developed in the licensing and operation process reducing efforts and facilitating the acceptance of new practices by stakeholders including technical experts.

It's important to highlight that advanced WCRs have different features compared to conventional reactors. These differences should be analysed in order to create new and specific requirements, but they could be easily adapted for new and more modern technology."

Another important consideration is the validation of the tools used in the SMR safety analysis process. Brazil is currently working on establishing technical cooperation with other countries to facilitate a more extensive exchange in this process. For instance, Brazil's involvement in the second phase of the NHSI has shown CNEN technicians the importance of recommending that the country adopts a licensing process that includes pre-licensing.

In addition to these concerns, it is important to establish specific safety criteria and requirements for cogeneration facilities connected to small modular reactor (SMR) units, such as hydrogen generation and desalination, and others. The discussions held in the Nuclear Safety and Security Infrastructure (NHSI) were particularly significant for Brazil, as the country actively participated in defining the requirements and criteria for general SMR users.

Considering the challenges mentioned above as examples, it is important to highlight Brazil's experience in the facility licensing process. FOAK, Brazil has experience in licensing processes for innovative nuclear installations, as there is a National Reactor Project under development, it is correct to say that CNEN has been working to adapt and improve its standards for considering new nuclear reactor technologies.

Another practice that should be incorporated into the regulatory framework is the certification by other countries. Despite the country's existing experience, a need for standard regulation still exists.

Currently, CNEN is applying the regulation to small reactors with the same licensing criteria and approach used to conventional nuclear reactors. Is important the development of a graduated approach to the regulation, proportional to the risk and appropriate to SMRs. However, the most of recommendations are difficult to apply to SMR due to a lack of knowledge and operational history.

## conclusion

Whereas the nuclear energy sector has adopted a strong emphasis on safety, and this emphasis on safety has resulted in a conservative decision-making process and a risk-averse culture; to deal with new and innovative technologies, the Brazilian regulatory body needs to review the regulatory framework for SMR reception.

Is essential considering evolving to simultaneously maintain responsible nuclear and radiological safety regulation, while facilitating advantageous technological innovation.

The history of large reactor deployment demonstrates that regulatory frameworks and licensing processes impact commercialization costs, project schedules, and budgets.

The development of legal and regulatory frameworks for small modular nuclear reactors is a major challenge, so the regulator must anticipate that the implementation of a future SMR in Brazil will not be impacted by the inertia of the regulatory regime adaptation process and efforts are being undertaken to ensure an effective and timely transition.

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