FEDERATIVE REPUBLIC OF BRAZIL

CONVENTION ON NUCLEAR SAFETY

NINTH NATIONAL REPORT

FOR THE

JOINT EIGHTH AND NINTH REVIEW MEETING IN MARCH 2023

AUGUST 2022

FOREWORD

On 20 September 1994 the Convention on Nuclear Safety was open for signature at the headquarters of the International Atomic Energy Agency in Vienna. Brazil signed the Convention in September 1994 and deposited the instrument of ratification with the Depositary on 4 March 1997 [1].

The Convention's objective is to achieve and maintain a high level of nuclear safety throughout the world. One of the obligations of the Parties, to the Convention, is the preparation of a National Report describing, for a specified period, the national nuclear program, the nuclear installations involved according to the Convention definition, and the measures taken to fulfill the objective of the Convention.

Brazil has presented periodically its National Report, prepared by a group of specialists, composed of representatives of the various organizations in Brazil with responsibilities related to nuclear safety and has submitted its National Report for the Review Meetings organized in 1999, 2002, 2005, 2008, 2011, 2014, 2017 and 2020 (postponed meeting). Due to the implications of the Fukushima nuclear accident in 2011, an Extraordinary National Report was produced and presented during the 2012 meeting, leading to an updated Sixth National Report, presented in the 2014 meeting and a renewed Extraordinary Report, including the lessons learned from the Fukushima accident. Since then, some information related to Fukushima subjects became a part of the National Report. It can be also mentioned that this Ninth National Report includes relevant information for the period of 2019/2021 and is an update of the Eight National Report in relation to the Articles of Convention on Nuclear Safety and the information is provided according to the Guidelines Regarding National Reports (INFCIRC/572-Rev6) [2]. In addition, its National Report highlights the issues identified by the Contracting Parties at the seventh Review Meeting, at the Organizational Meeting and at the Vienna Declaration on Nuclear Safety (VDNS).

The authors decided to prepare the Ninth National Report of Brazil as a self-standing document, with some repetition of the information provided in the previous National Reports so that the reviewers would not need to consult frequently the previous documents.

The executive summary presents the level of fulfillment of the obligations of the Convention on Nuclear Safety by Brazil. Based on these considerations, it can be concluded, that Brazil has achieved and also maintained, a high level of safety in its nuclear installations. The Brazilian nuclear safety-licensing regime has proved to be effective in implementing and maintaining strong defenses against potential radiological hazard to protect individuals, society and the environment of the harmful effects of ionizing radiation, to prevent nuclear accidents with radiological consequences and prompt to act effectively in the case of an emergency. Consequently, Brazil has achieved the objectives of the Convention on Nuclear Safety.

PREFÁCIO

Em 20 de setembro de 1994 a Convenção sobre Segurança Nuclear foi aberta para assinaturas na sede da Agência Internacional de Energia Atômica, em Viena. O Brasil assinou a Convenção em setembro de 1994 e ratificou-a através do decreto legislativo nº 4 de 22 de janeiro de 1997, depositando o instrumento de ratificação em 4 de março de 1997 [1].

O objetivo da Convenção é alcançar e manter o alto nível de segurança nuclear em todo o mundo. Uma das obrigações dos países-membros é a preparação, a cada 3 anos, de um Relatório Nacional descrevendo o programa nuclear, as instalações nucleares existentes, e as medidas tomadas a fim de cumprir este objetivo.

O Brasil tem apresentado periodicamente seu Relatório Nacional preparado por um grupo composto de representantes de várias organizações brasileiras relacionadas à segurança nuclear e submeteu seu Relatório Nacional às Reuniões de Revisão organizadas em 1999, 2002, 2005, 2008, 2011, 2014, 2017 e 2020 (reunião adiada). Devido às implicações do acidente nuclear de Fukushima em 2011, um Relatório Nacional Extraordinário foi apresentado em 2012 e no Sexto Relatório Nacional, apresentado em 2014, uma atualização do Relatório Extraordinário referente às lições aprendidas do acidente de Fukushima foi incluída. Desde então, as informações relacionadas aos assuntos de Fukushima se tornaram parte dos Relatórios Nacionais. Este Nono Relatório Nacional do Brasil inclui informações relevantes para o período de 2019 a 2021 e atualiza a informação contida no Oitavo Relatório Nacional em relação aos artigos da convenção sobre Segurança Nuclear e estas são fornecidas de acordo com as Diretrizes sobre Relatórios Nacionais (INFCIRC/572-Rev6) [2]. Além disso, o Relatório Nacional destaca as questões identificadas pelas Partes Contratantes na sétima Reunião de Revisão, na Reunião Organizacional e na Declaração de Viena sobre Segurança Nuclear (VDNS).

Os autores decidiram preparar o Nono Relatório Nacional do Brasil como um documento completo, com alguma repetição das informações contidas nos outros Relatórios Nacionais de maneira que os revisores não tivessem que consultar freqüentemente os relatórios anteriores.

No sumário executivo é apresentado o grau de cumprimento das obrigações da Convenção sobre Segurança Nuclear pelo Brasil. Com base nessas considerações pode-se concluir que o Brasil alcançou e vem mantendo um alto nível de segurança em suas instalações nucleares. O regime de licenciamento e segurança tem se demonstrado efetivo em implementar e manter defesas efetivas contra o perigo radiológico potencial, a fim de proteger os indivíduos, a sociedade e o meio ambiente de possíveis efeitos nocivos da radiação ionizante, evitando acidentes nucleares com consequências radiológicas e mantendo-se preparado para agir efetivamente em uma situação de emergência. Consequentemente, o Brasil alcançou os objetivos da Convenção sobre Segurança Nuclear.

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A. INTRODUCTION

A.1. The Brazilian nuclear policy

The Brazilian Federal Constitution of 1988 states in articles 21 and 177 that the Federal Government has the exclusive competence for managing and handling all nuclear energy activities, including the operation of nuclear power plants[1]. The Federal Government also holds the monopoly for the survey, mining, milling, exploitation and exploration of nuclear minerals. All these activities shall be solely carried out for peaceful uses and always under the approval of the National Congress.

The Decree 9.828, of June 10th, 2019, recently restructured the Committee for the Development of the Brazilian Nuclear Program (CDPNB, acronym in Portuguese), created by the Decree of July 2nd, 2008, and resumed by the Decree of June 22nd, 2017, which assigned its coordination to the Minister of State Chief of the Institutional Security Cabinet of the Presidency of the Republic. Pursuant Decree No. 9.828/2019, this Committee is an advisory body to the President of the Republic aimed to establish guidelines and goals for the development of the Brazilian Nuclear Program and supervise its enforcement. This Committee is responsible for: I - formulating public policies related to the nuclear sector and proposing improvements to the Brazilian Nuclear Program; and II - to supervise the planning and execution of joint actions by agencies and entities related to the development of the Brazilian Nuclear Program.

The Decree 9.600, of December 5th, 2018, consolidates the guidelines of the Brazilian Nuclear Policy. This Policy is intended to provide guidelines for: the development of the Brazilian nuclear industry; the capacity building of qualified human resources; the maintenance of the domain and the use of nuclear technology in various segments. In addition, it outlines nuclear and radioactive activities in order to ensure the safe and secure use of this technology and reinforces Brazil's position in favor of disarmament and non-proliferation of nuclear weapons.

This document aims to establish general provisions, objectives, and principles for the sector, among which the following stand out:

- safe and secure use of nuclear technology.
- use of nuclear technology for peaceful purposes.

[1] In this Report the terms Nuclear Installation and Nuclear Power Plant are used as synonyms, in accordance with the definition adopted in the Nuclear Safety Convention (Art. 2 - i).

- Brazil's position in favor of disarmament and non-proliferation of nuclear weapons.
- adequate structuring of the nuclear sector.
- safe management of radioactive waste and nuclear spent fuel.
- ensure the safe use of nuclear technology and strengthening activities related to planning and responding to emergencies and events related to nuclear safety and security of nuclear facilities.
- compliance with conventions, agreements and treaties to which the Federative Republic of Brazil is a signatory, e
- international cooperation for the peaceful use of nuclear technology.

Thus Decree 9.600 provides coherence to infraconstitutional legislation with the objectives of the Brazilian State, aligned with the international commitments assumed by the Government and, above all, contributes to the national development and for the promotion of the well-being of Brazilian society."

The National Nulear Commission of Nuclear Energy (CNEN, as the acronym in Portuguese) was created in 1956 (Decree 40.110 of 1956.10.10) to be responsible for all nuclear activities in Brazil. Later on, CNEN was re-organized, and its responsibilities were established by the Law 4118/62 with amendments determined by Laws 6189/74 and 7781/89. Since then, CNEN has became the Regulatory Body in charge of regulating, licensing and controlling nuclear energy, and the nuclear electric generation was transferred to the electricity sector.

On October 15, 2021, was promulgated the Law No. 14,222, that creates the National Nuclear Safety Authority (Autoridade Nacional de Segurança Nuclear, ANSN). the ANSN will became the New Regulatory Body in Brazil, responsible for regulating, licensing, and controlling of civilian use of nuclear energy and protect the public health and the environment against ionizing radiation. The ANSN will assume the regulatory functions previously performed by CNEN.

In that case, an independent Regulatory Body is being created from the separation of the current CNEN into two distinct organizations. The new CNEN will have the competences associated with research and development of nuclear energy, including the operation of research reactors, responsible to produce radiopharmaceuticals, construction of the new Brazilian Multipurpose Reactor - RMB and implementation of an intermediate national deposit of waste. In this sense, 3 decrees were drawn up, establishing (1) qualification of directors, competencies, enforcement actions and ANSN licensing fees (on October 15th, 2021), (2) link to the Ministry of Mines and Energy (on November 19th, 2021), and (3) the organizacional structure of the ANSN. The ANSN will have 3 directors, who will form a collegiate body, with terms of office: A President-Director, a Director of Nuclear Installations and Safeguards and a Director of Radioactive Installations and Control (on 21st July, 2022). This new organization began to function after the approval of the directors, on a meeting to be held by the Brazilian Senate. This hearing is scheduled to take place in August or September 2022. The technical team of this new organization will be composed of the current Directorate of Radioprotection and Safety (DRS), by the Institute of Radioprotection and Dosimetry (IRD), by the Laboratory of Poços de Caldas and by the CNEN Districts.

Finally, ANSN will be linked to the Ministry of Mines and Energy, in according to the Decree No. 10,861, issued on November 19, 2021.

Considering the budget planning of the Federal Government, the national policy for the nuclear sector is implemented by the Multiannual Plan (PPA, as the acronym in Protuguese) for Science and Technology, which establishes quantitative objectives that define the Government strategy. Among these targets one can mention the National Nuclear Policy which guides research, development, production and utilization of all forms of nuclear energy considered of strategic interest for the Country in all aspects, including scientific, technological, industrial, commercial, energy production, civil defense, safety of the public and protection of the environment.

Lastly, the Nuclear Program also aims to increase the participation of nuclear energy in the national electricity production and involves continuous development of technology for the design, construction and operation of nuclear facilities related to the nuclear fuel cycle, which requires improvements on human and financial resources.

A.2. The Brazilian Nuclear Power Program

The main Nuclear Facilities and Organizations in Brazil are showed in Figure 1.

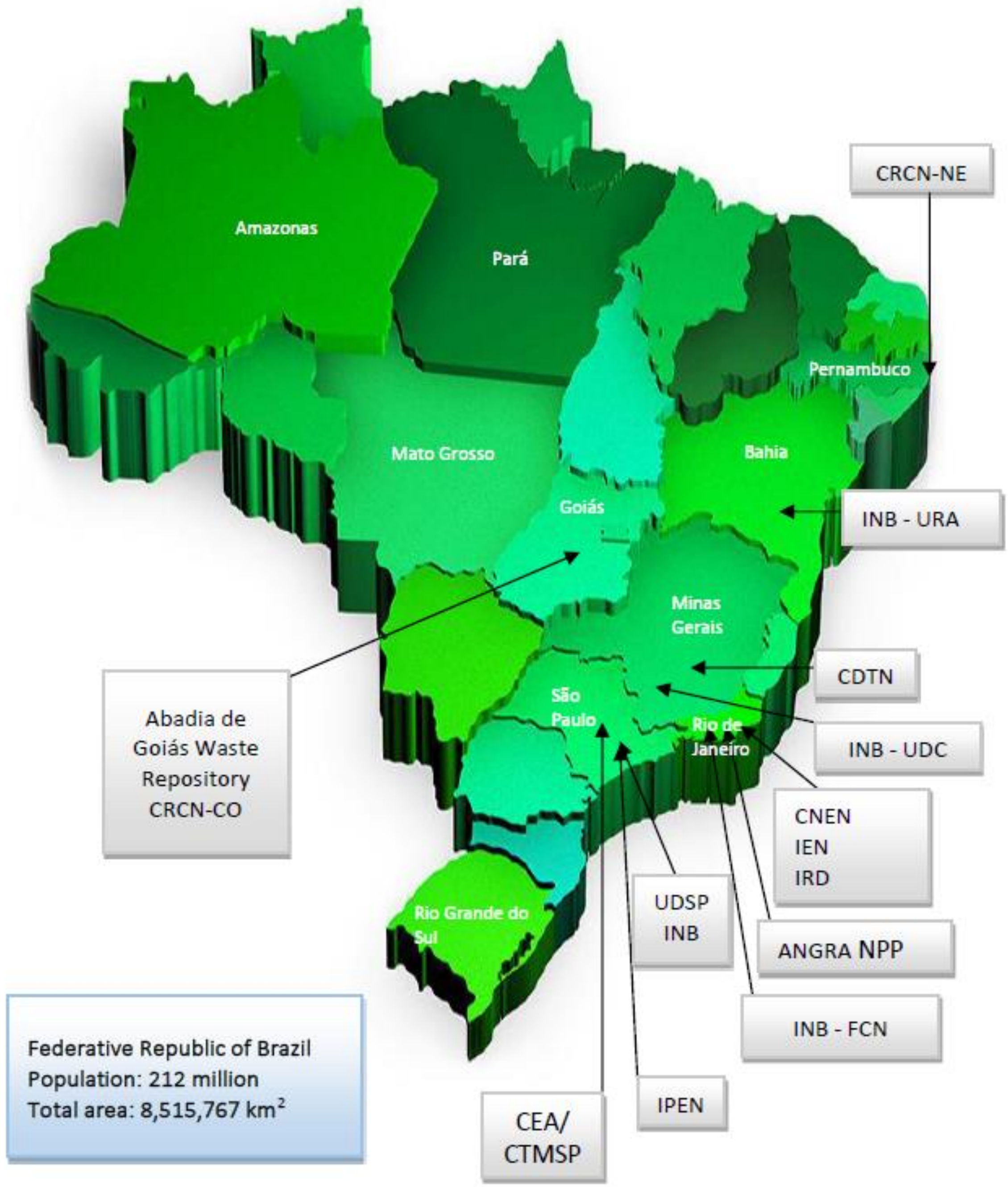

Figure 1 - Main Brazilian Nuclear Facilities and Organizations (*Brazil Report 2020 for the Joint Convention* [3]).

A.2.1 – Nuclear Power Plants

ELETROBRAS-ELETRONUCLEAR S.A, a state-owned company which has succeed FURNAS/ELETROBRAS in 1997 is responsible for design, procurement & follow-up of Brazilian and foreign equipment, management of construction, erection and commissioning of nuclear power plants and is the sole owner and operator of nuclear power plants in the country.

Currently, Brazil has two nuclear power plants in operation (Angra 1, 640 MWe gross / 609 MWe net, 2-loop PWR and Angra 2, 1350 MWe gross / 1280 MWe net, 4-loop PWR), and one under construction (Angra 3, 1405 MWe gross, 4-loop PWR). Angra 1, 2 and 3 share the same site, Itaorna Beach, a municipality of Angra dos Reis, about 130 km from Rio de Janeiro. The construction of Angra 3 was postponed in 1983 and restarted in 2009, having reached an overall progress of 61% by 2015 when it was interrupted due to accumulated delays associated with a restructuring of electricity market in Brazil that caused severe cash restraints for Eletrobras (MP 579). Afterwards, corruption scandals involving some of the construction contracts became public. Since then, all contracts affected by corruption were nullified, and other contracts were suspended. A serious and extensive preservation work was established, to keep all equipment and structures supplied in preserved conditions, ready for project restart.

Following a decision by the National Council for Energy Policy in 2018, Eletronuclear has been working with the National Development Bank BNDES to restructure the project of Angra 3 NPP in its financial and contractual aspects. Also, a deliberation from the Board of Eletrobras in 2021 allowed direct investments in the project, and construction works at site are restaring. The COD (Commercial Operation Date) is estimated to the end of 2027 (See Article 6). At this site there are interim storages for spent fuel (UAS) as well as disposal facilities for low and intermediate level nuclear wastes (CGR).

As it was the case in other countries, the Fukushima accident highlighted the need to reassess not only domestic nuclear safety standards, but also the overall level of participation of nuclear power in the Brazilian energy matrix. Since then, renewed domestic discussions have been taking place on the previous long-term planning studies on energy policy that outlined the convenience of building four new nuclear power plants in Brazil. The Fukushima Plan of Eletronuclear result of joint works between the areas of Engineering and Operations at the company, improved the conditions for on-site and off-site management of emergency situations in alignment of actions undertaken in response to the accident at Fukushima by the international nuclear industry.

The Ten-Year Energy Expansion Plan 2031 (Plano Decenal de Expansão de Energia 2031 – PDE 2031), issued by the Ministry of Mines and Energy of Brazil through one of its organizations, the Energy Research Enterprise (Empresa de Pesquisa Energética – EPE), presents alternatives for the resumption of the Brazilian Nuclear Plan that includes new power plants up to 2031. ELETRONUCLEAR (ETN), jointly with EPE, has worked in the selection of suitable sites for the deployment of new nuclear power plants in the Northeast, Southeast and South of the country. This work is presently in hold.

On December 16, 2020, the Ministry of Mines and Energy (MME) approved the National Energy Plan 2050 (PNE 2050, acronym in Portuguese). Prepared by the Energy Research Company (EPE) based on MME guidelines, the plan is an instrument to support the design of the planner's long-term strategy in relation to the expansion of the energy sector. For this, a set of recommendations and guidelines to be followed over the horizon of 2050 is presented. According to PNE 2050, the government will seek to insert between 8 GW and 10 GW in new nuclear plants over the next three decades.

The construction of nuclear power plants in Brazil has required considerable effort in qualifying domestic engineering, manufacturing, supplier and construction companies, in order to comply with the strict nuclear technology and requirements. The result of this effort, based on active technology transfer, has led to an increase in the participation of domestic technology in the nuclear power sector.

Eletronuclear expects to resume the construction of Angra 3 by 2022, which leads to a start of commercial operation in 2028. The company expects to engage private partners in the project.

A.2.2 – Research Reactors (RR)

In Brazil, all nuclear R&D activities are developed by governmental institutions. They are carried out mainly by CNEN's six R&D Institutes, which are under the Ministry of Science and Technology, Innovations and Communications, and by military technology institutes, which are under the Ministry of Defense. These ministries are responsible for the establishment of the country nuclear R&D policies and strategies, as well as for the provision of the necessary budget and financing mechanisms to make the corresponding R&D projects feasible [4].

Eight nuclear research centers have been established for carrying out R&D in nuclear sciences, technology, and engineering. Research reactors, accelerators, and several R&D laboratories, including pilot plant facilities, were progressively set up in these centers. These research centers belong to the Research and Development Directorate (DPD) of the CNEN and are listed below:

1. IPEN (São Paulo/SP) – Nuclear and Energy Research Institute Research Reactors: 02 pool type reactors, one of 5 MW power and the other of 100 W power. Cyclotron: Radioisotopes Production (99mTc; 131I; 123I; 18F, etc.). Research on fuel cycle and materials, reactor technology, safety, nuclear fundamentals, radiation and radioisotope applications, biotechnology, environmental and waste technologies.
2. IEN (Rio de Janeiro/RJ) – Nuclear Engineering Institute Research Reactor: 01 (100 kW, Argonaut type nuclear reactor). Cyclotron Radioisotopes: production (123I, 18F, etc.). Research on instrumentation, control, and man machine interfaces; chemistry and materials, safety, and reactor technology.
3. CDTN (Belo Horizonte/MG) – Nuclear Technology Development Centre Research Reactor: 01 (250 kW power, TRIGA pool type nuclear reactor). Research on mining, reactor technology, materials, safety, chemistry, environmental and waste technologies.
4. IRD (Rio de Janeiro/RJ) – Radiation Protection and Dosimetry Institute.Research on radiation protection and safety, environmental technology, metrology, and medical physics.
5. CRCN-NE (Recife/PE) - Nuclear Sciences Regional Centre of the Northeast. R&D on radiation protection, dosimetry, metrology, and reactors technology.
6. CRCN-CO (Goiânia/GO) – Nuclear Sciences Regional Centre of the Central-West R&D on underground water and environmental technologies [4].

Therefore, Brazil has 4 research reactors (IEA-R1, IPR-R1, Argonauta, MB-01) operating at CNEN’s institutes and 1 under licensing process. For details and technical data see Article 6 and Annex III. CNEN is currently performing the Safety Assessment of the Preliminar Safety Analysis Report in order to issue a construction licence of a Brazilian Multipurpose Research Reactor – The RMB Project.

A.2.3 - Other Nuclear Installations

Brazil has established a nuclear power utility / engineering company Eletrobrás Termonuclear S. A. (ELETRONUCLEAR), a heavy components manufacturer, Nuclebrás Equipamentos Pesados (Nuclebrás Heavy Equipment - NUCLEP), a nuclear fuel manufacturing plant (Fábrica de Combustível Nuclear - FCN) and a yellow-cake production plant belonging to Indústrias Nucleares do Brasil (Nuclear Industries of Brazil - INB). Brazil has also the technology for Uranium conversion and enrichment, but, up to now, have done it in a small scale. There are also private engineering companies, research and development (R&D) institutes and universities devoted to nuclear power development. Over 15,000 individuals are involved in these activities. Brazil ranks sixth in world Uranium ore reserves, which amounts to approximate 310,000 t U3O8 in situ, recoverable at low costs.

Related to the nuclear fuel cycle, Uranium mining activities developed in the mine of Caetité have the capacity of an annual output of 400 tons of yellow cake, which is enough to meet the needs of both Angra 1 and Angra 2. Reconversion, pellet production and fuel fabrication for both plants is performed 100% in Brazil by INB. The enrichment facility, operates in Resende, with an installed capacity that accounts for 6% of the fuel used in the two power plants. Whereas full capacity in the enrichment process at national level has not yet been achieved, the goal of INB continues to be achieving self-sufficiency, as is already the case in the subsequent phases of the nuclear fuel cycle.

A.2.3.1 – Fuel Cycle Installations

Indústrias Nucleares do Brasil S.A. - INB, a state-owned company which has succeed NUCLEBRAS, has as its main goal the implementation of industrial units related to nuclear fuel cycle for NPPs. Nowadays, in Brazil, there are industrial units for: uranium mining and milling, isotopic enrichment, reconversion, pellet production and fuel element assembly. The mineral exploration program carried out in the last decades resulted in the discovery of new deposits that projected Brazil to be the seventh geological resource in the world, responsible for 11% of that total. It should be taken into account that only 50% of favourable areas of the Brazilian territory have been prospected.

A.2.3.1.1 – Mining and milling

Systematic prospecting and exploration of radioactive minerals in Brazil began in 1952. The exploration was accelerated by the availability of funds for this purpose from 1970 onwards. There was active exploration, and many occurrences were identified through the use of geological, geophysical and geochemical surveys, and related research. From 1974 to 1991, the total amount spent in uranium exploration was equivalent to US$ 150 million. With changes in nuclear policies and, consequently, uranium requirements, investments fell sharply. Since 1991, uranium prospecting was limited to the surroundings of the Caetité production plant.

Brazilian uranium resources occur in several geological environments and, consequently, belong to several deposit types, some of them hosted in near surface. In addition to known resources, there is a high potential for further discovery of economic uranium deposits.

Brazil has been producing uranium since 1982. Between 1982 and 1995 the cumulative uranium production was 1,030 tU from the Poços de Caldas Unit and since March 2000 the cumulative production was 3,761 tU from the Caetité Unit, the only commercial plant currently in operation, for which the short-term uranium concentrate production capability has been 340 tU/year.

Expansion of milling capacity of Caetité to 670 tU/year has been studied. After the planned expansion of Caetité, INB will concentrate on the development of Santa Quiteria deposits. However, since at this new site uranium will be a coproduct of phosphate, the feasibility of the project depends mainly on the phosphate market. Direct employment in Brazilian uranium industry is rising. Losses caused by closure of the Poços de Caldas Unit were offset by increases associated with the beginning of operation and planned expansion of the Caetité Unit.

In 2022, the licensing of a mining-industrial facility and a processing facility to produce uranium concentrate began, in Santa Quitéria (Itataia mining), in the state of Ceara. This mine is expected to produce 2.300 tU/Year

Uranium production in Brazil is only for domestic use. All uranium concentrate produced is shipped to other countries for conversion and enrichment and then returned to Brazil for fuel fabrication.

Brief information on main uranium sites is given below:

a. Poços de Caldas Site

The Poços de Caldas Site, Figure 2, is located at one of the biggest alkaline intrusions in the world. Discovered in 1948, this deposit was developed into an open pit mine. Poços de Caldas Unit started production in 1982 with a design capacity of 425 tU/year.

Since the exploration of the uranium deposit was no longer economically feasible, the Poços de Caldas Unit ceased operations in 1995. After two years of standing by, it was finally shut down in 1997. The closure planning and rehabilitation actions are still under development.

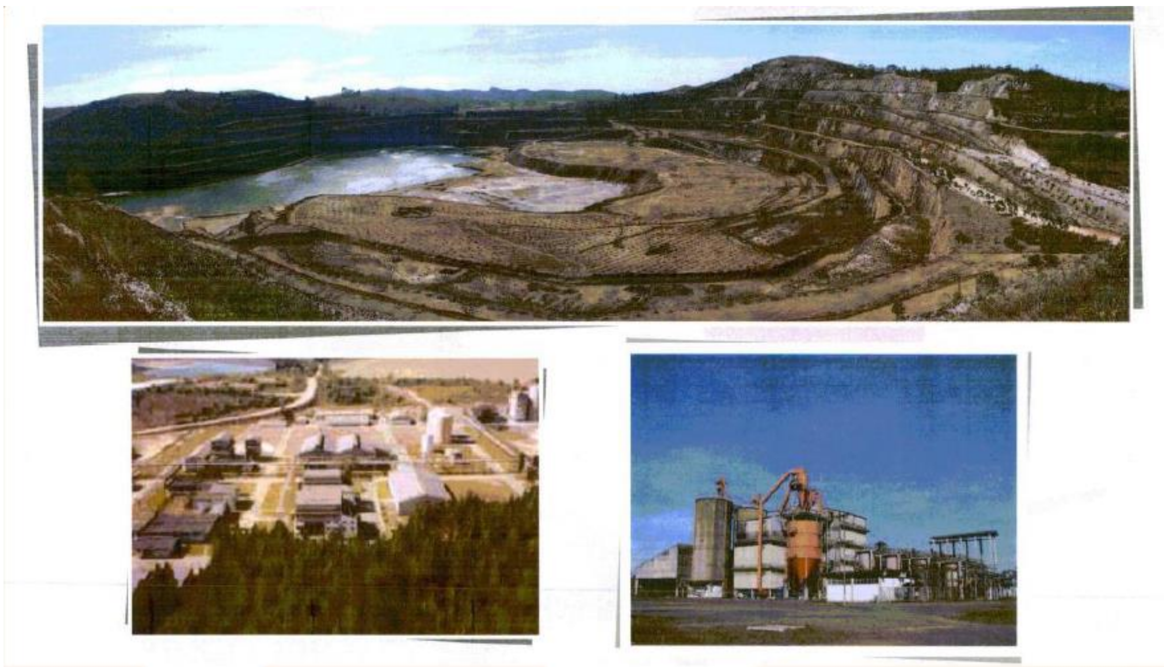

Figure 2 – Poços de Caldas Mining and Milling Facilities

The closure of Poços de Caldas Unit in 1997 brought to an end the exploitation of a low-grade ore deposit, which produced vast amounts of waste rock. Studies for proper decommissioning are being conducted by INB. The operational costs of collecting, pumping, and treating acid drainage were estimated to be US$ 610,000 per year. With the end of the mine exploitation, INB in the first half of last decade used the industrial facilities for other projects such as monazite chemical processing and rare earth production. The project was aborted some years after due to market reasons.

b. Lagoa Real Site (Caetité Unit):

Caetité Unit, Figure 3, is currently the only operating uranium site in Brazil. The deposits were discovered in 1977 and its known resources were estimated to be 85,000 tU in the below US$ 80/KgU cost category, averaging 0.30% U3O8. There are 35 occurrences detected, 12 of which were considered uranium ore deposits. Cachoeira deposits were mined by open pit methods. Surface acid heap leaching methods are used. The plant has a design capacity to produce 400 t/year of uranium concentrate (which is enough to meet the needs of both Angra 1 and Angra 2 nuclear power plants) and there are plans for expansion.

Figure 3 – The Uranium Concentrate Unit (UDC) - Caetité

Mining activities, decommissioning planning, and area rehabilitation are done simultaneously. Monitoring programs are implemented to demonstrate compliance with regulatory requirements. As part of the regulatory licensing process, INB has done an independent hydrogeological assessment of the local aquifer.

Feasibility studies and basic project for Caetité Unit expansion have been carried out. The expansion will increase annual production capacity, which will double current production levels. The cost of expansion is estimated to be US$ 90.0 million.

Since the Cachoeira mine is exhausted as an open pit and waits for the commissioning of an underground mine, the new project for an open pit mine at the Engenho deposit is underway, expected to start production in 2020.

c. Santa Quiteria Site:

The deposit of Santa Quitéria, located in the state of Ceará, is the largest discovered uranium reserve in Brazil. An estimated 142.2 thousand tons of uranium is inter-mixed with phosphates. The economic viability of the mine depends on the exploration of the associated phosphate, which will be used in the production of fertilizers. Current plans are that the mine will be operational by 2026. It is planned to produce 2,300 tons of U_3O_8 per year as a by-product of 240,000 tons of P_2O_5.

There will be two Facilities on the site. A mining-industrial facility, and a nuclear facility for the processing and production of uranium concentrate. The Licensing process began in 2022, with the receipt of the Site Report and the Pre-Operational Environmental Radiological Monitoring Plan, which is in the safety assessment phase.

The Brazilian Institute of the Environment (IBAMA) has already held three public hearings, with the participation of CNEN, and is carrying out an evaluation of the Report (RIMA) and the Environmental Impact Study (EIA).

A.2.3.1.2 – Uranium Enrichment and Fuel Manufacture

In the city of Resende, located in the state of Rio de Janeiro, there is an industrial complex, named Nuclear Fuel Factory (Fábrica de Combustível Nuclear - FCN), consisting of two buildings, which contains four nuclear installations operated by INB, aimed to the manufacturing of nuclear fuel for the Brazilian Nuclear Power Plants.

Figure 4 – The Unit of Enrichment, Reconversion and Fuel Pellets Facilities - Resende/RJ

One building performs three activities: (i) uranium hexafluoride is converted into UO2 powder; (ii) fuel pellets are manufactured and (iii) uranium hexafluoride is enriched (up to 5% enrichment), Figure 4. The nominal production capacity is 160 tons/year of UO2 powder and 120 tons/year of UO2 pellets, but in fact the current demand corresponds only to a part of it. The plant for uranium enrichment, based on ultracentrifuge technology developed by the CTMSP is in operation since 2008, with the current nominal capacity of 50 tons of SWU (Separative Work Unit).

In the other building, PWR fuel assemblies are manufactured using the UO2 fuel pellets from the first unit and other additional components, either imported or produced locally, Figure 5. The nominal capacity is 240 tons/year of uranium oxide. Since 1982, this unit produces fuel assemblies for the Brazilian Nuclear Power Plants, Angra-1 and Angra-2.

Figure 5 – The Unit of Fuel Assembly – Resende/RJ

A.2.4 - The Navy Nuclear Program

In the second half of 1979, the Brazilian Navy started a nuclear technology research and development programme, intended to design, build and operate a nuclear propelled submarine. This programme is carried out by the Navy Technological Center at São Paulo (CTMSP, acronym in Portuguese), which has its headquarters in the city of São Paulo and an experimental site, named Aramar Experimental Center (CEA), located in the rural area of the city of Iperó, where the experimental activities of the programme are performed. Thus, all the CTMSP nuclear facilities, except a small-scale research and development laboratory, are located at CEA. These include: a pilot scale fuel manufacturing unit (LABMAT); uranium enrichment laboratories (LEI and USIDE); an UF6 conversion facility (USEXA) that is being commissioned; a land-based prototype reactor (LABGENE) for a nuclear propelled submarine that is still under construction; and a radio-ecological laboratory (LARE). All these nuclear facilities have been submitted to two licensing processes: a nuclear licensing process conducted by CNEN, and an environmental licensing process conducted by IBAMA. [4]

The safety assessment of the Prelimar Safaty Analysis Report of LABGENE unit is currently in progress. Partial construction permits are being issued, as the safety assessment evolves.

However, should be highlighted that all the Navy nuclear installations, above mentioned, are under the safeguard of the International Atomic Energy Agency (IAEA) – as well as the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC).

The great majority of funds for the installations at CTMSP come from the Brazilian Navy annual budget, which is provided by the Ministry of Defense. Some special projects may also be funded by other governmental institutions, such as governmental research support agencies. [4].

A.2.5 - Other Organizations, Institutions and Companies Involved in Nuclear Power Related Activities

- ***Amazônia Azul Tecnologias de Defesa S.A. - Amazul (Blue Amazon Defense Technologies) – https://www.amazul.mar.mil.br***

Amazul is a state-owned company created in 2012, by to Law 12,706, of August 8, 2012, in order to promote, develop, transfer e maintain sensitive technologies for the Navy Nuclear Program (Programa Nuclear da Marinha – PNM), in particularly concerning the nuclear submarine (Programa de Desenvolvimento de Submarinos – PROSUB), due to its strategic role on the protection of immense Brazilian coast.

Amazul participates in the following programs:

- Navy Nuclear Program (PNM).
- Submarine Development Program (PROSUB); and
- Brazilian Nuclear Program (Civil program).

Amazul participates in the Angra 1 Reactor Operating License Renewal Program. The project aims to extend the operation of the Angra 1 plant for another 20 years, in addition to the 40 years covered by the operating authorization in force until 2024. Amazul together with INVAP also participates in the RMB project in the execution of the detailed design of this reactor. As co-executor of the project, Amazul will participate in several decisive phases, such as development and review of engineering projects, quality control of contracted consultancy services, site logistics, prospection of equipment suppliers in the national and international markets, review of the budget, support for the licensing of the enterprise, etc.

- *Associação Brasileira de Energia Nuclear – ABEN (Brazilian Nuclear Energy Association) – https://aben.com.br*

Founded in 1982 and with its headquarters in Rio de Janeiro, Brazil, ABEN is an independent non-profit organization responsible for the promotion of the pacific uses of nuclear energy in all its different fields, as well as for acting as an information channel on nuclear issues for the Brazilian society in general. Among its members, research scientists, qualified technicians, strategy and defense specialists give advises on: Power production; Naval propulsion; Research, development, application and education; Safeguards; Quality assurance and control; Nuclear and environment licensing, among others.

- *The Agência Brasileiro-Argentina de Contabilidade e Controle de Materiais Nucleares – ABACC (Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials)*

All Brazilian nuclear activities are under safeguard control of CNEN, IAEA and ABACC the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials, created on July 18, 1991, with the signing of the Agreement between Argentina and Brazil for the Exclusively Peaceful Use of Nuclear Energy, henceforth named the Bilateral Agreement.

After having been approved by the Congresses of the two countries, the Bilateral Agreement entered into force in December 1991.

The principal mission of ABACC is to guarantee Argentina, Brazil, and the international community that all the existing nuclear materials and facilities in the two countries are being used for exclusively peaceful purposes. The objective of ABACC is to administer and apply the Common System of Accounting and Control of Nuclear Materials (SCCC), whose aim is to verify that the nuclear materials in all the nuclear activities of the two countries are not deviated towards nuclear weapons.CC is the first integration link between Argentina and Brazil in the nuclear field.

The existence of ABACC is a clear demonstration of the political willingness of the two countries to provide transparency in their nuclear programs, creating an environment of mutual trust, and contributing to an increase in regional and international security.

The two countries provide the financial resources required for the operation of ABACC and must guarantee its institutional independence.

Other factors that determine the success of ABACC are the technical staff, the use of state-of-the-art equipment and the permanent coordination with the national authorities of Brazil and Argentina and with the International Atomic Energy Agency.

The verification activities, such as inspections, are implemented by the IAEA in Argentina and Brazil under an agreement between the two countries, the IAEA and ABACC, and cooperation extends also to support the development and testing of equipment and training.

- ***Associação Brasileira para Desenvolvimento de Atividades Nucleares – ABDAN (Brazilian Association for the Development of Nuclear Activities) – https://addan.org.br***

Established in Rio de Janeiro on October 27, 1987, the Brazilian Association for the Development of Nuclear Activities is a non-profit organization that brings together most of the most important capital goods, construction and assembly companies in the consulting sector. and engineering, operation of plants and manufacturing units of systems and equipment, which participate in nuclear activities in Brazil.

It is currently composed of 25 associates who work together and through ABDAN to promote and disseminate the development of nuclear technology; its public acceptance in the most different applications; intensifying scientific exchange with similar entities and providing assistance to associated companies in their common interests.

Its activities are also geared towards supporting the Brazilian Nuclear Program, the continuation of which will allow the country to ensure the mastery of cutting-edge technology, which is completely aligned with the paths outlined for a sustainable world economy, without carbon emissions and with the capture of green hydrogen.

- ***Nuclebrás Equipamentos Pesados S/A -NUCLEP (Nuclebras Heavy Equipment) – www.nuclep.gov.br***

Founded on December 16, 1975, to serve the Brazilian Nuclear Program, Nuclebrás Equipamentos Pesados S.A.'s main goals are to design, develop, manufacture and sell heavy equipment for the Nuclear sectors; Defense; Oil and gas; Energy and others. Strategic due to the technology it dominates and the unique characteristics of its facilities and equipment, NUCLEP reinforces the Brazilian-based industry, contributing to its development and economic advancement in the country.

Associated with the Ministry of Mines and Energy, Nuclebrás Equipamentos Pesados S.A. - NUCLEP was created by Decree 76,805, of December 16, 1975, as a strategic company to serve the Brazilian Nuclear Program, being responsible for the development and production of replacement equipment for the Angra 1 and 2 nuclear power plants, as well as all components for future power plants.

- *Brazilian Institute for Nuclear Quality (Instituto Brasileiro da Qualidade Nuclear – IBQN) – www.ibqn.com.br*

IBQN was created in 1978 to be an Independent Technical Supervision Organization (Organismo de Supervisão Técnica Independente – OSTI) responsible 1978 to introduce the best practices on Quality Assurance for all Brazilian organizations involved on nuclear activities.

The IBQN is a non-profit civil entity, with legal personality governed by private law, administrative and financial autonomy. Acting upon request, its purpose is to prepare analyses, tests, technical opinions and carry out the monitoring of the design, construction and operation of nuclear facilities, their systems, and components, aiming at the safety and reliability of these facilities and the protection of people and material goods, with competence to:

I. perform analysis and evaluation of projects, manufacturing procedures and functional and pre-operational tests.
II. monitor testing of materials and manufacturing methods.
III. monitor, on site, construction tests, and functional and operational tests.
IV. participate in the commissioning of nuclear facilities.
V. perform in-service inspections, especially with respect to safety-related systems, assemblies, and parts.
VI. monitor technical changes and repairs.
VII. analyze damage resulting from malfunction, improper operation, defects, and accidents.
VIII. advise and/or provide the necessary technical support on the decommissioning of nuclear facilities, especially in the evaluation and inspection, and radiological protection of personnel.
IX. advise and/or provide the necessary technical support on the qualification of the operation and maintenance personnel.
X. perform analysis, testing and inspection of materials and equipment.
XI. qualify Independent Technical Supervisors and Quality Control Inspectors.
XII. qualify institutes and laboratories to carry out studies, analyzes, and tests, in support of their specific activities.

XIII. technically qualify the entities that can provide services, materials, parts and components, equipment, and systems for nuclear and industrial installations in general.

XIV. transfer to the country the techniques and procedures related to Quality Assurance and the technology involved in controlling this quality. In this regard, it should be noted that the analysis and evaluation of projects, from the point of view of safety, are carried out as a subsidy to the licensing agency, to the extent that it deems it necessary.

The OSTI's areas of expertise are civil construction, metal-mechanics, electrical, electronics and instrumentation and control, operation, and maintenance. The OSTI must be qualified by the Regulatory Body, for each of the above areas.

A.3. Commitment to the Nuclear Safety

Brazil was always committed to conduct its nuclear program in compliance with its own safety regulations and best international practices. Brazil has participated actively in the development of the Convention on Nuclear Safety [1], and has signed, ratified, and implemented it since the first review meeting.

The National Reports presented until today have demonstrated compliance with the Convention objectives. The reviews, comments and recommendations in the various review meetings have assisted Brazil in improving even further the level of safety.

Both Brazilian Regulator (CNEN) and Operator (ELETRONUCLEAR) have actively participated in international forums or events related to nuclear safety. In 2014, Eletronuclear created the Nuclear Safety Oversight Committee (COSIS) to do independent assessments of the NPP's safety. Since then, areas like Plants Safety Performance, Supply Chain Management, Integrated Management System and Main Design Modifications, among other relevant topics, are constantly on the agenda of this committee's meetings. The organizational unit in charge of nuclear oversight performed an update of its atribuitions in 2021 in order to reinforce this function. Besides that, it still benefits from the association with the international initiative Latin-America Independent Nuclear Oversight (Lat-iNOS), a joint project carried out together with the nuclear operators of Mexico and Argentina, focused on the continuous improvement of nuclear safety through review processes based on IAEA/WANO Guidelines (See Articles 12 and 19).

Due to this approach, the Brazilian installations have never had a mentionable safety problem, although continuous improvement in safety is being a permanent goal. There are always partially solved or new safety related issues to be worked out, mainly after Fukushima accident, as will be showed in the present Report.

A.4. Structure of the National Report

This Ninth National Report has been prepared by Federal Republic of Brazil to meet the requirements of Article 5 of the Convention on Nuclear Safety [1]. In the first part it describes the national nuclear program, the nuclear installations involved according to the Convention's definition and the measures taken to fulfill the obligations and follows the new Guidelines Regarding National Reports (INFCIRC572/Rev¨6/Jan2018) [2]. In addition, Brazil has used several other sources to present information related to the compliance with the convention (CNS). These include:

1. Summary Report of the President of the Seventh Review Meeting, regarding the key safety issues discussed at the Seventh review meeting.
2. Report of the President of the Seventh Review Meeting, regarding the key safety issues discussed at the Seventh review meeting.
3. The Vienna Declaration on Nuclear Safety: On principles for implementation of objective of the Convention on Nuclear Safety to prevent accidents and mitigate radiological consequences.
4. The Template to Support the drafting of National Report under the Convention on Nuclear Safety referring to relevant IAEA Safety Requirements.
5. Additional recommendations for the preparation of National Reports for the 8^{th} Review Meeting.
6. Generic Safety Observations Report – Report of the IAEA Secretariat to the Eighth Review Meeting of Contracting Parties to the Convention on Nuclear Safety; and the
7. Written and verbal questions raised (and the answers given) on the Brazilian Report to Seventh Meeting of Convention and on the presentation made at the review meeting in March 2017.
8. Country Review Report for BRAZIL, Final Version, Drafted by Country Group No. 5, Convention on Nuclear Safety 7th Review Meeting – 2017, Rapporteur: Mr. Reno Alamsyah.
9. Country Review Report for BRAZIL, Revision 2, Drafted by Country Group No. 7, Convention on Nuclear Safety 8th Review Meeting – 2020, Rapporteur: Ms. Kimberly Green.

10. Compendium of the Information on the 8th Review Cycle, 8th Review Meeting of the Contracting Parties to the Convention on Nuclear Safety, Vienna, Austria, 6 October 2021.
11. Organizational Meeting of the Joint Eighth and Ninth Review Meeting of Contracting Parties, Report of the President, Convention on Nuclear Safety, 20 October 2021.

Part B presents a summary of the national report, highlighting the main safety issues, and addressing the recommendations from previous meeting to all Parties and especially to Brazil. Part C presents an article-by-article review of the situation in Brazil, highlighting the new information related to the period January 2019 - until December 2021. Following the approach used since the first reports the Ninth National Report of Brazil has been prepared as a self-standing document, with some repetition of the information provided in the previous Reports so that the reviewers do not have to consult frequently the previous documents.

Since Brazil has only two nuclear power plants in operation and one in construction, more plant specific information is provided in the report as recommended in the new CNS Guidelines [2]. This was purposely done for the benefit of the reader not familiar with the current Brazilian situation.

The report also includes three annexes providing more detailed information on the nuclear installations, the Brazilian nuclear legislation and regulations, and general information about research reactors.

B. Summary

In according with INFCIRC 572/Rev6/Jan2018 [2]:

"The Summary in the National Report should highlight the Contracting Party's continued efforts in achieving the Convention's objectives. It should serve as a major information source by summarizing updated information on matters that have developed since the previous National Report, focussing discussion on significant changes in national laws, regulations, administrative arrangements, and practices related to nuclear safety, and demonstrating follow-up from one Review Meeting to the next."

B.1 Important safety issues that have been identified in previous National Report or that have arisen since the previous National Report

Below are presented the updated information related to some important safety issues, reported in the Eight Brazilian National Report:

1. The independence of the regulatory body: (See Introduction, Items B.2.9, B.3.1, B.4.1, B.4.2.c, B.4.4.a.i, B.4.4.b.I, B.4.5.a.I and B.5 below and Articles 7 and 8)

2. The situation of PSA of Angra 1 and Angra 2: This item has progressed significantly, as described in Article 14(1). All planned studies for Angra 1 and 2 (fire, shutdown, external events and seismic, level 2) are in progress. (See Article 14)

3. Periodical Safety Review (PSR): Since the first PSR, completed in 2005 for Angra 1, it has become an established process. The second Angra 1 PSR was completed in 2014. The third Angra 1 PSR is in development, and it will address the life extension of the NPP. This assessment is one of the regulatory requirements to be assessed in the plant's life extension licensing process. Discussions are in progress between CNEN and ETN to establish the methodology to be used and to deal with pending issues. This PSR should be submitted in 2023. The current operating license for the Angra 1 plant will expire in December 2024.Now, the third Angra 1 PSR is planned to start in June 2022. The first PSR for Angra 2, covering the first 10 years of plant operation, was completed in November 2012. The second RPS of the Angra 2 plant is in development and discussions are in progress between CNEN and ETN to establish the methodology to be used and to deal with pending issues. (See items below B.4.1, B.2.6 and B.4.4.a.vii, and Articles 6, 7, 14 and 17)

4. Updating of the design of Angra 3: All safety relevant differences of the newest versions of the German Plants (country supplier of the technology), inputs from Angra 2 operational experience, other standards required by CNEN, as well as lessons learned from the Fukushima event, are being incorporated to the Angra 3 design. A full scope of PSA studies, for the design phase (internal events and flooding, fire, shutdown, external events and seismic, level 2), is foreseen and is in the final phase of development. Adittionally, it should be mentioned, that the development of a new Digital I&C Systems is undergoing by FRAMATOME. (See item B.2.5 and Articles 6, 7, 8, 9, 11, 16, 17 and 18)

5. The implementation of a quality management system at CNEN: During the period, the DRS made a great effort, and several directives were implemented or updated, of which the main ones stand out:
    - Processes for the preparation and review of standards and regulatory guides.
    - General Inspection Plan.
    - Radiological and Nuclear Emergency Response System.
    - Inspector's Training Program.

    each of these guidelines unfolds into procedures for the implementation of activities. The procedural framework has improved significantly since 2019, although it still does not present all the elements of an Integrated Management System. Many processes were developed or updated, and some new performance indicators were introduced. The ANSN will be a great opportunity to implement a more integrated system. (See items B.4.4.a.ii, B.4.4.b.II and B.4.5.a.II, and Articles 7 and 8)

6. The consideration of severe accidents in the plant analysis and procedures. This item has progressed significantly, as described in Article 14(1).

7. Simulator status. Two full scope simulators are available for initial training and continuing training for Angra 1 and Angra 2 NPP`s operators, including instructors. (See Article 12)

8. Licensing of new sites for new plants. This issue is on hold, since no application for new sites is anticipated in the near future. On the other hand, during the 2013-2015 period CNEN has issued the Site Approval for the Multiproposal Research Reactor

(RMB) and for an Independent Interim Storage of Spent Fuel which are located in previous approved sites for other installations. (See Article 17).

9. Spent fuel storage. The policy adopted about spent fuel from nuclear power plants is to keep the fuel in safe storage until a technical, economic, and political decision is reached about reprocessing and recycling the fuel or disposing it as such. Therefore, spent fuel is not considered radioactive waste, in the sense of this Convention. The spent fuel storage capacity of the pools of the plants is limited and according to the design of these plants, the fuel assemblies stored for a longer time must be transferred to a complementary storage facility. ELETRONUCLEAR completed the construction of a Complementary Dry Storage Facility in CNAAA, called UAS, in 2021, with the capacity to store of 72 HI-STORMs from the company HOLTEC INTERNATIONAL.The UAS consisted of a cask storage area, a control access cabin, a warehouse and resources for radiological protection and physical protection with a double fence. Additionally, upgrading was performed in Angra 2 and, more relevantly, in Angra 1, to enable the plants, the operations with the transfer cask. After the completion of the UAS construction, it was issued the Final Safety Analysis Report and the environmental and nuclear licenses (initial) for the transfer operation of spent fuels were granted. In 2021, 288 spent fuel elements from Angra 2 were transferred to the UAS, in 9 HI-STORMs, and in 2022, 222 spent fuel elements from Angra 1 were transferred to the UAS, in 6 HI-STORMs. There is a forecast of new nuclear licensing involving a new campaign for the transfer of used fuel from the spent fuel pool of the Angra 2 plant, with criteria different from those initially approved. This new licensing process is expected to start in November 2022. (See item B.2.8, Articles 6 and 19).

10. Emergency management. Lessons learned from the Fukushima event have indicated the need of more investment in the area of Emergency Planning and Response, as for instance, upgrading of the emergency centers and increasing the realism of the exercises. An Action Plan is undergoing to address these new insights. (See Article 16)

11. The assessment of safety culture. This is a continuous program. It has been carried out periodically by ELETRONUCLEAR, since the occurrence of the first company safety culture self-assessment in 1999, with the assistance of the IAEA. Further safety culture assessment was included in the 2011 OSART mission in Angra 2 NPP by IAEA decision, despite the company request of performing a separate SCART mission. Eletronuclear hosted in 2016, 2017 and 2019 three IAEA workshops on

fostering and maintaining safety culture during relevant organizational changes focused on the senior leadership of the company. Besides, the most recent WANO Corporate Peer Review and Plants Peer Review missions hosted in 2014 and 2018, with their respective follow-up missions, included safety culture assessments in their scopes. In 2019 Eletronuclear created a procedure to the company´s safety culture program encompassing all correlated initiatives throughout the company and initiated a 5 steps SC self-assessment based on IAEA and WANO guidelines. It is also foreseen an IAEA Independent Safety Culture Assessment (ISCA) mission to the company for October 2022. (See items B.3.4, B.4.1 and B.4.2.a, Articles 6, 8(1).9. 10 11(2) and 12(4))

12. Ageing management and life extension. Programs for ageing management are in place in both Angra 1 and Angra 2 Plants and are being expanded to meet present-day requirements. In particular, for Angra 1, a large program is being implemented with the support of the Plant Designer, to support it's life extension plan (end of original lifetime is 2024). The regulatory process is using the methodology of USNRC complemented by recommendations from the guides developed by Workgroup 4 of the International Generic Lessons Learned (IGALL) project, from IAEA. The associated technical documentation for this nuclear licensing was submitted in 2019 and completed in 2020. The safety analysis of this documentation is currently underway. The current operating license will expire in 2024. Several technical changes have already been made with a view to its life extension, such as the replacement of steam generators and the reactor vessel head, replacement of the electronic cards of the Control Rods System. Others are planned, such as the replacement of emergency sequencers and the radiation monitoring system. ELETRONUCLEAR has requested two IAEA PRE-SALTO missions to date in order to evaluate its capacity to develop this task. Recommendations were made in these missions, and several have already been considered fulfilled. All the recommendations were already addressed by CNEN. There is a forecast of a SALTO mission to be carried out in 2023. (See the itens B.2.1, B.2.2, B.3.8, B.3.13, B.4.1, B7, B8 and Article 14 (2) and 19(7))

B.2. Future safety related activities and programmes planned or proposed for the period until the next National Report

Future safety activities relate mainly to:

1. Long Term Operation (LTO) and Ageing Management (AM): Angra 1 NPP current license is valid until December 2024 and ELETRONUCLEAR is facing a huge task to demonstrate that the plant can run for more 20 years. For this purpose, ELETRONUCELAR submitted the License Renewall Application to CNEN in October 2019 and is preparing a comprehensive Periodioc Safety Review that shall be submitted to CNEN until December 2023. Consequently, CNEN is interacting with ELETRONUCLEAR technical team and is reviewing those documents and analises. (See the itens B.1.12, B.2.2, B.3.8, B.3.13, B.4.1, B7, B8 and Article 14 (2) and 19(7))

2. Ageing Management (AM): Angra 2 NPP is 21 years old and ELETRONUCLEAR is developing a formal Integrated Ageing Management Program, although there are several individual Ageing Management Programs (AMPs) implemented. (See the itens B.1.12, B.2.1, B.3.8, B.3.13, B.4.1, B7, B8 and Articles 14 (2) and 19(7))

3. Knowledge management – maintain competence and knowledge. (See item B.3.5 and Article 8).

4. Completion of the Fukushima Response Plan. Summary of status util December 2021:
    - completed activities: 38.
    - in progress – original scope: 15 activities.
    - in progress – adictional scope: 2 activities.
    - Canceled: 6 activites, and
    - Suspended: 2 activities. (See Articles 6 itens 6.2.1.1, 6.2.3 and 6.2.3.1, 12.4, 14(1).1, 14(1).3.1, 16(3), 17(3) and ANNEX V).

5. Completion of design and construction of Angra 3 power plant and the associated licensing process; (See the items B.1.4 above and Articles 6, 7, 8, 9, 11, 16, 17 and 18).

6. The third Angra 1 Periodic Safety Review is planned to start in June 2022 and the Second Angra 2 PSR. (See the items B.1.3 and B.4.1 above and items B.4.1 and B4.4.vii below, and Articles 6, 7, 14 and 17).

7. Development and licensing of new digital control and protection systems and the computerized control room of Angra 3. (See items B.1.4 and B.2.5 above and Articles 6, 8, 12, 14 and 18).

8. Nuclear Licensing and Inspection during Construction and Commissioning new campaign for the transfer of used fuel elements from the Angra 2 plant to the Spent Fule Storage installation (UAS).

9. Implementation of ANSN. (See Introduction, Items B.1.1, B.3.1, B.4.1, B.4.2.c, B.4.4.a.i, B.4.4.b.I, B.4.5.a.I and B.5 below and Articles 7 and 8)

B.3. Issues and Topics as identified and agreed upon by the Contracting Parties at the Organizational Meeting

Important topics from previous meetings that have some implication for Brazil are the following:

1. The independence of the regulatory body: (See Introduction, Items B.1.1, B.2.9, B.4.1, B.4.2.c, B.4.4.a.i, B.4.4.b.I, B.4.5.a.I and B.5 below and Articles 7 and 8).

2. Transparency: (See Item B.12 below and Articles 7(2)(ii) B) to transparency in IBAMA and 8(1).10 to CNEN)

3. Safety Oversight within Licensees: The Operating Organization (ELETRONUCLEAR) has established a third safety committee, called Independent Safety Oversight Committee (COSIS), established at the highest company level, comprising representatives of all directorates, reporting directly to the Company Board. In 2021, the Safety and International Affairs Coordination changed its name becoming Safety and Independent Oversight Coordination including special dedication to the independent oversight function at the corporate of Eletronuclear, updating its attributions. (See the Article 10)

4. The assessment of safety culture: (See items B.1.11, B.4.1 and B.4.2.a, Articles 6, 8(1).9. 10 11(2) and 12(4)).

5. Knowledge management – maintain competence and knowledge: CNEN started in 2013 with support of IAEA a project to capture and retain key knowledge need for regulatory process of Brazilian nuclear fuel cycle installations (Nuclear power plants, research reactors and other installations). The project encompasses three major areas: assessment of key knowledge (existing and needs), development of strategy to capture and retain key knowledge needed for the regulatory process of the nuclear fuel cycle installations in CNEN, and development and implementation of methodology (i.e. Mechanisms and tools) for identifying, capturing and disseminating lessons learned and good practices in key regulatory competence areas, see itens B.2.3 above and Articles 8(1).6 and 11(2) about Licensee program.

6. Quality and availability issues in the supply of materials and services: The Operanting Organization implemented an obsolescence programme. This programme includes proactive strategy for reliability and availiability, focusing on Structures, Systems and Components important to safety (SSCs), procedures to manage obsolescence and organizational arrangements for the implementation. (See Article 14 (2))

7. Instrument & Control (I&C) systems: See itens B.1.4 and B.2.5 above and Article 18(2)).

8. Long Term Operation: (See the itens B.1.12, B.2.1, B.2.2, B.3.13, B.4.1, B7, B8 and Article 14 (2) and 19(7)).

9. Reduction of radioactive releases: Lessons learned from the Fukushima event have indicated the need to install Hydrogen Passive Catalytic Recombiners (PAR) inside Containment, as well as a Containment Filtered Venting System, which vents the containment atmosphere through special filters to prevent loss of containment integrity, in case of BDBA like core melt causing high pressure inside the containment. This action is part of the Eletronuclear Fukushima Response Plan (Article 18(1)).

10. Severe accident management / Emergency Preparedness: (action from the Eletronuclear Fukushima Response Plan, see item B.5 and part D.

11. Bilateral Cooperation Issues and Regional Activities. CNEN has Bilateral Cooperation Agreement with Gesellschaft Für Anlagen und Reaktorsicherheit (GRS) of The Federal Republic of Germany for the exchange of technical information and Cooperation in Regulatory and Safety Research Matters. Under this agreement three Workshops were held in the period 2013 to 2019. In the period of 2015 to 2018, CNEN joint to Consortium RISKAUDIT IRSN/GRS carried out a Project, BR3.02/12 - "Support to the Nuclear Safety Regulator of Brazil" and it was dedicated to the enhancement and strengthening of the nuclear safety regulatory regime in Brazil in compliance with international criteria and practices. The Consortium RISKAUDIT IRSN/GRS was chosen by European Commission to carry out this project. This Consortium was composed by Institut de Radioprotection et de Sûreté Nucléaire (IRSN–France), Gesellschaft Für Anlagen und Reaktorsicherheit (GRS - Germany) mbH, Radiation and Nuclear Authority (STUK-Finland) and TECNATOM S.A. (Spain). (See Article 8 and Annex IV)

12. International Cooperation between Regulatory Bodies. CNEN is a member of The Ibero-American Forum of Radiological and Nuclear Regulatory Agencies (FORO). The FORO is an association created in 1997 with the aim of promoting radiological, nuclear and physical security at the highest level in the Latin American region. Today the FORO is composed of radiological and nuclear regulators from Argentina, Brazil, Chile, Colombia, Cuba, Spain, Mexico, Paraguay, Peru and Uruguay. The main objective of FORO is to provide an environment for the exchange of experiences and the development of joint activities related to common problems, in order to achieve the strengthening of the capacity and competence of its members. The FORO believes that one of the instruments for achieving its objectives is to set technical programmes which should be harmonized with the plans of the International Atomic Energy Agency. The basic pillars on which this program is based are: a common technical program that gives priority to national and regional needs, and development of a knowledge network. CNEN also has a Cooperation Agreement with USNRC in the area of safety analysis, including the use of Computational Codes (CAMP and CSARP). (See Article 8)

13. Peer Reviews. (See itens B.7, B.8 and B.9, Articles)

14. IRRS Missions. (See item B.4.5 b.I. Suggestion 1)

B.4. Issues resulting from previous Peer Review Process (Suggestions and challenges summarized in the Country Review Report and review of questions raised by others contracting parties on the 2016 and 2019)

B.4.1 - Overview of questions posted to Brazil by others Counter Parties in Group 7 and others on articles 6 to 19, in 2019:

Question By Article:	The main topics addressed in the questions:
General – 04 Art. 6 - 02 Art. 7 - 03 Art. 8 - 13 Art. 13 - 01 Art. 14 - 03 Art. 15 - 03 Art. 16 - 08 Total = 37	- Environmental Licensing. (Article 7 and 8) - Radioactive liquid and gaseous effluent releases. (Article 15) - Emergency exercise. (Article 16) - IRRS mission. (See item B.4.5 b.I. Suggestion 1) -Safety culture. (See items B.1.11, B.3.4, and B.4.2.a, Articles 6, 8(1).9. 10 11(2) and 12(4)) - Independent nuclear regulatory authority. (See Introduction, Items B.1.1, B.2.9, B.3.1, B.4.2.c, B.4.4.a.i, B.4.4.b.I, B.4.5.a.I and B.5 below and Articles 7 and 8) - Detection of non-conforming, counterfeit, suspect or fraudulent items. - Pre-Salto mission. (See items B.7, B.8 and B.9, Articles Article 14 (2) and 19(7)) - Knowledge management. (See items B.4.4.a.ii, B.4.4.b.II and B.4.5.a.II, and Articles 7 and 8) - Individual Radioprotection mesure. (Article 15) - Monitoring network. (Article 15) - Brazilian Nuclear Policy. (Item A.1) - Filtered containment venting (Post-Fukushima). (Items B.2.4, B.3.9, B.3.10, B.4.5.V, B.10 Articles 6, 14, 16(3), 17, 19(7).2 and Annex V) - Financial and human resource. (Article 8 and 11) - Nuclear Fuel. (Article 6 and 19) - Replacement of the obsolescent items important to safety. - Periodic Safety Review. (See items B.1.3 and B.2.6 above, item B.4.4.vii below and Articles 6, 7, 14 and 17) - Post-Fukushima. (Items B.2.4, B.3.9, B.3.10, B.4.5.V, B.10 Articles 6, 14, 16(3), 17, 19(7).2 and Annex V) - Radiological Environmental Monitoring Program. (Article 15) - Probabilistc Safety Assessment. (Article 14)

B.4.2 – Update the Common Issues emerged from the Country Group discussions during the 7th Review Meeting:

a. Safety culture. (See items B.1.11, B.3.4 and B.4.1, Articles 6, 8(1).9. 10 11(2) and 12(4))
b. International peer reviews. (See subitem 13 of iItem B.3, Articles 14(2) and 19(7))
c. Legal framework and independence of regulatory body. (See Introduction, Items B.1.1, B.2.9, B.3.1, B.4.1, B.4.4.a.i, B.4.4.b.I, B.4.5.a.I and B.5 below and Articles 7 and 8)
d. Financial and human resources. (See Articles 8 and 11)
e. Knowledge management. (See items B.4.4.a.ii, B.4.4.b.II and B.4.5.a.II, and Articles 7 and 8)
f. Supply Chain.
g. Managing the safety of ageing nuclear facilities and plant life extension. (See items B.1.12 2. Of Item B.2, Articles 6, 14 and 19).
h. Emergency preparedness. (See Article 16)
i. Stakeholder consultation and communication:

> "CNEN maintains open channels with stakeholders and regularly meets with them to address pertinent matters. The Standards development process gives a wide scope for stakeholder participation, in addition to public consultation." (See Article 7 and 8)

j. Cybersecurity. (See item 6.3 of Article 6)

B.4.3 - The Common issue emerged from the Compedium of information on the 8th Review Cycle:

a. Information on their experience with response to the COVID-19 pandemic. (See Articles 6, 11, 16 and 19(7).5)

B.4.4 - Suggestions and challenges summarized in the Country Review Report of 7th Review Meeting:

a. After Brazil national presentation, the following topics were discussed during the session:
    i. Independence of the CNEN: (See Introduction, Items B.1.1, B.2.9, B.3.1, B.4.1, B.4.2.b above, and B.4.4.b.I, B.4.5.a.I and B.5 below, and Articles 7 and 8)
    ii. Quality Management System and Integrated Management System. (See items B.1.5 above, B.4.4.b.II and B.4.5.a.II below, and Articles 7 and 8)
    iii. Enforcement capabilities of the CNEN. (See Article 7 and 8)

iv. Future IRRS Mission in Brazil. (See item B.4.5 b.I. Suggestion 1)
v. Relationship between IBAMA and CNEN.
vi. Workforces and Knowledge Management in the context of early retirement scheme.
vii. Periodic Safety Review of the existing facilities, including identification of recent safety standards and guidelines. (See items B.1.3, B.4.1 and B.2.6 above, and Articles 6, 7, 14 and 17)
viii. Preparation of Angra-1 LTO, and Angra-3 project.
ix. Angra dry spent fuel project. (See subitem 9 of Item B.1 and Article 6, 19)

b. The Country Group 5 of the 7th Review Meeting identified the following Challenges for Brazil:
   I. **Challenge 1**: Enhancing independence of the regulatory body: (See Introduction, Items B.1.1, B.2.9, B.3.1, B.4.1, B.4.2.b, B.4.4.a.i, B.4.5.a.I and B.5 below and Articles 7 and 8)
   II. **Challenge 2:** Implementation of a quality management system at CNEN. (See items B.1.5 and B.4.4.a.ii above and B.4.5.a.II below, and Articles 7 and 8)
   III. **Challenge 3**: Staffing, Knowledge Management, and maintenance of competence within the regulator and the operating organization, considering the on-going early retirement. (See items B.4.1, B.4.4.a.ii, and B.4.5.a.II, and Articles 7 and 8)

c. The Country Group 5 of the 7th Review Meeting identified the following suggestion:
   I. **Suggestion 1**: Brazil should consider inviting a full-scope IRRS mission. (See item B.4.5 b.I. Suggestion 1)

d. The Country Group 5 of the 7th Review Meeting made the following observation related to Implementation of the Vienna Declaration on Nuclear Safety (VDNS):

   I. Implementation of the VDNS's principle on new nuclear power plants:
      1. *Brazil is in the progress of incorporating the VDNS principles into a draft of CNEN standard as a part of the EC Project with the support of STUK (Finland), GRS (German) and CNS (Spain). The draft incorporates new concepts based on the IAEA safety standards and WENRA Harmonization Guidelines; and,*

2. *Brazil established Fukushima Action Plan with the objectives of: Assuring that safety systems are preserved in case of extreme conditions associated with external or internal events, beyond the design basis; Provide alternative possibilities for reactor and fuel pool cooling, for beyond design basis; and, provide means to minimize the risk of losing containment integrity and releases of radioactivity materials to the environment.*

II. Implementation of the VDNS's principle on existing nuclear power plants:

"The report does identify measures to revise some of the existing guidance or adopt new guidance, for example on SAMG, to fully incorporate the second principle of VDNS regarding reasonable upgrades in existing NPPs viz a viz avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions."

III. Taking into account IAEA Safety Standards and other international Good Practices in the national requirements and regulations addressing the VDNS principles

"The third principle of VDNS was adopted in Brazil national requirements and regulations."

IV. Issues faced by Brazil in the implementation of the VDNS

"No information available regarding how Brazil faces or expects to face issues in applying the Vienna Declaration principles and safety objectives to its existing fleet or new builds of NPPs."

e. The Country Group 5 of the 7th Review Meeting s identified the following areas of good performance by Brazil:

I. ***Area of Good Performance 1****: Upgrade of Seismic Analysis using the US NRC methodology of Probabilistic Seismic Hazard Analysis – PSHA performed in accordance with international best practice and consistent with the guidelines of the Regulatory Guide 1.208 (USNRC, 2007) – A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion. The* *calculations were performed with the OpenQuake hazard-engine developed by the Global Earthquake Model (GEM) project; and,*

II. ***Area of Good Performance 2**: Development of SAMGs for Angra 1 based on WestinghouseOwners Group (WOG) Methodology and SAMGs for Angra 2 based on AREVA SevereAccident Management Concept.*

B.4.5 - Suggestions and challenges summarized in the preliminary Country Review Report of 8th Review Meeting:

a. The Country Group 7 of the 8th Review Meeting identified the following Challenges for Brazil:

   I. **Challenge 1**: Enhancing independence of the regulatory body. (See Introduction, Items B.1.1, B.2.9, B.3.1, B.4.1, B.4.2.b, B.4.4.a.i, B.4.4.b.I above and B.5 below and Articles 7 and 8)

   II. **Challenge 2**: Implementation of a quality management system at CNEN. (See items B.1.5, B.4.4.a.ii and B.4.4.b.II above, and Articles 7 and 8)

   III. **Challenge 3**: Staffing, Knowledge Management, and maintenance of competence within the regulator and the operating organization, considering the on-going early retirement:

   "This is still a challenging subject. ANSN, as an independent regulator with better financial support, will seek resources to face this challenge."

   (See items B.4.1, B.4.4.a.ii, and B.4.4.b.ii, and Articles 7 and 8)

   IV. **Challenge 4**: Preparation for the review of the License Renewal application for Angra 1 NPP and for its long-term operation:

   "The License Renewal process is undergoing. The operator has submitted the License renewal Application and the assessment and audits performed by the regulator until now do not result in concerns or unresolved issues"

   (See the itens B.2.1, B.2.2, B.3.8, B.3.13, B.4.1, B7, B8 and Article 14 (2) and 19(7))

   V. **Challenge 5**: Completion of the Fukushima Response Plan. (See items B.2.4, B.3.9, B.3.10, B.4.1, B.10 Articles 6, 14, 16(3), 17, 19(7).2 and Annex V)

   VI. **Challenge 6**: Construction of a complementary dry storage to complement the capacity of the Angra 1&2 spent fuel pools:

"The UAS construction was completed, and the commissioning was successful and an Authorization for operation was issued."

(See Article 19(8).2)

b. The Country Group 7 of the 8th Review Meeting held the same suggestion identified in the 7th Review Meeting:

I. **Suggestion 1**: Invite an IRRS Mission.

"It should be mentioned that not only during the 6th, 7th, and 8th RM this suggestion was done. This aspect is also, sometimes, a side discussion topic during the Board of Governors and General Conference Meetings. It can be also stated that Brazil is undergoing, in the last years, some actions have been done in the preparation of an effective IRRS mission. Two IAEA expert missions related to lessons learned, from other countries, of the adequate structuring and functioning of the regulatory body and a self-assessment process has been initiated for the identification of weaknesses. As presented in item B.4.5. a.i. above, Brazil creates the National Authority on Nuclear Safety (Autoridade Nacional de Segurança Nuclear, ANSN). The ANSN will assume the regulatory functions previously performed by CNEN. It is our understanding that this new regulatory body should undergo, after a reasonable time for its complete implementation, a self-assessment process for the preparation of an IRRS mission, in the future."

c. The Country Group 7 of the 8th Review Meeting identified the following areas of good performance by Brazil:

I. **Area of Good Performance 1**: Organization of peer review with other Latin American countries (i.e., Lat-iNOS mission).

B.5. - Describe significant changes to the Contracting Party's national nuclear energy and regulatory programs and measures taken to comply with the Convention's obligations

Recently, the Federal Government approved the Law No. 14,222, of October 15, 2021, which creates the National Nuclear Safety Authority (ANSN, as the acronym in Portuguese), a federal agency with its own assets, administrative, technical and financial autonomy, with the institutional purpose of monitoring, regulating and inspecting nuclear safety, nuclear security and radiological protection of nuclear activities and installations, nuclear materials and sources of radiation in the national territory, in accordance with the provisions of the Brazilian Nuclear Policy and the guidelines of the federal government. The ANSN will assume the regulatory functions previously performed by CNEN.

The establishment of ANSN was proposed by a technical group created within the scope of the CDPNB, with the objective of presenting a proposal to separate the government policy and the coordination of promotion activities for the use of nuclear energy from activities related to inspection, regulation, licensing and control of the uses of nuclear energy and nuclear materials.

By the establishment of this new agency, Brazil keeps the regulatory structure of the nuclear sector up to date, observing the areas of action of its stakeholders, and fully complies with the provisions of Article 8 of the Convention on Nuclear Safety, which establishes that "each Contracting Party shall take appropriate measures to ensure an effective separation between the functions of the regulatory body and those of any other body or organization related to the promotion or use of nuclear energy".

The ANSN basically covers all the competences and responsibilities that are currently performed in the Brazilian regulatory system, but it brings some new important features:

- Full independence from regulatory activities in relation to nuclear technology promotion and operation activities
- Establishment of a new decision-making process, through a Board of Directors, composed of three directors with recognized experience in the nuclear sector, approved by the Senate, and with a mandate of 5 years.
- Increase in licensing fees, which will provide better financial support to ANSN.
- Creation of a new type of sanction, through fines, which is presented as the biggest challenge for the ANSN, as it was not part of previous regulatory practices.

Despite the Law, the ANSN has not yet come into force, as it depends on administrative arrangements to implement the separation from CNEN, which will be encharged of promotion, research and development of nuclear subjects.

(See Introduction, Items B.1.1, B.2.9, B.3.1, B.4.1, B.4.2.b, B.4.4.a.i, B.4.4.b.I above, and Articles 7 and 8),

B.6. - Respond to the IAEA Generic Safety Observations Report (see Section III of the Guidelines regarding the Review Process under the Convention on Nuclear Safety) if provided and if relevant to the particular national situation.

Important challenges identified by the Special Rapporteur for consideration by Contracting Parties in the Generic Safety Observations Report issued before the 7th Review Meeting:

1. How to minimize gaps between Contracting Parties' safety improvements? (Articles 6, 14)

According to the Law 6.189/74, the License for construction and authorization for the operation of nuclear facilities will be conditioned to adapt, as applicable, to newly emerging conditions necessary for safe installation and preventing the risk of accidents arising from its operation. CNEN Standard CNEN-NE-1.14[6] requires that the Operating Organization systematically carry out the assessment of its own operating experience, as well as of other plants. The operational experience should be examined in order to detect any warming signs of possible adverse trends to safety. The Operating Organization shall maintain communication channels with designers, manufacturers and other organizations to obtain the feedback of other operational experience, as well as obtaining, the update information related to the changes and also the advice in the event of equipment and / or abnormal events faults.

The Operating Organization, ELETRONUCLEAR, integrates the PWR Owners Group of Westinghouse, with focus on the following objectives:

a. Support safe and reliable plant operations,
b. Provide an effective regulatory interface,
c. Effectively leverage the resources of its members, including Westinghouse and FRAMATOME,
d. Provide a forum for joint discussions and resolution of issues common to more than one member,
e. Provide a mechanism for allocating costs and resources relative to resolution of owners group issues, whether performed Westinghouse, FRAMATOME, or others,
f. Provide an effective interface with NEI, EPRI, INPO and other industry groups and owners groups on industry issues,

g. Share best practices and lessons learned among US and International Members.

ELETRONUCLEAR is also a member of WANO and systematically hosts plant and corporate peer reviews missions, conducted as mentioned in item B.3.12) above and Article 19(7).

Other important aspects that shoud be mentioned, from our point of view, is the increase of CNEN´s participation in various forums and projects, where specific subjects are discussed and its status are presented for each country. (See item B.3.11), B.3.12 and Article 8).

As a suggestion, IAEA should organize specific discussions among regulators from various countries with similar or same NPP design and designer. For example: Workshops or meetings among "Westinghouse Regulators", "GE Regulators", "KWU Regulators" "VVER Regulators", and so on.

2. How to achieve harmonized emergency plans and response measures? (Article 16)

It should be noted that, due to the particular geographical location of the Angra NPP´s no radiological impact is expected in any neighboring countries, even in the improbable event of a major release. Notwithstanding the fact, that Brazil has signed both the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency, as well as a bilateral agreement with Argentina for notification and assistance in case of a nuclear accident (See Article 16 and Annex III).

Nevertheless, Brazil has taken the necessary steps to improve its emergency preparedness, more specifically, CNEN started in 2015 the Project BR3.01/12 supported by RiskAudit under UE assistance to:

- Advise CNEN on the selection of relevant information related to emergency situations, to be made available in CNEN's Headquarters Emergency Room in Headquarters on-line and in real time.
- Support CNEN to further enhance the functionalities of the ARGOS-BR code in order to deal with the Brazilian Emergency Planning Zones (EPZs).

On the area of emergency preparedness, CGRC is an active member of the ARGOS consortium and participate on the yearly seminar to share experience with other international users.

It can be said that the harmonization of emergency plans and response measures are not easy tasks since there are differences among national legislations and the organizations involved in each country. In some countries there are few organizations to respond to an event, while in others there are a lot of them, including different governmental levels as municipality, state or federal. In spite of that, a good practice could be the improvement of regional cooperations.

3. How to make better use of operating and regulatory experience, and international peer review services? (Article 19)

Brazil participates actively in the IRS and IRSRR meetings. The operator undergoes regularly peer review, as mentioned above and has increased the number of reports during the period 2013-2015. (See Article 19 (7)). It should be mentioned that, as a suggestion, IAEA should discuss an improve on the treatment of small or near missing events, to make a better use of them.

ELETRONUCLEAR has adhered to IAEA and Wano Peer Review Programs from their inception, and and more recently asked for two Pre-SALTO missions as a part of its preparation for Angra 1 NPP license renewal, see table 7 and 8 in Article 19.

In 2009, an IAEA's expert reviewed the CGRC's processes against some IAEA documents related to regulatory activities. The conclusion was that the CGRC's processes were consistent with the IAEA recommendations, but there were room for improvements. At that time, 36 recommendations were done and about two third of that were already implemented. However, some are still pending, mainly those one related to standardization of some processes. The status of each subject is somehow described along this Report.

CNEN is planning to request in the future an IRRS mission in Brazil.

As a suggestion the IAEA should discuss an improvement on the treatment of small or near missing events, to make a better use of them.

4. How to improve regulators' independence, safety culture, transparency and openness?

As evidenced in Article 8 (2) the regulatory function (DRS) and the promotion function (DPD) are both inside CNEN and are independent from the Operating Organization. As mentioned, above, CNEN has made efforts to increase its regulatory independence. As stated, in B.5, the Brazilian government create National Nuclear Safety Authority (ANSN, as the acronym in Portuguese).

The better way to improve regulatory effectiveness is still through international cooperation. Benchmarking among Member States with similar Nuclear Programs, is also seen as a good practice.

5. How to engage all countries to commit and participate in international cooperation?

There are a lot of good IAEA's initiatives in terms of cooperation. As a suggestion for further enhancement, IAEA should increase the participation of the developing countries as observers in peer reviews and stimulate regional cooperation.

B7. - International peer review missions and follow-up missions, including a description of policies, plans and schedules for such missions.

ELETRONUCLEAR has regularly requested Peer Review Missions performed by the WANO and the IAEA, as they aim to identify industry best practices concerning safety and reliability in plant operation. ELETRONUCLEAR adhered to these review programs from their inception, and since 2004 has established policy of performing a complete internal (self-assessment) and external evaluation at 3-year cycles, alternating IAEA OSART and WANO Peer Reviews. For Angra 1 NPP, ELETRONUCLEAR asked for two IAEA Pre-SALTO Missions in 2013 and 2018, a Pre-SALTO Followup Mission in 2022 and a Full Scope SALTO Mission in 2023 in order to evaluate its capacity to operate the plant for Long Term Operation, In 2014 and 2018, ELETRONUCLEAR hosted two WANO Peer Review and Follow-up Missions as well as a Corporate Peer Review Mission in 2014 with respective follow-up in 2018. There is a forecast of a SALTO mission to be carried out in 2023. (see Articles 14 (2) and 19 (7)).

B8. - Results of international peer review missions including the IAEA missions conducted in Brazil during the review period, progress made in implementing any findings, and plans for follow-up.

At first part of 2022, The IAEA Crew integrated by expert from Argentine, Hungary, Sweden ans Slovenia carried out an Inspection on Angra 1 to conclude the Pre-Salto Mission for Angra 1. Thw objwctive was verify the implementantion status of mesures stablished by ELETRONUCLEAR (ETN) to complay with the recommendation made by the IAEA Experts in previous missions in 2013 and 2018. A new mission, with integral scope, is already scheduled for 2023 that will focus on the safety aspects related to long term operation of Angra 1. The objective of thi process, requested by ELETRONUCLEAR, is carried out an idenpendent evaluation of Life Extension Program of Angra 1.

In the mission helded in 2022, the IAEA Expeets were able to verify the ELETRONUCLEAR's efforts to implement significatives improvements in the areas of aging management to comply with recommendation. The mission considered that 11 of the 21 deficiencies identified in the 2018 report had been resolved. In eight of the others, progress was evaluated as satisfactory, with only following the path outlined to reach the final solution. In the remaining two, it was judged that there could still be further improvements. (See Articles 14 (2) and 19 (7))

B.9. - The measures taken by Brazil to voluntarily make public the reports on their international peer review missions.

ELETRONUCLEAR has made available through digital media a summary of the missions and the results obtained. CNEN has made avaible the National Report for Covention on Nuclear Safety in this link: https://www.gov.br/cnen/pt-br/assunto/radioprotecao-e-seguranca-nuclear/relatorios-de-convencoes-de-seguranca.

B.10. - Operating experience, lessons learned and corrective actions taken in response to accidents and events having significance for the safety of nuclear installations.

Operational experience is an important tool to ensure the safety of nuclear installations. CNEN has a standard establishing regulatory criteria for the notification and classification of operational events, and the development of associated technical reports, using the USNRC normative basis as a reference. When classified as relevant to safety, the notification to the regulatory body must be made within 1 or 4 hours and the respective report must be submitted within 30 days. These reports present root house analysis, associated corrective actions, safety significance and lessons learned. These reports are evaluated by the regulatory body to verify compliance with regulatory requirements. The resident regulatory inspection routinely monitors the occurrence and treatment of operational events at Angra's nuclear plants. ETN also monitors operational events of interest that occur at other nuclear plants through WANO. Annually, audits are carried out in the area of operational experience.

CNEN participates in the IAEA's International Report System (IRS) committee, registering operational events that take place at the Angra plants, presenting at the committee's annual meetings, the events of greatest interest that occurred in the current and previous year. This information is shared with ETN through the IRS database. In a similar way, CNEN acts in the evaluation of research reactor events.

The ELetronuclear Response Plan to Fukushima can be mentioned as goog example of the initiatives originated by the external operating experience. The corrective actions taken in response to this accident are discussed in the Articles 14(1).2 and 19(7). Finally, the ANNEX IV shown a balance of activities implementation.

B.11. - Actions taken to improve transparency and communication with the public.

CNEN is a governmental organization and as such is subject to Access to Information Act (Law 12.527/11), this law regulates the right of the public to acess information and establishes the principle of maximum disclosure of information held by public authorities, and secrecy as an exception. The exceptions are linked with proprietary information, security-related information, and sensitive information. CNEN makes availiable at https://www.gov.br/cnen/pt-br all information related to nuclear activities and the national policy to the public access. Questions can be done in the Government Website, and it has 30 days to be answered. Finaly, public consultation is part of the standard and regulations development process and has the objective of improving the Transparency of nuclear regulations elaboration process, allowing the participation of interested parties such as professional associations directly involved, organizations interested in its application and the public.

B.12. - Conclusions

At the time of the Ninth review meeting of the Nuclear Safety Convention, Brazil had demonstrated that the Brazilian nuclear power program and the related nuclear installations met the objectives of the Convention. During the period of January 2019 to December 2021, Brazil has continued the operation of Angra 1 and Angra 2 in accordance with the same safety principles, including the Research Rectors.

Based on the safety performance of the nuclear power plants in Brazil, and considering the information provided in this Ninth National Report, the Brazilian nuclear organizations consider that its nuclear program has:

- Achieved and maintained a high level of nuclear safety in its nuclear installations.
- Established and maintained effective defenses in its nuclear installations against potential radiological hazards to protect individuals, the society and the environment from harmful effects of ionizing radiation.
- Prevented accidents with radiological consequences and is prepared to mitigate such consequences should they occur.
- Improved the conditions for on-site and off-site management of emergency situations in alignment of actions undertaken in response to the accident at Fukushima by the international nuclear industry.

Therefore, Brazil considers that its nuclear program related to nuclear installations has met and continues to meet the objective of the Convention on Nuclear Safety.

C. REPORTING ARTICLE BY ARTICLE

ARTICLE 6 – EXISTING NUCLEAR INSTALLATIONS

"Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact."

6.1 – Existing nuclear installations as defined in Article 2 of the Convention

Brazil has two nuclear power plants in operation, Angra1, 640 MWe gross / 610 MWe net, 2-loop PWR and Angra 2, 1350 MWe gross / 1280 MWe net, 4-loop PWR. A third plant, Angra 3, 1400 MWe gross / 1330 MW net, PWR, having as reference plant Angra 2, had the construction postponed in the mid-eighties. By a Governmental decision, the Angra 3 NPP project has resumed, and construction activities restarted in 2009. The Construction Permit was granted by CNEN, in May 2010. Because of contractor problems and a political decision, construction was interrupted again, in September 2015 (see section 6.3 of this Article).

In 2018 Eletronuclear hired the National Development Bank – BNDES for restructuring the project. As of February 2022, Due Dilligences hired by BNDES were under way. It is expected that the bid for the main constructions takes place in the first quarter of 2023. The current time schedule for start operation is November 2027. In a parallel initiative, Eletronuclear hired civil construction works to speed up the critical path of the time schedule. The scope of this work in mainly focused on the reactor building. (See section 6.3 of this Article).

Angra 1, 2 and 3 NPPs are located at a common site denominated Almirante Álvaro Alberto Nuclear Power Station (Central Nuclear Almirante Álvaro Alberto - CNAAA), Itaorna beach, near the city of Angra dos Reis, about 130 km from Rio de Janeiro. More details about these units can be found in Annex 1, as well as at the ELETRONUCLEAR home page www.eletronuclear.gov.br. In addition, the governmental decision included a discussion for a new nuclear power plant site that would add up to 4.000 MWe to the national electrical grid by the year 2030.

Others nuclear facilities located at CNAAA are: On-site Initial Low & Medium level Waste Disposal Facility, the old steam Generators Storage Facility and Spent Fuel Assemblies Storege Facility.

The waste of Angra-1 and Angra-2 is being stored in an initial storage facility located at the Angra site. The storage facility consists of three buildings, which are submitted to CNEN inspections. In addition to these buildings, Angra-2 NPP has an internal storage facility (KPE located in UKA Building) with a total capacity of 1,644 two-hundred-liter drums.

With the replacement of Angra-1 steam generators, a new facility was constructed on-site. The Old Steam Generator Storage Building is a reinforced concrete structure designed to provide shielding and storage for the two Angra-1 replaced steam generators, the reactor pressure vessel head, all associated contaminated material and part of the radioactive waste evaporator and components of a primary system cooling backup pump.

The facility is located inside the Eletrobras Eletronuclear (ETN) property area, close to the site dock and within the site boundary. The old steam generators were arranged side by side in separate compartments and the reactor pressure vessel head with its CRDM`s in other separate compartments. The building is designed to be seismic qualified according to Angra-1 class I structure design criteria and the concrete wall thickness provides radiological shielding according to CNEN-NN-3.01 [15] standard and annual limit of operational dose.

For additional information see Article 19 (8) and the Brazil Report 2020 for the Joint Convention [3].

6.1.1 - Angra 1

Site preparation for Angra 1, the first Brazilian nuclear unit, started in 1970 under the responsibility of FURNAS Centrais Elétricas SA. The actual construction of the plant began, however, only in 1972, shortly after the contract with the main supplier of equipment, Westinghouse Electric Co. (USA), was signed. The Westinghouse contract included supply and erection of the equipment, as well as engineering and design of the plant on a turnkey basis. Westinghouse sub-contracted Gibbs and Hill (USA) in association with the Brazilian engineering company PROMON Engenharia S.A. for engineering and design. For the erection work, Westinghouse contracted a Brazilian company, Empresa Brasileira de Engenharia S.A. (EBE). For the supply of the containment steel structure and the civil works not included in the Westinghouse contract, FURNAS contracted directly, respectively the Chicago Bridge & Iron Company and Construtora Norberto Odebrecht S.A, a Brazilian contractor.

CNEN granted the Construction License for the plant, in 1974 and the Operating Licence was issued in September 1981, at which time the first fuel core was also loaded. First criticality was reached in March 1982 and the plant was connected to the grid, in April 1982. After a long commissioning period due to a generic steam generator design problem, which required equipment modifications, the plant, finally, entered into commercial operation on 1st January 1985. In December 1994, FURNAS received from the Brazilian Nuclear Regulatory Commission (CNEN) the Permanent Operation Authorization (POA) for a 30 years period, subject to a Periodic Safety Review (PSR) at each 10 years of operation.

In 1998, plant ownership has been transferred to the newly created company ELETRONUCLEAR, which absorbed all the operating personnel of FURNAS, and part of its engineering staff, and the personnel of the engineering and design company Nuclebrás Engenharia (NUCLEN).

Since 2009, when Angra-1 Steam Generators were successfully replaced after a 5-month outage, the power limitation of 80% to slow down tube degradation imposed by operation of the older SGs was no longer necessary and the plant returned to the grid, with a new gross unit power of 640 MWe. The Plant has been since then operating without any problems associated with the new SG, with good trends of the WANO Availability Performance Indicator, as shown in Table 1 below.

Table 1 - Angra 1 Plant Availability

Year	Energy Generation (MWh)	Accumulated Energy (MWh)	Plant Availability (%)
2001	3.853.499,20	37.499.392,40	82,94
2002	3.995.104,00	41.444.496,40	86,35
2003	3.326.101,30	44.770.596,70	73,30
2004	4.124.759,20	48.895.356,90	90,05
2005	3.731.189,70	52.626.546,60	81,61
2006	3.399.426,40	56.025.973,00	74,88
2007	2.708.724,00	58.734.697,00	60,65
2008	3.515.485,90	62.250.182,90	77,49
2009	2.821.494,71	65.071.677,61	58,01

2010	4.263.040,75	69.334.717,90	77,26
2011	4.654.487,03	73.989.204,93	89,58
2012	5.395.561,26	79.384.766,19	97,26
2013	3.947.626,43	83.299.601,58	71,20
2014	4.989.574,57	88.289.176,15	88,71
2015	4.102.089,90	92.391.266,06	73,68
2016	5.092.873,3	97.484.139,40	90,14
2017	4.204.308,8	101.688.448,21	74,68
2018	4.972.688,2	106.661.136,39	88,60
2019	5.546.164,1	112.207.300,44	99,56
2020	4.603.623,4	116.810.923,87	82,39
2021	5.131.493,6	121.942.417,43	90,49

The first PSR of Angra 1 covered the period 1994-2003, the first 10 years of operations after the first Permanent Operation Authorization (POA). In the first PSR of Angra 1 there were identified 44 Improvement Opportunities, with no impediments for the continuity of the plant operation. The 44 Improvement Opportunities resulted in Action Plans, some implemented, and some included in long term duration implementation plans, in agreement with CNEN. Considering the attendance level of the action plans, CNEN accepted the first PSR of Angra 1 as of February 25, 2010.

On September 2010, CNEN granted the Eletronuclear the ratification of the Unit 1 POA, for a 14 years period, conditioning the realization of the second PSR until July 2014. The Operating Licence included requirements for the implementation of a series of safety improvements, some of which are described in section 6.1.1.1 and others referenced therein.

The Second Periodic Safety Review of Angra Nuclear Power Station, Angra 1, covered the period 2004-2013, was performed in compliance with the item 21 of the Standard CNEN-NE-1.26, [9] supplemented by IAEA Safety Guide SSG-250, in application to the requirement of the Paragraph 16 of the Permanent Operation Authorization of the Angra 1, issued by the Order of Regulation CNEN/PR Nº 087 on 17 September 2010.

On 19 December 2019, CNEN granted the Eletronuclear with a new ratification of the Unit 1 POA, for a 5 years period, conditioning the submission of the results of the third PSR until January 2024. The Operating Licence included requirements for the implementation of a series of safety improvements, some of which are described in section 6.1.1.1 and others referenced therein.

Angra 1 current license expires in 2024 and Eletronuclear submitted in 2019 and in 2020 the license renewal application (LRA) for Angra 1. The third Angra 1 PSR en conjunction with the LRA will be the main documents to be analised by CNEN in order to deliberate about the extention of Angra 1 operation license for more 20 years. The basis of these documents will be the rules CNEN-NE-1.04, CNEN-NE-1.26, Thecnical Notes CNEN NT-CGRC-007/18, NT-CGRC-008/18 and NT-CGRC-01/2020, US NRC 10 CFR 54, NUREG-1801, NEI 95.10 as well as the IAEA NS-G-2.12 and Safety Guides No. SSG-25 and SSG-48.

6.1.1.1 - Main safety improvements at Angra 1

In this review period, the most significant modifications in the Angra 1 plant were:

- Installation of electrical connections for the operation of a 250 kVA mobile emergency diesel generator, supplying essential loads, as recommended by the initiatives related to the Fukushima project.
- Installation of an alternative source of cooling water for the Used Fuel Pool, as recommended by the initiatives related to the Fukushima project.
- Replacement of butterfly valves in the 20-inch lines of the Service Water System (SAS);
- Increase in the operational reliability of main transformers through the installation of redundancies in instrumentation, control and protection components.
- Modifications to enable "Bleed & Feed" in Angra 1 Secondary System in an eventual accident beyond the project bases (Fukushima Project) caused by an external event.
- Adaptation of the Fuel Building Crane to allow the transfer process of Spent Fuel Elements to Dry Storage (UAS). The modifications were to meet the criteria established in NUREG 0554 and NUREG 0612, contemplating the complete replacement of the existing troller, control systems and other auxiliary items.
- Implemented alternative cooling for the Emergency Diesel Generators, as recommended by the initiatives related to the Fukushima project (Beyond the Project Bases).
- Replacement of the Battery Banks of the Emergency Diesel Generators that supply the Plant's Safety buses.

In addition, other relevant modification and programs, for improvement of safety and reliability, are listed below:

- Inspections and data collection from PQAEE (Program for Environmental Qualification of Electrical Equipment) to enable Long-Term Operation - LTO.
- Inspections of passive SSC (Structures, systems, and components) relate to Angra 1 Long Term Operation Program (LTO);
- Installation and commissioning of new 4,16kV electrical circuit breaker models for the plant's safety main equipment.
- Implementation of the Dry Storage Unit (UAS);
- Obsolescence related activities, such as modernization of I&C and modernization of fire detection system.
- Use of advanced fuel 16 NGF, with cladding of zirlo – 100% of the core are compounded by these New Generation Fuel elements.

Other noteworthy achievements in the 2018 -2021 period are:

- In 2018 there was a Peer Review conducted by the World Association of Nuclear Operators (WANO) and some Areas for Improvement (AFI) were raised.
- In 2021 there was a Follow Up conducted by the World Association of Nuclear Operators (WANO) regarding progress in Areas for Improvement (AFI) identified during the 2018 Peer Review, the results of this follow up showed that were good improvements in many AFI and some AFI still need some improvements. In gerenal the results were sufficiently good.
- In 2020, under a contract with Westinghouse, the Angra 1 SAMG was updated based on the PWROG-16059-P PWROG Severe Accident Management Guidance for International Plants. Some of important issues that were addressed in this update were:
    - Post-Fukushima upgrades
    - Other Operating Modes (Shutdown, refuelling)
    - Spent Fuel Pool iniciated accidents
    - Severe accident mitigation systems (Passive Hydrogen Recombiners)
    - Integration of important improvements from the new consolidated PWROG SAMG (TSC support guides; improved guide fluidity; specific guides for I&C and BO)
- Human performance and safety culture follow-up and improvement committees established during the previous review period continue to provide initial and refreshing

training on the use of human error prevention tools as well to monitor trends in personnel performance, as can be seen in Article 12.

6.1.2 - Angra 2

In June 1975, a Cooperation Agreement for the peaceful uses of nuclear energy was signed between Brazil and the Federal Republic of Germany. Under this agreement Brazil accomplished the procurement of two new nuclear power plants, Angra-2 / 3, from the German company, KWU - Kraftwerk Union A.G., later SIEMENS / KWU nuclear power plant supplier branch, at present Areva ANP.

Considering that one of the objectives of the Agreement was a high degree of domestic participation, Brazilian-German engineering company Nuclebrás Engenharia S.A. - NUCLEN (now ELETRONUCLEAR, after merging with the nuclear branch of FURNAS, in 1997) was founded in 1975 to act as architect engineer for the Angra 2 and 3 project, with KWU as the overall plant designer, and, on the process, to acquire the required technology to design and build further nuclear power plants.

Furthermore, great efforts were dedicated to qualify Brazilian engineering firms and local industry to comply with the strict standards of nuclear technology.

Angra 2 civil works started in 1976. However, from 1983 on, the project suffered a gradual slowdown due to financial resources reduction. In 1994, the financial resources necessary for its completion were defined and in 1995, a bid was called for the electromechanical erection which started in January 1996.

Hot trial operation was started in September 1999. In March 2000, after receiving from CNEN the Authorization for Initial Operation (AOI), initial core load started, followed by initial criticality, on 17th July 2000, and first connection to the grid on 21st July 2000. The power tests phase was completed in November 2000. Angra-2 NPP has been operating at full power since mid-November 2000 and began the commercial operation on February 1st 2001.

Due to legal constraints imposed by the Brazilian Public Ministry related to the environmental licensing (see Article 7(2), Angra 2 was operating based on an Authorization for Initial Operation (AOI) issued by CNEN that was extended for a period of 8 months. On 15th June 2011, CNEN issued the Authorization for Permanent Operation with conditions to be fulfilled during operating life. One of these conditions was the performance of a Periodic Safety Review (PSR), each 10 years, as stated at CNEN-NE-1.26[9]. The first PSR was started in July 2011 and concluded in November 2012 with the issuance of the Global Report of Periodic Safety Review for CNEN approval.

Angra 2 operational record for the period 2001/2018, as measured by the WANO Unit Capability Factor (UCF), is shown in Table 2 below.

As reported in the previous National Report, and shown in Table 2, Angra-2 had a very good performance in its first three years of operation. In the two subsequent years, the plant performance has declined due to a series of problems, with major secondary side components, such as main transformer, electric generator, main condenser and the motors of the main recirculating water pumps.

These problems have been addressed, their root causes have been identified and measures for their elimination have been implemented. The positive trend resulting from the actions taken are reflected in Table 2 by the Unit Capability Factor, which has shown steady improvement beginning in 2006 reaching values of the best operating plants in the following years.

On June 19th, 2020, Angra 2 reached a historic milestone. The unit – which started commercial operation in 2001 – reached an accumulated production of 200 million MWh. Another important fact is that the Plant generated energy for 13 months continuously in cycle 16. The capacity factor of this cycle was 99.43%, the highest of the plants in the Eletrobras System, and the Forced Loss Rate was only 0 .02%.

Since the plant's return after the 2P15 Outage, at the end of May 2019, Angra 2 had an indication of a fuel element failure in the Reactor. The plant remained in the same situation for the remainder of cycle 16, until the start date of the 2P16 shutdown on June 22. During the course of cycle 16, action level 1 of the Integrity Monitoring Program procedure Nuclear Fuel (2PA-GE 53) was reached, however, the activity levels of Xenon-133 and Iodine-131 remained considerably below the limits of the Technical Specification, which allowed the Unit to operate at full power, and the planned power reductions were performed at lower than usual rates. At Outage 2P16, during the unloading of the core, the existence of a faulty R-series Fuel Element was confirmed. The same was removed from the core, not returning to cycle 17. Additionally, during the unloading of the core, the presence of unexpected surface oxidation was identified in the coating of the rods of the fuel elements (EC) of the R series, which were the same ones that were loaded at Stop 2P15 and were in their first cycle of operation. Because of this, a series of measures were necessary to guarantee the safe, reliable return of the Plant to operation in the shortest possible time. Thus, 2P16, whose initial duration was 22 days, already considering a reduced scope due to the COVID-19 pandemic, was extended and ended with a duration of 56.7 days. The Unit was connected to the National Interconnected System (SIN) on August 17th.

In line with external operational experience, one of the measures taken after the event of oxidation of the fuel rods in cycle 16 was to start and remain in operation at 90% of the rated power at cycle 17. Other factors also contributed to the operation at reduced power was necessary, one of them was the proximity between Angra 1 and Angra 2 in 2021. Another factor was the need to extend the Angra 2 cycle so that the Dry Storage Unit (UAS) is in operation and receives the load of Fuel Elements Irradiated required before the new fuel recharge in Angra 2, scheduled for June 2021.

As of December 14, 2020, data from the primary system's radiochemistry analysis showed values indicative of Fuel Element failure in cycle 17. However, the activity levels of Xenon-133 and Iodine-131 remain below action level 1 of the procedure Nuclear Fuel Integrity Monitoring Program (2PA-GE 53), which, in preliminary analysis, indicates a minor flaw.

The periods of scheduled downtime during the year were due to the Stop for Refueling (2P16), tests of valves and Turbine protection devices and the operation at 90% of rated power in cycle 17, which started at the end of August.

In 2021, Angra 2 featured the following highlights:

- There was no Reactor tripping in Angra 2 in 2021. It is the second cycle of operation in a row without any Reactor tripping.
- Considering the challenging scenario imposed by the COVID-19 pandemic, the Refueling Outage 2P17 was successful. The actions taken to prevent the spread of the virus among employees during 2P17 were effective, the progress of the services and the critical line of the Shutdown were not compromised at any time due to possible absences of employees.
- Completion of Refueling Outage 2P17 in 46.2 days, ie within the stipulated duration target of 48 days. It is important to emphasize that the objective was achieved even with the challenge of the unusual surface oxidation event in the coating of the rods of the series S fuel rods, identified during the unloading of the core in 2P17.
- Continuation of improvements in the Main Cooling Water Pumps – PAC.
- Beginning of the development of the database “Equipment Qualification Data Base - EQDB” for Angra 2.
- Analysis of the list of spare parts for Group 1 and Group 2 Diesel Generators, to identify pending issues and forward the acquisition with alternative suppliers, when possible.
- Specification, acquisition, installation, and commissioning of a new nationalized MAW exhaust system, replacing the obsolete original model that was inoperable.
- Carrying out the 2P17 refueling outage with various activities, including:
    - Replacement of 112 sets of support springs of the Upper Internals of the Reactor Pressure Vessel (RPV) that presented values defined for replacement.
    - Internal Visual Inspection of the JEB20 Reactor Cooling Pump.

  - Inspection by ECT of Steam Generators (GV) 20 and 30;
  - Hydrostatic Tests of the Steam Generator 30 and the KAA20BC001 heat exchanger.
  - Execution of the Containment Tightness Test – ILRT.
- Transfer of the 288 Fuel Elements from the PCU from Angra 2 to the Spent Fuel Dry Storage Unit (UAS), with the movement of the 9 hulls, as planned.
- Technical support in the execution of the commissioning test of Spent Fuel transfer equipment from Angra 1 carried out in Angra 2.
- Specification, acquisition, installation, and commissioning of new compressors GCX01AN001/002, replacing the old ones that were obsolete and malfunctioning.
- Thickness measurement was carried out by digital gammagraphy at 16 points of lines of the Secondary System in compliance with the thickness measurement program (FAC – Flow Accelerated Corrosion).
- NR13 Safety Inspection on Auxiliary Boilers QHA01/02BB001, successfully and without abnormalities.

In Angra 2, the 17th Outage for Refueling was held – 2P17. It started on 06/06/2021 at 00:02, with an expected duration of 48 days, and was concluded on 07/22/2021 at 05:46, after 46.2 days, with the synchronization of the Unit to the Electric System. The outage was also planned in the context of the COVID-19 pandemic, and several measures were adopted to minimize or prevent the spread of the virus during its realization. Initially, 2,780 Work Permits (LT) were scheduled for the 2P17 stop, but 4,193 were executed. This total includes those that were issued and executed as a diversion during the shutdown, or by opportunity LTs that had been initially postponed due to the reduction in scope due to the pandemic.

Table 2 - Angra 2 Unit Capability Factor

Year	Gross Energy Generation (MWh)	Total Production (MWh)	Unit Capability Factor (%)
2001	10.498.432,70	13.121.084,70	93,90
2002	9.841.746,20	22.962.830,90	91,50
2003	10.009.936,10	32.972.767,00	91,30
2004	7.427.332,20	40.400.099,20	74,60

2005	6.121.765,30	46.521.864,50	64,50
2006	10.369.983,90	56.891.848,40	89,00
2007	9.656.675,00	66.548.523,40	85,73
2008	10.488.288,90	77.036.812,30	90,11
2009	10.153.593,49	87.190.405,79	92,24
2010	10.280.766,54	97.471.172,56	88,09
2011	10.989.764,07	108.460.936,63	99,09
2012	10.645.229,04	119.106.165,67	92,06
2013	10.692.555,33	129.798.721,00	90,15
2014	10.444.932,54	140.243.653,54	88,83
2015	10.707.070,63	150.950.724,17	90,60
2016	10.771.423,54	161.722.147,71	90,22
2017	11.535.537,51	173.257.685,22	97,04
2018	10.701.345,23	183.959.030,45	91,23
2019	10.582.662,10	194.541.692,55	89,60
2020	9.448.896,10	203.990.588,65	80,18
2021	9.572.685,50	213.563.274,15	80,77

6.1.2.1 - Main safety improvements at Angra 2

Angra-2 NPP belongs to the 1300 MWe Siemens-KWU PWR family, with 4 x 50% redundant safety systems, with consequent physical separation of trains. The plant has also a high degree of automation of the reactor control, limitation, and protection systems, complying with the 30 minutes non-intervention rule and a very reliable emergency power supply system, consisting of 2 independent sets of 4 Diesel Generators each. A separate, fully protected building is provided to host the Emergency Control Room and the required water and energy (batteries and 2nd set of Diesel Generators) supplies to shut down and maintain the cooling of the plant, in case of major natural or man-made hazards.

Angra 2 status is the one of a modern NPP, as a result of a consistent program of upgrading that has been carried on along the construction years, with implementation of all safety related modifications added to the German reference plant Grafenrheinfeld, as well as most improvements built in the newest German KONVOI plant series.

Several ongoing programs for improvement of safety and reliability being conducted at the Angra 2 Plant are:

- Evaluation and planning for substitution of electrical and I&C equipment due to obsolescence.
- Reliability Centered Maintenance program.
- Improvement of operating performance of major plant equipment including identification and elimination of design and maintenance weaknesses.
- Improving the calculation of the thermal power through reconciliation of data.

In 2017, the implementation of INPO AP-913 Equipment Reliability Process was started in Angra 2. This is a program that, when fully implemented, will result in high reliability standards to the Plant. The program consists of six major steps. The component classification phase was completed, accounting for a total of 105,402 classified components. The methodology application phase to the 10 main systems:

- Reliability Assessment – The analysis of the failure modes of the selected systems is proceeding as planned, with no evolution expected for this month.
- Preventive maintenance implementation activities proceed as planned.

In this way, the planned progress at the end of December 2021 (considering implementation in 10 systems) is 63.36% and what has been achieved is within expectations, maintaining the completion date, November 2023.

Some selected modifications, important to safety and/or reliability, in the period 2019 – 2021, are:

- Relocation of the QUP30AP001 pump to prevent air ingress into the suction mainly at the beginning of the return operation.
- Alternatives for cooling the Angra 2 fuel element pool in the event of an ABP accident.
- Update of QKA01/02/03/04GS001 panels using iskamatic B modules.

- Expansion of the autonomy of the battery banks of the ULB building through 250KVA mobile diesel generator connection.

In May/2021, the 12 control bars and 34 flow restrictors from the Grafenrheinfeld plant were received in the warehouse, supplying part of the stock need for these items.

The movement and transfer activities of irradiated fuel elements from Angra 2 to the UAS started in April/2021 with the transfer and storage of 3 (three) canisters/Hi Storms before 2P17. The continuity of the activity, with the transfer of another 6 (six) canisters/Hi-Storms in August/2021, which totaled the transfer of 9 (nine) canisters/Hi-Storms of 32 elements, making a total of 288 irradiated fuel elements transferred from the Angra 2 PCU to the UAS. The inspection to verify the activities resulting from the transfers of ECI's from the PCU of Angra 2 to the Dry Storage Unit (UAS) were accompanied by inspectors of Safeguards by ABACC, IAEA and CNEN. These activities were carried out by surveillance cameras and human surveillance.

In the area of Operational Experience, the systematic for collection, trending and reporting of minor events and near-events has been developed and implemented for both Plants. The established external operational experience committees evaluate significant event reports from USNRC, WANO, INPO and VGB as well as Plant Supplier Information Notes making recommendations for plant implementation when pertinent.

WANO sponsored best practices from the nuclear industry, such as Operational Decision-Making procedures, as well as comprehensive familiarization with human performance error prevention tools and training in their use have also been developed and implemented for both plants.

The models and software upgrade of Angra 2 full scope simulator was concluded in October 2015, including the replacement of instructor system hardware and operational system, as well as the completion of all validation tests required to comply with ANSI 3.5 standard. In this upgrade, the models of some relevant systems were included, for example, the Reactor Core and almost all primary systems. In June 2019, the upgrade of interface hardware and simulator communication software was completed, including the replacement of the original simulator interface that was in operation since 1985.

6.1.3 – Angra 3

In June 2007 the Federal Government through its National Council for Energy Planning approved the restart of construction of Angra 3 after a 23-year interruption.

For the actual restart of construction, two licenses were required: the Construction License from the Nuclear Regulatory Body – CNEN, based on the acceptance of a Preliminary Safety Analysis Report (PSAR) and the Installation License from the Environmental Regulatory Body – IBAMA, based on the acceptance of an Environmental Impact Assessment (EIA) Report.

Concerning the Construction License, in accordance with the original concept, Angra 3 was planned to be a twin plant of Angra 2, using the same licensing bases. This concept had been submitted to and approved by the Brazilian nuclear licensing authority – CNEN, considering "Angra 2 as-built" as the reference plant for Angra 3. This concept was used by ELETRONUCLEAR as basis for preparation of the first version of the Angra 3 PSAR, submitted to CNEN.

Later in 2008, along the process of evaluation of the Angra 3 PSAR for issuance of the Construction License, the original licensing bases were questioned by CNEN, and a review of the applicable regulations was requested, with the goal of comparing the original requirements with the corresponding current requirements.

As a result of this review it was identified that in most of the cases the original requirements did not change. Where there were changes, in most of the cases it could be shown that the design in accordance to the original requirements allowed sufficient margins to accommodate the new requirements. In the case where the design did not fulfil the new requirements plant modifications were done.

The PSAR has been revised to include the results of the regulation review and, after several rounds of evaluation, the plant safety concept was considered acceptable. Angra 3 Limited Construction License was issued by CNEN in 1st of July of 2009.

On May 25th 2010, CNEN issued the Construction License with a list of 56 Conditions to be fulfilled before the Authorization for Initial Operation (AOI).

These conditions are splited in eight areas as follows:

[1] Six (6) general conditions

[2] One (1) condition related to civil construction area

[3] Eight (8) conditions related to mechanical area

[4] Three (3) conditions related to electrical area;

[5] Six (6) conditions related to I&C area

[6] Four (4) conditions related to safety analysis area

[7] One (1) condition related to human factors engineering

[8] One (1) condition related to physical protection

Some highlights of these conditions are:

- Submittal of the test procedures including the acceptance criteria and commissioning programs, before the start of each test.
- Submittal of the detailed design for each of the safety related buildings, for CNEN approval and release, before construction begins;
- Availability of an Angra 3 specific full scope simulator for operator training before core loading;
- Development of Angra 3 specific levels 1 and 2 PSA that shall be functional before Initial Operation;
- Submittal for approval of the concept for control of Severe Accidents.

The preparation of Final Safety Analysis Report, including a new chapter 19 (Severe Accidents and Probabilistic Safety Analysis), is under way at ELETRONUCLEAR, in order to be submitted to CNEN two years before the Authorization for Initial Operation.

The training of plant operators was already initiated.

With respect to Angra 3 environmental license, IBAMA proposed in 1999 the Terms of Reference for the preparation of the development of the EIA/RIMA. The EIA/RIMA Reports for Angra 3 where prepared under the responsibility of ELETRONUCLEAR and submitted to IBAMA in May 2005.

Since CNEN has the technical competence for the evaluation of the radiological impact on the environment, IBAMA and CNEN have established a formal agreement to specify the respective scope of evaluations and to optimize both licensing processes.

The Preliminary License for Angra 3 was issued by IBAMA, through Preliminary License No. 279/08 of 24th of July 2008, subjected to 65 conditions, as follows:

- 5 conditions of general character, related to aspects of the project and obligations of the Owner, such as environmental monitoring, conservation areas, etc;
- 60 specific conditions, related to:

- Support to the surrounding Counties directly affected by the project, in providing the infrastructure needed to accommodate the increase in permanent and variable population;
- Submittal of the Basic Environmental Plan, that allows follow up of the construction activities relative to control and monitoring of the impacts of the construction on the environment;
- Start up of the planning for development of a Final Radwaste Repository, to dispose the plant radioactive waste;
- Submittal of a regional "Insertion Plan" of social character, with the goal of providing better living conditions for the population of the areas affected by the project.

The content of these conditions emphasizes planning and preparation for the project installation phase.

IBAMA issued the Installation License No.591/09 for the Angra-3 project in the 5^{th} of March 2009, with additional conditions, as follows:

- 5 general conditions related to aspects of the project and obligations of the Owner (same as for the Preliminary License);
- 46 specific conditions related basically to meeting of the planning and deadlines presented by the Owner in response to the conditions of the Preliminary License.

In December 2009, IBAMA issued the first amendment to the Angra 3 Installation License Nr.591/09 including a new specific requirement related to the Paraty-Cunha Road implementation.

At the time of the issuing of the combined environmental operational licence for the site, the specific Installation License No.591/09 was revised again and generating a second amendment with set of 33 exclusive new requirements for Angra 3 plant construction.

The Brazilian environmental laws establish that at least 0.5% of the overall cost of a project with potential harmful effects on society and environment shall go to environmental compensatory measures. It is expected that of the order of 4-5% of the total cost of the Angra 3 project will be spent to comply with the above referred conditions.

Unfortunately, in September 2015, the Angra 3 construction was stopped as a result of a bribery investigation being carried out which involves several national main construction contractors, including those contracted to perform the electromechanical erection of this unit. Until all these matters are clarified the activities for construction are frozen.

The present activities at the Angra 3 construction site are associated with the preservation of the buildings partially constructed and the equipment already installed as well as the storage and preservation of the national and international supplies being delivered. Additionally, activities related to maintenance and storage of the regulatory documentation are in place. During the work stoppage time CNEN inspected the preservation activities and the structures conditions and the installed components.

Concerning the status of construction of the plant first concrete for the reactor base plate was poured following CNEN's Construction License conditions, on June 1st 2010. By December 2015 around 70% of the civil construction work has been completed and at this date, the reactor building was built up to the elevation of 19 meters high. The spherical steel containment bottom part has floated for positioning and securing in place and its erection is 50% done.

The turbine building is close to completion with its crane already installed still missing are the condensers. The installation of the tanks that are civil construction dependent is being done. At the moment the borated water storage tanks have been mounted in the reactor building annulus, as well as several tanks in the reactor auxiliary building.

Concerning supplies, more than 65% in value of the imported equipment is already stored in the warehouses, including not only the primary circuit heavy components and the turbine-generator set but also special pumps, valves and piping material.

Excellence of the preservation plan for long-term storage was demonstrated during Angra 2 completion, whereby no relevant equipment malfunctions due to long-term storage had adverse impact on plant commissioning or initial operation. The preservation measures, including the 24 months inspection program, continue to be applied for the Angra 3 components stored at the site.

The training program for the first 260 people hired specifically for Angra 3 of a total of 520 authorized to compose the Plant staff, to cover the different Plant disciplines is essentially completed, including licensed and non licensed operators and engineers and technicians for all Plant disciplines. Because of the interruption of construction most of this personnel is being assigned to different areas of the existing Plants, mainly to Angra 2.

Most of the required engineering is essentially available, since for standardization reasons Angra-3 is to be as similar as possible to Angra-2, including as applicable as possible, Fukushima lessons learned.

In 2018 Eletronuclear hired the National Development Bank – BNDES for restructuring the project. As part of this work BNDES hired several consortiums to perform Due Diligences in the project, construction and preservation, accounting, licencing, environmental etc.. As of Feb 2022, those Due Dilligences are under way. It is expected that the bid for the main constructions takes place in the first quarter of 2023. The current time schedule forees the ION on November 2027.

In a parallel initiative, Eletronuclear hired civil construction works to speed up the critical path of the time schedule. This contract was signed in February 2022 and the concrete pouring works shall start on may. The scope of this work in mainly focused on the reactor building, Emergency building, Auxiliary building and Water Intake, with relation to civil structure finishing.

6.1.3.1 - Main safety improvements at Angra 3

The reference plant of Angra-3 NPP is Angra-2 NPP, as built, but also incorporating into the design the up-to-date requirements of rules and standards in force at the time of the application to the Construction License, in 2003. On the other hand, some design modifications made in structures and systems to increase the protection and the capability of the plant to resist design basis accidents were also included. Some additional improvements were also introduced to withstand beyond design basis accident scenarios. Considering those scenarios, for example, Angra-3 is being built at an elevation that is one meter higher than the one of Angra-2.

A tornado hazard study was specifically prepared for Angra-3 design, taking into consideration a probability of occurrence of 10-7/year, as required by the USNRC, RG 1.76, "Design Basis Tornado and Tornado Missiles for Nuclear Power Plants" (2007). The hazard assessment indicated a maximum tornado wind speed of 209 km/h for the site. However, considering the maximum occurrences in the region, equivalent to the EF3 category, ELETRONUCLEAR conservatively adopted 242 km/h as the design speed for tornadoes (average between the limits of the EF3 category), also similarly to the design tornado established for the Region III in the USA. Adittionally, the corresponding tornado missiles have been also adopted in the design.

The seismic event SSB (combination of Burst Pressure Wave – BPW with SSE effects) is being applied for the design of all safety related structures, systems and components (class I and IIA civil structures; class 1 or 2A systems and components). The design concept, which is based on the KWU PWR 1300 MW Standard Model, includes an increased staggered defense-in-depth configuration, which does not only provide highly redundant safety systems to cope with design basis accidents, but in addition it provides a further line of defense consisting of dedicated ultimate safety features. By use of these ultimate safety features, some specific events can be coped with, like loss of main control room (including absence of operators for up to 10 hours) and station blackout. In addition, these features provide a robustness reserve even for beyond design basis external events.

The low probability external events SSB and Tornado were raised to "classical" design basis accidents against the previous consideration as "design extension" events in Angra-2. This concept represents an upgrade when compared to the one adopted for the reference plant, Angra-2, where some safety related SSC´s where designed only for SSE and not for SSB (e.g., Switchgear Building - UBA, Large Diesel Generator (D1) Building - UBP). This upgraded concept is conservatively adopted at the plant, and can be considered as an additional safety margin in the defense-in-depth line.

As referred in the previous paragraph all Unit 2 safety design features are being maintained in the safety design concept for Unit 3 (as for instance: decoupling between Emergency Feed Building - ULB and Switchgear Building - UBA; internal flooding protection, design criteria of up to 10 hours for SSB and up to 2 hours for SSE).

In Angra 3 the emergency power supply consists of two sets of Diesel generators:

- Emergency Power Supply D1 (4 x 50% large Diesel Generators) which supplies the power for all safety related systems in case of Loss of Off-site Power (LOOP);
- Emergency Power Supply D2 (4 x 50% small Diesel Generators) which supplies the power in case of LOOP and loss of D1 emergency Diesel Generators for the minimum required set of safety related systems (reactor protection system, emergency control room, emergency feedwater system, emergency residual heat removal chain and the main steam blowdown stations). The D2 emergency Diesel generators could be called "SBO Diesels", in order to reflect on international requirements.

These two completely separated and independent sets can be electrically interconnected so that in case of LOOP only the D1 EDGs are started. In case of failure a set, the corresponding D2 EDG will be started to feed the corresponding electrical busbars.

Even considering the above mentioned situation, an additional power supply installation for Angra 3, consisting of mobile Diesel Generating sets, with the necessary power for safety loads included in the plant design, due to the following points:

- The applied edition June/1999 of Standard KTA 3701, introduced in item 3 (2) d) a new requirement regarding an independent power supply installation, additionally to the two offsite connections;

- Requirement for energy supply 72 hours after an external event where the external energy supply (525 kV and 138 kV) fails (KTA 3701, App.C, item C 2.4).

These Mobile DGs fulfill also with the pos-Fukushima concerns according to the Eletronuclear Fukushima Response Plan.

Therefore, ELETRONUCLEAR decided to include the UBN structure with installed switchgear distribution panels for connecting the mobile Diesel generator set including all necessary supporting systems.

The additional Diesel generator (probably more than one set operating in parallel to achieve desired power) can also replace any one of the 4 diesel generators of the Emergency Power Supply D1 or even feeding selected EDG D1 redundancies, assuring the secured removal heat chain and imporatant safety loads.

The initiatives of ELETRONUCLEAR's Fukushima Response Plan focus on the plants in operation, Angra 1 and Angra 2. The results of the studies related to site conditions have been basically completed, except the evaluation of the resistance of the wave breaker, in front of the Plants sea water intakes, to waves produced by extreme sea conditions. Need for minor interventions in the site infrastructure as well as in the plants, have been identified. Part of the initiatives related to design improvements in Angra 2, mainly in relation to beyond design basis accidents, is already considered in Angra 3 design. Other design modifications in Angra 2, resulting from specific issues addressed in connection with the Fukushima accident, such as the possibility of connection of mobile equipment, will be afterwards incorporated in Angra 3 design.

The following recent improvements, all related to control and mitigation of beyond design events, including Severe Accidents, are being implemented in Angra 3:

- Hydrogen Reducing System, which reduces the Hydrogen content in the containment continuously by means of PAR’s (Passive Autocatalytic Recombiners) during normal operation, design basis accidents (DBA) as well as after beyond design basis accident (BDBA);

- Nuclear Sampling System for the Containment Sump and Atmosphere, which is designed for the purpose of obtaining high quality samples of the containment atmosphere even after a BDBA. In addition also the containment sump can be sampled after BDBA.; Containment Filtered Venting System, which vents the containment atmosphere through special filters to prevent loss of containment integrity in case of BDBA like core melt causing high pressure inside the containment;

- The Primary Side Bleed & Feed, to remove core heat in case of BDBA, has its capacity increased and the bleed valves are powered by dedicated batteries to be available in case of Station Black-out (SBO);
- The Secondary Bleed & Feed, to remove primary side heat in case of BDBA, has the bleed valves powered also by batteries to be available in case of SBO (including the loss of the D2 emergency Diesel generators called "SBO-Diesels").

6.1.4 Research Reactors

Since the Seventh National Report Brazil decided to voluntarily submit some information related to Research Reactor, which are overall described in A.2.2 and in Annex III.

6.1.4.1 - The IEA-R1 Research Reactor

The IEA-R1 is the largest research reactor in Brazil (Figure 6), with a maximum power rating of 5 MWth. IEA-R1 is a pool reactor, with light water as the coolant and moderator, and graphite and beryllium as reflectors. The reactor was commissioned on September 16, 1957, when it achieved its first criticality, and it is located at the Institute for Energy and Nuclear Research (IPEN), in the city of São Paulo. Although designed to operate at 5 MW, the reactor operated only at 2 MW between the early 1960's and mid 1980's, on an operational cycle of 8 hours a day, 5 days a week. After that, the IEA-R1 was uprated to 4.0 MWth (until July 27, 2011) and nowadays is operating at 4.5 MWth (from August 01, 2011) with a 8-hour a day, 3 days a week schedule. The reactor originally used 93% enriched U-Al fuel elements. Currently, it uses 20% enriched uranium (U3Si2-Al) fuel that is produced and manufactured at IPEN. The reactor is operated and maintained by the Research Reactor Center (CERPq) at IPEN, São Paulo, which is also responsible for irradiation and other services.


Figure 6 - IEA-R1 – Pool of Reactor and Reactor Building

The research reactor is located in a multidisciplinary facility which has been consistently used for research in nuclear and neutron related sciences and engineering. The reactor has also been used for training, radioisotope production for industrial and nuclear medicine applications, and for general irradiation services. Several departments within IPEN routinely use the reactor for their research and development work. Scientists and students from universities and other research institutes also use it for academic and technological research. The main applications of the reactor are basic and applied research in the areas of nuclear and neutron physics, nuclear metrology, and nuclear analytical techniques. In the early 1960's, IPEN produced I-131, P-32, Au-198, Na-24, S-35, Cr-51 and labeled compounds for medical use. After 1980, it started producing 99mTc generator kits from the fission of 99Mo imported from Canada. This production is continuously increasing, with the current rate of about 17,000 Ci of 99mTC per year. The 99mTc generator kits, with activities varying from 250 mCi to 2,000 mCi, are distributed to more than 300 hospitals and clinics in Brazil. Several radiopharmaceutical products based on I-131, P-32, Cr-51 and Sm-153 are also produced at IPEN.

Since 2020, a concentrated effort has been made in order to upgrade the reactor schedule operation, through an intensive aging program and the training of 26 reactor operators and 4 workers for radiological protection activities. The main target of this action is to operate the reactor in a cycle of 9 days continuos (216 hours), with 5 days dedicated to maintenance activities, in order to meet the 177Lu Brazilian demand.

6.1.4.2 - The IPR-R1 Research Reactor

The IPR-R1 TRIGA Mark I is a research reactor and has been operating for 62 years at the Nuclear Technology Development Center (CDTN), at the Campus of Federal University of Minas Gerais (UFMG) located in Belo Horizonte. The IPR-R1 TRIGA (Trainning, Research, Isotopes, General Atomics) Mark I is a pool type design nuclear research reactor, with an open water surface and the core has a cylindrical fuel element with aluminium or steel cladding enclosing self-moderating uranium zirconium hydride fuel (Figure 7). The first criticality was achieved in November 1960 and operates at a power of 100 kW and / or under demand. The integrated burn-up of the reactor since its first criticality is about 2.1 GW.h. Due to the low nominal power, spent fuel is far from being a problem, except for ageing concerns.

There was no fuel element replacement so far. Some laboratories, which give support to the IPR-R1, were renewed especially for increasing and improving the reactor applications. The IPR-R1 is mainly used for neutron activation analysis, experiments and applied research, as well as for the production of some radioisotopes, like Co-60, Au-198, Ir-192, Mn-56, Na-24 etc, that are used in the stainless steel industry, and environmental research activities. Additionally, it can be also used for training purposes, including Brazilian NPP operators.

Figure 7 - IPR-R1 – Control Room and Reactor Pool

6.1.4.3 - Argonauta Research Reactor

The third Brazilian RR is named Argonauta (Figure 8) and is located at the Institute of Nuclear Engineering (IEN) on the campus of the Federal University of Rio de Janeiro, in the city of Rio de Janeiro. The first criticality of the reactor was reached in February of 1965.

The reactor is a pool type and can operate at a maximum power of 1kW during one hour or 500 W continuously. It is usually operated in the range of 170 to 340 W. The accumulated burnup of the reactor since its first criticality is less than 1% and due to its low nominal power, storage of spent fuel is not a problem. It is used for training purposes, research, samples irradiation and for the production of some radiotracers for industrial use.

Figure 8 - IEN-R1-Argonauta

6.1.4.4 - IPEN/MB-01 Research Reactor

The most recent Brazilian RR is IPEN/MB-01 (Figure 9), also located at the Institute for Energy and Nuclear Research (IPEN). This research reactor is the result of a national joint program developed by CNEN and the Brazilian Navy.

The first criticality of the IPEN / MB-01 reactor was reached on November 9, 1988. From November 1988 to July 2018, more than 3,663 reactor operations were carried out to measure reactor physics parameters to validate neutronic codes, to train reactor operators and train students undergoing graduate and post-graduate courses. Some critical experiments are international benchmarks of the Nuclear Energy Agency (NEA-OECD). IPEN/MB-01 is a zero power reactor because the maximum power level is 100 watts, with an average thermal neutron flux of about 5.0 × 108 n/cm2.s. This neutron flux is not high enough to raise the temperature during its operation and fuel burn up. The reactor, a water tank type critical facility, had a core that consisted of up 680 stainless steel fuel pins with UO_2 pellets inside.

The pins were manually inserted into a perforated matrix plate, enabling any experimental arrangement within a 28 x 26 matrix. The control and safety rods are composed of 48 pins that contain absorbing neutron material. Each safety and control rod has 12 pins. Ten nuclear channels around the structure that sustains the matrix plate complement the critical arrangement, which is maintained within a stainless-steel tank. Deionized water is used as moderator and as coolant of a natural circulation cooling system.

A new core for IPEN/MB-01 Reactor was designed and installed in the 2013-2018 period. This new core is a 4x5 assembly containing 19 fuel elements with fuel plates of U_3Si_2 with enrichment of 19.75% ± 0.20% and 1 aluminum element massive close to the core central position. Each fuel element contains 21 fuel plates and cadmium wires to compensate core excess reactivity. Light water is the moderator at axial direction and heavy water (D_2O) is inserted around the core at radial direction inside aluminum boxes. There are four control rods made of hafnium and reactor criticality is obtained with all the rods inserted inside the core. The maximum power level and neutron flux are 100 watts and 5.0 × 108 n/cm2.s, respectively. The power, and average thermal neutron flux are similar to first core (680 pin fuels).

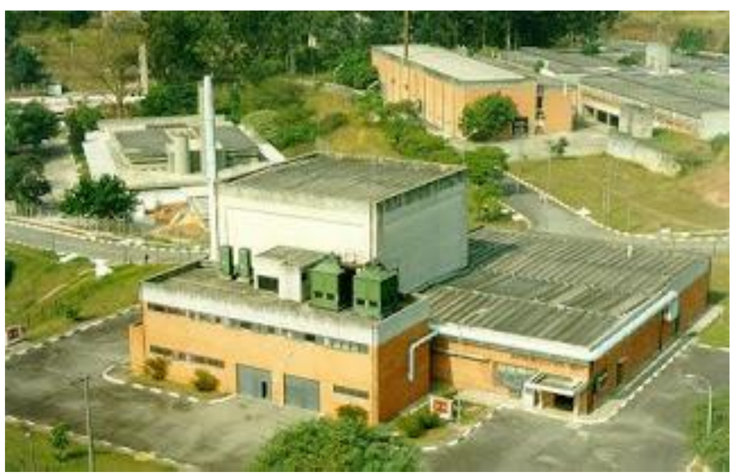

Figure 9 - IPEN/MB-01-Research Reactor

The first criticality of the new reactor core was reached on March 03, 2020. The main goals set for this new reactor core are to test neutronic parameters calculated for the future Brazilian Multipurpose Research Reactor (RMB); to train reactor operators; and to use the reactor during courses for graduate and post-graduate students at University of São Paulo.

Operators licensed by the Brazilian Regulatory Authority, named CNEN/DRS, shall perform all the operations conducted at IPEN/MB-01 reactor.

Although the Brazilian Research Reactors are used for different purposes, all the operations shall be done by operators licensed by the Brazilian Nuclear Regulatory Body (CNEN).

6.1.4.5 - The Brazilian Multipurpose Research Reactor – The RMB Project

Brazil has an ongoing project to build a Multipurpose Research Reactor (RMB), open pool type with a primary cooling system through the core. With a maximum power of 30 megawatts and powered by uranium silicate enriched up to 19.9%, it will have a neutron flux of over 2x1014 neutrons per square centimeter per second. The RMB will be a new Nuclear Research and Production Center to be built in Iperó city, about 110 kilometers from Sao Paulo city, in the southeast part of Brazil. IBAMA, the environmental licensing body in Brazil gave the authorization for starting the site works. The DRS/CNEN, the nuclear licensing body in Brazil gave the approval for the new nuclear site, in 2015, and the Preliminary Safety Analysis Report is under analysis for the reactor construction authorization.

This reactor will enable the production of radioisotopes for application in medicine, industry and environment; irradiation tests of advanced nuclear fuels; irradiation and testing of materials; and development of fundamental scientific research with neutron beams in several areas of knowledge. In addition, it will enable the formation and training of human resources to meet the demands of the Brazilian Nuclear Program. The RMB Master Plan can be seen bellow in Figure 10.

The conceptual and basic projects were completed. The detailed engineering design of the Reactor and Conventional Systems was completed as well. More than 16,000 documents were produced. Fuel elements for RMB operation and uranium target fabrication technology for the production of Molybdenum-99 have been developed. The Australian research reactor OPAL (Open Pool Australian Light water Reactor) projected by Argentina and built in Australia are being used as initial references for the RMB project. The basic engineering projects are under way, benefiting of the cooperation with Argentina, see Annex III. The Initial License was issued in 2015, the Environmental Installation License in 2019 and Environmental Programs were conducted, meeting the requirements of environmental licensing. Regarding nuclear licensing, the Site Approval was issued in 2015 and the Preliminary Safety Analysis Report was delivered in 2018, being under analysis to enable the issuance of the Construction License.

Figure 10 - RBM Project – RMB Master Plan

The conceptual design of the reactor, carried out to meet specific requirements linked to its multipurpose profile, is illustrated in Figure 11.

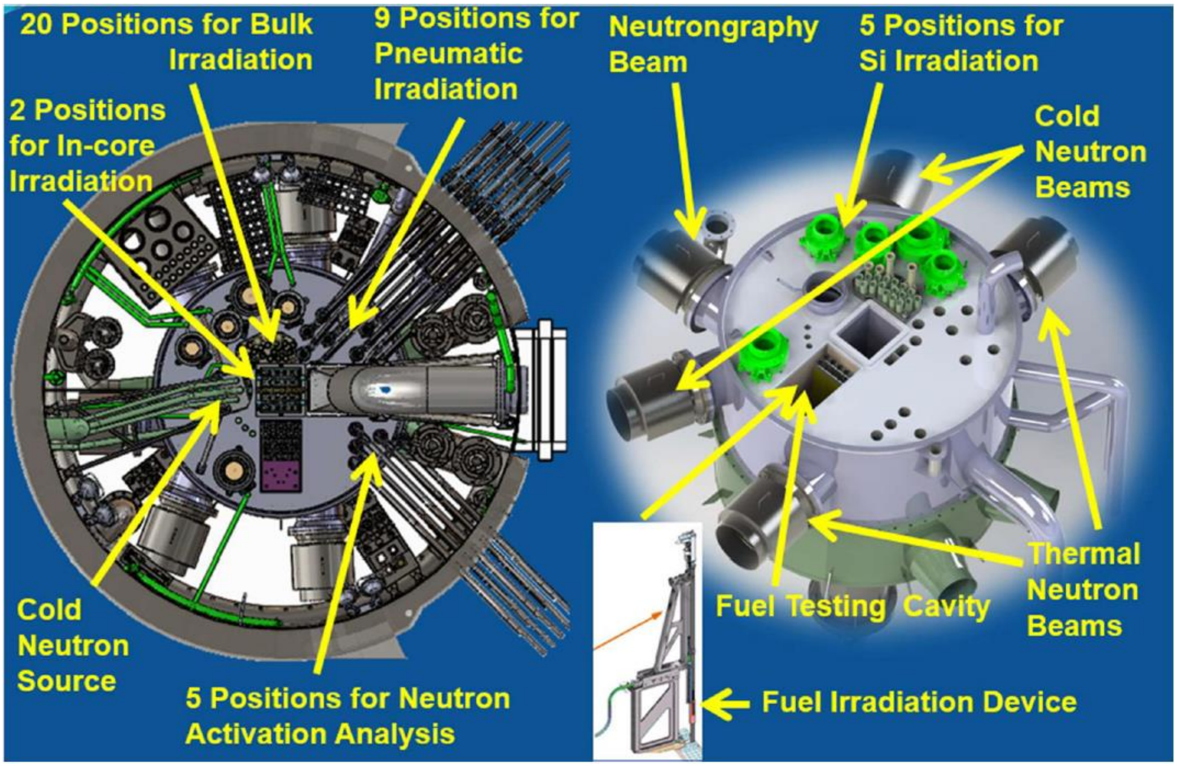

Figure 11 – Reactor Conceptual Design

Laboratories and specific facilities associated with each of the applications will complement the enterprise:

- Radioisotope processing facility.
- Neutron Activation Analysis Laboratory.
- Neutron Beam Laboratory.
- Post-Irradiation Analysis Laboratory.

In addition, the Project will have the following infrastructure facilities:

- Installation for temporary storage of used fuel elements.
- Installation for intermediate storage of generated radioactive waste.
- Support laboratories.
- Administrative and operation support facilities.
- Site infrastructure, water treatment and supply system, electrical substation, etc.

The RMB project phases related to the detailed engineering design of laboratories and administration and infrastructure buildings, acquisition, construction, assembly, and commissioning require financial resources to be initiated.

After commissioning, the RMB must operate for 50 years, until its decommissioning.

Concerning the treatment and storage of radioactive waste at the site, a dedicated facility will be constructed to the handling, processing and safe storage of all radioactive waste produced by the multipurpose research reactor. The waste storage facility has been designed to accommodate all the low- and intermediate-level waste, produced throughout the whole RMB operational lifetime, set in 50 years.

For the spent fuel elements, the RMB design will also have space to store all the produced material, during the reactor lifetime of 50 years. In addition, the holding time of this irradiated fuel can last more 50 years, reaching a total storage time of 100 years.

6.1.4.6 - The Nuclear-Electric Generation Laboratory (LABGENE)

The Nuclear-Electric Generation Laboratory (LABGENE), located in the Navy's Technological Center in São Paulo (CTMSP) in the Iperó city in São Paulo State, it's a PWR type with 30MWe, designed by Brazilian Navy. The LABGENE, Figure 12, was designed with the purpose of validating new concepts and devices that will improve the performance and safety of the nucleoelectric generation and will be a powerful tool for R&D activities relating to fuels and systems that will give support to the development of commercial and naval applications.

Figure12 – Aerial view of LABGENE

CNEN issued the Site Approval for The CTMSP to start the site preparation for the LABGENE Unit 1999. After the first evaluation of RPAS of LABGENE, CNEN issued the 1st Partial Constructions License (LCP-1) in 2000 regarding the concreting of the foundations of the reactor building. The 2nd Partial Constructions License (LCP-2) was issued in 2012 and the electromechanical assembly was excluded from this. The 3rd Partial Constructions License (LCP-3) was issued in 2019 referent to electromechanical assembly of part of the containment vessel and shield pool. The 4th Partial Constructions License (LCP-4) was issued in 2021 referent to electromechanical assembly of second part of the containment vessel.

6.2 - Interface between Safety and Security

- ***The Regulatory framework***

In general terms, the CNEN Standard CNEN NN 2.01 (2019) require that the interfaces of Security Systems of Nuclear Installations, with Radiological Safety and Accounting and Control of Nuclear Material, be evaluated and managed in a way that there is no harmful interference between them and, when possible, that they act in mutual support.

- ***Cybersecurity***

CNEN recognizes that cyber attacks represent a major (and quickly evolving) issue and started studies in order to elaborate a regulation regarding cyber aspects, as well as disseminating culture among stakeholders.

On August 25, 2021, the DRS/CNEN, by means of Ordinance 48/2021 (amended by Ordinance DRS 52/2021), constituted a Working Group with a objective to preparing the base text of a Standard about implementation and maintenance of a Cyber Security Program applicable to nuclear installations, the Standard “CNEN NN 2.07 - Cyber Security of Nuclear Installations".

The Working Group, under the coordination of DISEN/DRS/CNEN carried out its work over a period of approximately six months, ending on February 9, 2022.

The process is now in the phase of constituting a Study Commission, which will then have to prepare the draft standard itself, based on the aforementioned base text."

Training Courses (with IAEA) held in Brazil:

a. TC in Cybersecurity (Rio de Janeiro, 2014)
b. NTC in Computer Security at Nuclear Facilities (Rio de Janeiro, 2016)
c. RTC Hands-on for Operators (Rio de Janeiro, 2017)

- *Cybersecurity – Operating Organization Actions*

These are the updates from the last 3 years of the work of the Information and Communication Technology Superintendence, which include activities in the areas of cyber security, network design and hardware and software projects

a. 2019:

The year of 2019 was marked by some realizations towards a new level of improvements on Cybersecurity. Some achievements took place under coordination of the Strategic Committee for Information Security of Eletrobras Companies (CESIE) and some of them were conducted as initiatives of Eletronuclear.

As the name suggests, CESIE is a committee made up of all companies in the Eletrobras group and whose mission is to discuss and study process improvements, risk and threat assessments, cybersecurity diagnosis based on the NIST Cybersecurity Framework and technological advances to strengthening the security and protection of companies.

i. Cyber Guardian Exercise – Second Edition

From July 2nd to 4th, 2019, Eletronuclear attended the second edition of the Cyber Guardian Exercise (EGC 2.0), that is an initiative of the Brazilian Army, under Cyber Defense Command (ComDCiber) coordination, being a collaborative action in order to share experiences and technical skills in Cybersecurity as well as promote tight integration among Nuclear Energy, Finance, Electrical Energy, Telecommunications and National Defense sectors on critical infrastructures protection.

The EGC 2.0 also count on academic community participation and other government agencies of support or associated with cybernetic protection of the State and Brazilian society.

In general, EGC is a three-day long tabletop exercise in simulation of crisis caused by cyber incidents, including the virtual operation simulation using the Asherah Nuclear Power Plant simulator, that was developed by the Brazilian Navy, in conjunction with the University of São Paulo (USP) and sponsored by the International Atomic Energy Agency (IAEA).

According to ComDCiber, the three main goals of the EGC are:

a. To coordinate and integrate cyber security and defense for protection of critical infrastructures of the Brazil;
b. To exercise the decision-making process in different levels of responsibility and competence, emphasizing the need for collaborative actions in the prevention, solution or mitigation of damages caused by cybernetic threats;
c. To verify effectiveness of procedures for solution of cyber security incidents in information critical infrastructures.

ii. General Law for the Personal Data Protection (LGPD) Project

In August 2018, the Brazilian government sanctioned the General Law for the Protection of Personal Data (LGPD), with which companies and organizations from the most varied economic sectors and the Brazilian market must comply by August 2020.

With the challenge that had begun to arise, Information Security specialists of the Eletronuclear began the study of the new law, four people were enrolled in training on the subject and then, the activities of the Eletronuclear adaptation project to the new legal requirements began to be defined.

On December 11th, 2019, the Executive Board of the Eletronuclear approved the Opening Term of the Project (TAP) for LGPD Project at the company and the activities continue to this day, with an expected completion date in June 2022.

Also in December 2019, the Policy of Protection of Personal Data and Privacy, was approved by Eletrobras holding for its companies.

iii. Information Security Awareness and Education Program (PECSI)

With the knowledge that Information Security involves a set of measures to protect processes, technology and people, in August 2019 the then Department of Security and Information and Communication Technology Services (DSS.A) submitted to the Information Security Committee of the Eletronuclear (CSI) a proposal of an Information Security Education and Awareness Program (PECSI) for employees of many areas of the company. PECSI would provide activities in eight dimensions:

1. Maintain the Virtual Learning Environment.
2. Train Downtime Plant Maintenance Personnel.
3. Management Training.

4. Annual Information Security Week.
5. Promote Lecture Series.
6. Production of Booklets and Educational Materials.
7. Issuance of Awareness Bulletins.
8. Training of the Technical Staff.

CSI approved the proposal of the DSS.A and then, the document describing PECSI was presented to Executive Board of the Eletronuclear, that approved the program on December 6th, 2019.

iv. Process for Handling Information Security Incidents of Eletrobras Companies

Along the year of 2019, DSS.A coordinated the preparation of the Technical Note of the Process for Handling Information Security Incidents of Eletrobras Companies (PTISIEE), a consistent document aimed at to drive how the companies can handle and respond incidents ranging from low to critical levels.

The PTISIEE introduces a new culture in the discipline of handling and responding to information security incidents, because it guides the participation not only of Information Technology and Cyber Security specialists in critical situations, but of a variety of areas of the business such as: Legal, Security, Internal Audit, Risks and Internal Controls, Compliance, Institutional Communication and other areas, each of them with their tasks to solve a crisis.

In addition to guiding the treatment in an Information Technology (IT) environment, the PTISIEE also disciplines the treatment of incidents in industrial Operation Technology (OT) environments.

The PTISIEE document would become the basis for the Regulation for the Treatment of Information Security Incidents of Eletrobras Companies document, which was approved by the Executive Board of Eletrobras holding on May 11th, 2020.

Within Eletronuclear, the guidelines of the PTISIEE document would be unfolded in revision 01 of the internal Normative Instruction 14.12 (IN 14.12), published on April 16th, 2020, and, in more detail, in the Corporate Procedure PC-AG-IN- 015, published on May 29th, 2020.

v. Process for Management of Technological Vulnerabilities of Eletrobras Companies

After concluding the PTISIEE document, DSS.A coordinated the preparation of the Technical Note of the Process for Management for Technological Vulnerabilities of Eletrobras

Companies, a consistent document aimed at to drive how the companies can identifiy and solve vulnerabilities throughout their systems in the IT and OT environments.

This document was concluded in the following year, 2020.

b. 2020

The Covid-19 pandemic has posed the toughest challenges to Cyber Security and Information Technology teams in institutions all over the globe. People had to get used to a new reality of remote work and processes had to be reinvented to survive the whirlwind of changes that the health crisis brought about in the world.

The year was marked by a strong appeal to raise awareness and educate employees at Eletronuclear.

Since remote access via VPN connection, which was restricted to a few users — even for obvious security reasons —, had to be released to all company employees, representing a point of vulnerability in overall Cybersecurity process of the Eletronuclear, the necessity of instructing people regarding security during remote work was all the time in mind, requiring a rigorous job with preparation of training, lectures and security bulletins.

i. General Law for the Personal Data Protection (LGPD) Project

In January 2020, Eletrobras holding entered into a contract so as to give a special DPO training course for the DPOs of its companies.

ii. New contracting of a Managed Security Services (MSS)

In 2020, the bidding for the contract for an MSS by Eletronuclear was finalized, which spent a few months without the coverage of this service.

The contract between the supplier and Eletronuclear was signed on February 21st, 2020, with a duration of 36 months, for the provision of the following services within the scope of the MSS:

a) Provision and management of antivirus for workstations and servers,
b) Provision and management of protection for mobile devices,
c) Provision and management of SIEM (Security Information and Event Management),
d) Providing and managing email security service,

e) Management of IPS (Intrusion Prevention System) and web content filter of the Eletronuclear,
f) SOC (Security Operations Center).

iii. Execution of the Fundamentals of Corporate Information Security course

Provided within the scope of the PECSI, this online course was responsible for training and raising awareness among 2015 Eletronuclear employees during the critical phase of the pandemic, between April 20th and June 12th, 2020.

The course covered various topics related to preventing phishing attacks, safe Internet browsing, the Cybersecurity Incident notification process and other important topics.

iv. Security Lectures and Bulletins

On May 20th, 2020, CIO of the Eletronuclear, Mr. Rodrigo Costa dos Santos, gave the lecture "Be the Protagonist in the Security of Your Information", providing many guidelines for the adoption of preventive behavior by users.

On July 29th, 2020, Data Protection Officer (DPO), Mr. Rodrigo Albernaz, gave the lecture "General Data Protection Law (LGPD) and What Eletronuclear Does to Protect Its Privacy".

CERT.Br is the Center for Studies, Response and Treatment of Security Incidents in Brazil. On October 28th, Cyber Security specialist Mrs. Miriam von Zuben, from CERT.Br, gave the lecture "Safe Internet for Your Children", bringing many guidelines on the care that parents should have with their children when browsing the Internet.

At least 5 security bulletins were released between March and December 2020.

Eletrobras holding released, on December 20th, 2020, for all group companies, the video "Information Security in Telework", which can be accessed at https://www.youtube.com/watch?v=b4WEmSbGf3Q.

v. Normative Instruction and Corporate Procedure for Security Incident Handling

On April 29th, 2020, Eletronuclear published the first revision of Normative Instruction 14.12, which unfolded the guidelines of the PTISIEE document in executive instructions for various areas of the business when information security incidents occurred.

A month later, on May 29th, Corporate Procedure PC-AG-IN-015 was published. This is a document with more technical language intended to guide the handling of security incidents in IT and OT environments.

vi. Critical Systems Contingency and Continuity Plan

In 2020, Eletronuclear prepared and tested the Continuity and Contingency Plan for two systems elected as the most critical to begin a gradual process of preparing a broader Continuity Plan along the time, with a gradual increase in scope in three systems each one or two years.

For the year 2020, the IBM Maximo EAM and the Sicronia systems were selected. The first is responsible for managing assets and supporting the maintenance of the plants at the Admiral Álvaro Alberto Nuclear Power Plants Complex (CNAAA) and is also widely used by the Engineering and Design areas as a source of consultations. The Sincronia system is basically an Electronic Document Management System (EDMS) that implements approval workflow processes, maintains nuclear unit operations manuals, procedures and a wide variety of technical documentation to support operations, engineering and projects.

The plan was tested on November 7th, 2020, with the systems being shut down in the Angra dos Reis datacenter and successfully "recovered" in the Rio de Janeiro datacenter. Subsequently, the systems were turned off at the Rio de Janeiro datacenter and "recovered" at the Angra dos Reis datacenter, with normal return to operation.

In 2022, the Continuity and Contingency Plan will be expanded with three more systems, which have already been selected: Siemens COMOS, CCN (Nuclear Fuel Control) and IBM SmartCloud Control Desk (SCCD).

Siemens COMOS is a system whose mission is to manage and create a systems engineering flowchart and a catalog of technical data for mechanical components in the valve and ventilation areas.

CCN aims to carry out the safeguard control of all nuclear material existing in the Angra 1 and Angra 2 nuclear units.

SCCD is the system used by the departments of the Information and Communication Technology Superintendence (ST.A) IT asset management, user service management, change and configuration management.

In fact, the known Continuity and Contingency Plan will be turned into a Disaster Recorey Plan (DRP) from 2022.

c. 2021

Still under pandemic conditions, 2021 was a year of profound improvements of the cybersecurity processes of the Eletronuclear.

i. Adhesion to the Integrated SOC of Eletrobras companies

Faced with the urgent need to improve the processes of prevention, detection and response to incidents, vulnerability assessment and monitoring of all used IT equipment used by Eletronuclear, it was proposed by Eletrobras holding still in 2020, the institution of a Single Security Operations Center (SOC) to serve all group companies.

The Integrated SOC of the Eletrobras companies has, among its most varied applications, enabling the evaluation of events and the detection of cybersecurity incidents in real time, instituting a single security base for all signatories of the service, allowing the correlation of adverse events, comprehensive and integrated visibility of the group of the companies, robust improvement of information security risk management, vulnerability management and incident handling processes.

The Integrated SOC raised the level of security for entire corporate network of the Eletronuclear, enabling a drastic reduction in the success of any cyber-attacks, identification and containment of violations that have the potential for extremely high costs, and compliance with the level of requirements within the scope of compliance audits. with the Sarbanes-Oxley Act (SOx).

ii. Cyber Guardian Exercise – Third Edition

From October 5th to 7th, 2021, Eletronuclear attended the third edition of the Cyber Guardian Exercise (EGC 3.0). In this edition, the transport and water and sewage treatment sectors were included.

iii. Adaptation of Eletronuclear to the LGPD

On June 1st, 2021, the consultancy contracted to support the LGPD project at Eletronuclear started its activities.

Several deliverables are foreseen in the contract, such as data inventory support, data discovery service in order to locate personal data on the network, design and documentation of a personal data privacy governance process, training and other important activities and products.

Consultancy support continues until June 2022.

iv. Update of the Information Security Incident Handling Regulation

In October 2021 the Information Security Incident Handling Regulation was reviewed and updated in order to cover data protection and privacy incident handling issues and processes.

v. Information Security Week of the Eletrobras Companies

From November 23rd to 26th, 2021, Eletrobras holding promoted the first edition of the Information Security Week of the Eletrobras Companies, an event that had the participation of 19 speakers with the presentation of topics easy to understand by the end user, lectures for managers and directors, and lectures for cybersecurity and IT experts.

On each day of the week, a president of one of the Eletrobras companies opened the event with a word of support and encouragement for the Information Security Week, demonstrating commitment and sponsorship of the Information Security theme.

On November 18th, there was a lecture with a specialist in Information Security only for managers, directors and presidents of Eletrobras companies. This was a preparatory event for Information Security Week, raising awareness among leaders of its importance.

6.4 - A statement on the position of the Contracting Party concerning the continued operation of the nuclear installations, including those that do not comply with the obligations as stated in Articles 10-19 of the Convention, explaining how safety and other aspects were taken into account in reaching this position.

(See the item B.13)

ARTICLE 7 - LEGISLATIVE AND REGULATORY FRAMEWORK

> *"1. Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.*
>
> *2. The legislative and regulatory framework shall provide for:*
>
> *(i) the establishment of applicable national safety requirements and regulations;*
>
> *(ii) a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a licence;*
>
> *(iii) a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences;*
>
> *(iv) the enforcement of applicable regulations and of the terms of licences, including suspension, modification or revocation."*

7 (1) Establishing and maintaining a legislative and regulatory framework

7(1).1 - General overview of the main legislative framework in relation to nuclear safety.

The legislative framework in Federative Republic of Brazil is Brazilian is divided into three hierarchical groups: constitutional norms, infra-constitutional norms (legal norms) and infra-legal norms, with no hierarchy between norms of the same group:

- Constitutional Norms:
  - Federal Constitutions,
  - Constitutional Emends and
  - International Human Rights Treaties and Conventions.
- Infra-Constitutional norms (Legal Norms):
  - Complementary Law,
  - International Treaties and Convention,
  - Ordinary Law,
  - Delegated Law,
  - Provisional Measure,
  - Legislative Decree, and

    - Resolutions.
- Infra-Legal Norms:
    - Decree,
    - Ordinance, and
    - Normative Acts.

The Complementary laws are intended to complement the norms provided in the Federal Constitution. For the Legislative Power (National Congress) to approve a Complementary Law, a special quorum is required (art. 69 of Federal Constitution), therefore, different from ordinary laws.

The international treaties and Convention have the same procedure as ordinary laws.

The Ordinary Laws are the normative acts per excellence, constituting the large number of normative acts that make up the set of laws of the Brazilian State, aiming at the regulation of precepts destined to the regulation of social coexistence and the structuring of the State.

Delegated Law is a normative act prepared by the head of the executive branch at the federal, state and municipal levels, with the authorization of their respective legislative house, for cases of relevance and urgency, when the production of an ordinary law would take a long time to respond to the situation. The chief executive requests authorization, and the legislative power sets the content and terms of its exercise. After the law is created by the chief executive, it is sent to the legislature for evaluation and approval. Considering that the limits have been respected and that the law is convenient, the legislature approves it, however, this norm enters the legal system as an ordinary law.

The Provisional Measure, a one-person act, edited by the President of the Republic, has the force of law for 30 days. Within this period, it must be rejected or transformed into Law by the Legislative Power or reissued for another 30 days. Its assumptions are urgency and relevance.

Legislative decrees are rules that regulate matters of exclusive competence of Congress. For example, ratifying international acts, suspending normative acts by the President of the Republic.

Resolutions are normative administrative acts issued by the high authorities of the Executive (but not by the Chief Executive, who must only issue decrees) or by the presidents of courts, legislative bodies and administrative collegiate, to discipline matters within their specific competence.

Decrees are decisions of a higher authority, with the force of law, to discipline a particular fact or situation. The Decree, therefore, being hierarchically inferior, cannot contradict the law, but it can regulate it, that is, it can make it explicit, clarify or interpret it, respecting its foundations, objectives and scope.

The Normative Acts are those that contain a general command of the Executive, aiming at the correct application of the law. The immediate objective of such acts is to explain the legal norm to be observed by the Administration and by the administrators. This category includes regulatory decrees and regulations, as well as resolutions, deliberations, and ordinances of general content.

The Ordinance is an administrative act of any public authority, which contains instructions on the application of laws or regulations, recommendations of a general nature, rules of service execution, appointments, dismissals, punishments, or any other determination of its competence.

Brazil has established and maintained the necessary legislative and regulatory framework to ensure the safety of its nuclear installations. The Federal Constitution of 1988 specifies the distribution of responsibilities among the Federal Government, the States and the Municipalities with respect to the protection of the public health and the environment, including the control of radioactive materials and installations (Articles 23, 24 and 202). As mentioned in item A.1, the Federal Government is solely responsible for nuclear activities related to electricity generation, including regulating, licensing and controlling nuclear safety (Articles 21 and 22). In this regard, the Comissão Nacional de Energia Nuclear (National Commission for Nuclear Energy - CNEN) is the Brazilian nuclear national regulatory body, in accordance with the Brazilian Legislation.

However, the Law No. 14,222, promulgated on October 15, 2021, creates the National Authority on Nuclear Safety (Autoridade Nacional de Segurança Nuclear, ANSN). The ANSN will became the New Regulatory Body in Brazil, responsible for regulating, licensing, and controlling of civilian use of nuclear energy and protect the public health and the environment against ionizing radiation. The ANSN will assume the regulatory functions previously performed by CNEN. Finally, ANSN will be linked to the Ministry of Mines and Energy, in according to the Decree No. 10,861, issued on November 19, 2021, see item B.5.

Furthermore, the constitutional principles regarding the protection of the environment (Article 225) require that any installation that may cause significant environmental impact shall be subject to environmental impact studies. More specifically, for nuclear facilities, the Federal Constitution (Article 225, paragraph 6) states that a specific law shall define the site of any new nuclear facility. Therefore, nuclear installations are subject to both a nuclear licence by CNEN and an environmental licence by the Brazilian Institute for Environment and Renewable Natural Resources - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), which is the national environmental authority, with the participation of state and municipal environmental agencies as stated in the National Environmental Policy Act (Law 6938/81) and the Supplementary Law 140 of 08 December 2011. These principles were established by the Federal Constitution of 1988, when Angra-1 was already in operation, and Angra-2 was in construction. Hence, the licensing of these power plants followed slightly different procedures, as described later on in this Report.

Therefore, the norms established by CNEN, called nuclear norms (or standard), are published by means of resolutions, are of mandatory nature, of application throughout the national territory, and their primary objective is to guarantee the safety of workers and the general public; to preserve the quality of the environment, in all activities involving ionizing radiation.

The Decree No. 9.600, of December 5th 2018, consolidates the guidelines of the Brazilian Nuclear Policy. This Policy is intended to provide guidelines for: the development of the Brazilian nuclear industry; the capacity building of qualified human resources; the maintenance of the domain and the use of nuclear technology in various segments. In addition, it outlines nuclear and radioactive activities in order to ensure the safe and secure use of this technology and reinforces Brazil's position in favor of disarmament and non-proliferation of nuclear weapons.

Thus Decree 9.600 provides coherence to infraconstitutional legislation with the objectives of the Brazilian State, is aligned with the international commitments assumed by the Government and, above all, contributes to the national development and for the promotion of the well-being of Brazilian society."

In the area of Nuclear Safety, the following laws were approved and officially published during the period from January 2019 to December 2021:

- Decree No. 9.600, issued on 01 January 2019, links Indústrias Nucleares do Brasil (INB) and Nuclebrás Equipamentos Pesados (Nuclep) to the Ministry of Mines and Energy (MME).
- Decree No. 9.828, 10 June 2019 - Restructured the Committee for the Development of the Brazilian Nuclear Program (CDPNB).
- Decree No. 9.865, iisued 27 June 2019, Predispose about the collegiate bodies of the Brazilian Nuclear Program Protection System.
- Decree No. 10.748, issued 16 July 2021, Establishes the Federal Cyber Incident Management Network (Rede Federal de Gestão de Incidentes Cibernéticos).
- Decree 10.791, issued 10 September 2021, Create the Brazilian Company of Holdings in Nuclear Energy and Binacional S.A. (Empresa Brasileira de Participações em Energia Nuclear e Binacional S.A.

- Law No. 14.222, of October 15th, 2021, which established the regulatory body of the National Authority on Nuclear Safety (Autoridade Nacional de Segurança Nuclear, ANSN).
- Decree No. 10,861, issued on November 19, 2021, links ANSN to the Ministry of Mines and Energy (MME).
- Legislative Decree No. 3 of February 23, 2022, Approves the text of the Amendment to the Convention on the Physical Protection of Nuclear Material, endorsed by Brazil on the Conference on the Amendment of the aforementioned Convention, held in 2005, in Vienna.
- Decree No 11.142 issue on July 21, 2022, establishing the organizacional structure of the ANSN.

7(1).2 - Ratification of international conventions and legal instruments related to nuclear safety.

Brazil has signed and ratified several international conventions and legal instruments (see Annex II.1) that, once ratified by the National Congress, become national legislation, and are implemented through CNEN regulations:

- Decree No. 8/1991: enacts the Convention on the Assistance in Case of a Nuclear Accident or Radiological Emergency
- Decree No. 9/1991: enacts the Convention on the Early Notification of a Nuclear Accident
- Decree No. 95/1991: enacts the Convention on Physical Protection of Nuclear Material
- Legislative Decree No. 93/1992: enacts The Vienna Convention on Civil Liability for Nuclear Damage, December 23, 1992.
- Decree No. 1.065/1994: enacts the Quadripartite Agreement (Safeguards Agreement)
- Decree No. 1.246/1994: enacts the Treaty of Tlatelolco
- Law No. 9112/1995: Export of sensitive goods and services Decree No. 2.648/1998: enacts the Convention on Nuclear Safety
- Decree No. 2.864/1998: enacts the Treaty on Nonproliferation of nuclear weapons (NPT) 21.
- Decree No. 3.976/2001: related to the implementation of the UNSC Resolution 1373 (2001) in Brazil.
- Decree No. 4.394/2002: enacts the International Convention on the Supression of Terrorist Bombings.
- Decree No. 5.935/2006: enacts the Joint Convention on the Safety of Spent Fuel Management and Radioactive Waste 27.

- Decree No. 7.722/2012: related to the implementation of the UNSC Resolution 1540 (2004) and UNSC Resolution 1977 (2011) in Brazil.

In the review period January 2019 to December 2021 Brazil has issued the:

Legislative Decree No. 3 of February 23, 2022, Approves the text of the Amendment to the Convention on the Physical Protection of Nuclear Material, endorsed by Brazil on the Conference on the Amendment of the aforementioned Convention, held in 2005, in Vienna

Article 7 (2) (i) - National safety requirements and regulations

7 (2) (i).1 – Overview of the secondary legislation for nuclear safety

By the Law 4118/62, with alterations determined by the Laws 6189/74 and 7781/89, CNEN became the Regulatory Body in charge of regulating, licensing and controlling nuclear energy. Since 2000, CNEN is under the Ministério de Ciência, Tecnologia e Inovação (Ministry of Science, Technology and Inovation - MCTI).

Now, the Law No. 14,222, promulgated on October 15, 2021, creates the National Authority on Nuclear Safety (Autoridade Nacional de Segurança Nuclear, ANSN). Therefore, the ANSN became the New Regulatory Body in Brazil, responsible for regulating, licensing, and controlling of civilian use of nuclear energy and protect the public health and the environment against ionizing radiation. The ANSN will assume the regulatory functions previously performed by CNEN. Finally, ANSN will be linked to the Ministry of Mines and Energy, in according to the Decree No. 10,861, issued on November 19, 2021

Under Law No. 14,222, the ANSN has financial, technical, and administrative autonomy from CNEN. (Art. 1.) The ANSN will be responsible for monitoring, regulating, and inspecting nuclear activities, materials, and facilities to ensure nuclear and radiological safety. (Art. 2.) As one of its main responsibilities, the ANSN will establish regulations and safety procedures for the use of nuclear materials and operation of nuclear facilities. (Art. 6(I).) Also, the ANSN will oversee the granting of licenses and permits to organizations involved in trading, importing, exporting, or transferring nuclear materials. (Art. 6(III).) In addition to other responsibilities related to issuing licenses or authorizations, the ANSN will select the sites for and approve the construction and operation of new nuclear facilities, as well as the decommissioning of other facilities. (Art. 6(V)(a).)

The ANSN will also impose sanctions on organizations for administrative infractions related to the violation of nuclear and radiological safety regulations. The sanctions applied will be based on the level of damage or risk caused to individuals, property, or the environment. (Art. 12.) Administrative infractions include failing to submit documents detailing the production and distribution of nuclear materials and neglecting to provide information about nuclear facility activities. (Art. 13(II, III).) Sanctions include fines and temporary suspension of nuclear facility functions. (Art. 14.) Organizations with the most serious infractions may have their licenses revoked. (Art. 24.)

The ANSN also has the authority to impose measures to prevent any accident or damage involving nuclear or radioactive material. These measures include suspending nuclear facility functions and seizing materials and equipment. (Art. 19.) The ANSN will also orient and collaborate with federal, state, and municipal public officials to develop emergency plans in the case of nuclear or radiological accidents. (Art. 6(XI).) Collaboration between the ANSN and international and foreign regulatory organizations may occur to shape regulations on nuclear safety, radiological protection, and control of nuclear materials. (Art. 6(XVII).)

According with Art.2 of Law No. 14,222, the responsibility for regulating, licensing, and controlling of civilian use of nuclear energy and protect the public health and the environment against ionizing radiation lies with the ANSN. The ANSN will also impose sanctions on organizations for administrative infractions related to the violation of nuclear and radiological safety regulations. The sanctions applied will be based on the level of damage or risk caused to individuals, property, or the environment. (Art. 12.) Administrative infractions include failing to submit documents detailing the production and distribution of nuclear materials and neglecting to provide information about nuclear facility activities. (Art. 13(II, III).) Sanctions include fines and temporary suspension of nuclear facility functions. (Art. 14.) Organizations with the most serious infractions may have their licenses revoked. (Art. 24.)

However, the Governmen not yet prepare the ANSN structure and its internal regiment; and is working on the transition from CNEN to ANSN. The ANSN is not totally implemented, therefore, CNEN continues to act as a Regulatory Body on an interim basis.

CNEN responsibilities related to this Convention include, among others:

- Preparation and issuance of regulations on nuclear safety, radiation protection, radioactive waste management and physical protection.
- Accounting and control of nuclear materials (safeguards).
- Licensing and authorization of siting, construction, operation and decommissioning of nuclear facilities.
- Regulatory inspection and enforcement of nuclear installations.

- Acting as a national authority for the purpose of implementing international agreements and treaties related to nuclear safety activities.
- Participating in the national preparedness, and response to nuclear emergencies.

Under this framework, CNEN has issued regulations related to radiation protection, licensing process of nuclear power plants, safety during operation, quality assurance, licensing of operational personnel, reporting requirements, plant maintenance, and others (see Annex II for a list of relevant CNEN regulations).

7 (2) (i).2 – Overview of regulations and guides issued by the regulatory body:

CNEN Standards are officially issued through a resolution of its Deliberative Commission, which is constituted by CNEN's President, three directors (Safety and Security, Research and Development and Institutional Management) and an external member representing society. The standards elaboration process is performed according to the documented procedure, with the participation of experts in several disciplines pertinent to the subject in matter, involving the several areas of the Commission.

CNEN Standards define the requirements, which shall be attended to ensure that the safety and security purposes are satisfied. These standards do not define how something can be done, thus, in certain cases, CNEN Standards only contain some requirements of general character. In special situations, it is necessary a formal interpretation of some requirements as well as some additional information of acceptable ways to accomplish them. For that purpose, in 1999 the "Regulatory Positions" were created according to the documented procedures and since then they have been regularly issued by CNEN's Radioprotection and Nuclear Safety Directory. They speed up regulatory control and work as a "bridge" between CNEN Standards and other reference documents, in particular those of the IAEA.

The licensing regulation CNEN NE 1.04[5] establishes that no nuclear installation shall be constructed or operated without a licence. It also establishes the necessary review and assessment process, including the specification of the documentation to be presented to CNEN at each phase of the licensing process. It finally establishes a system of regulatory inspections and the corresponding enforcement mechanisms to ensure that the licensing conditions are being fulfilled. The enforcement mechanisms include the authority of CNEN to modify, suspend or revoke the licence.

The Table 3 presents the list of regulations, guides and documents of CNEN's Management System reviewed and issued by the regulatory body during the period from January 2019 to December 2021.

Table 3 - list of regulations, guides and documents of CNEN's Management System reviewed and issued during period period from January 2019 to December 2021.

Number	List of standards updated from January 2019 to December 2021
CNEN NN 6.02	Licensing of Radiative Installations (Resolution CNEN 251/19) - Licenciamento de Instalações Radiativas – (Resolução CNEN 251/19)
CNEN NE 2.01	Physical Protection of Operational Units in the Nuclear Area (Resolution CNEN 259/19) - Proteção Física de Unidades Operacionais da Área Nuclear (Resolução CNEN 253/19)
CNEN NN 7.01	Certification of Qualification of Radiological Protection Supervisors (Resolution CNEN 259/20) - Certificação da Qualificação de Supervisores de Proteção Radiológica (Resolução CNEN 259/20)
CNEN NN 6.02	Licensing of Radiative Installations (Resolution CNEN 261/20) - Licenciamento de Instalações Radiativas (Resolução CNEN 261/20)
CNEN NN 5.01	Regulations for the Safe Transport of Radioactive Materials (Resolutions CNEN 271/21) - Regulamento para o Transporte Seguro de Materiais Radioativos (Resolução CNEN 271/21)
CNEN NN 6.10	Safety and Radiological Protection Requirements for Radiotherapy Services (Resolution CNEN 277/21) - Requisitos de Segurança e Proteção Radiológica para Serviços de Radioterapia (Resolução CNEN 277/21)
	List of standards issued from January 2019 to December 2021
CNEN NN 6.07	Safety and Radiological Protection Requirements for pit Profiling (Resolution CNEN 252/19) - Requisitos de Segurança e Proteção Radiológica para Perfilagem de Poços (Resolução CNEN 252/19)

CNEN NN 2.01	Physical Protection of Nuclear Materials and Installations (Resolution CNEN 253/19) - Proteção Física de Materiais e Instalações Nucleares (Resolução CNEN 253/19)
CNEN NN 2.06	Physical Protection of Radioactive Sources and Associated Radiative Installations Proteção Física de Fontes Radioativas e Instalações Radiativas Associadas (Resolução CNEN 254/19)
PR 3.01/012	Investigation and Reference Levels for Radioactivity in Potable Water (Resolution CNEN 260/20) - Níveis de Investigação e de Referência para Radioatividade em Água Potável (Resolução CNEN 260/20)
CNEN NN 6.11	Safety and Radiological Protection Requirements in Radioisotope Production Facilities with Cyclotron Accelerators (Resolution CNEN 267/20) - Requisitos de Segurança e Proteção Radiológica em Instalações Produtoras de Radioisótopos com Aceleradores Cíclotrons (Resolução CNEN 267/20)
CNEN NN 5.05	Design and Testing Requirements for Certification of Radioactive Materials, Packages and Volumes (Resolution CNEN 272/21) - Requisitos de Projeto e de Ensaios para Certificação de Materiais Radioativos, Embalagens e Volumes (Resolução CNEN 272/21)
Res 288/21	Requirements for facilities to obtain registration for NORM tailings cleaning and conditioning activities from the oil and gas exploration and production área (Resolution CNEN 288/21) - Requisitos para instalações obterem registro para atividades de limpeza e acondicionamento de rejeitos NORM da área de exploração e produção de óleo e gás (Resolução CNEN 288/21)
	List of standards in preparation from January 2019 to December 2021
CNEN NN 6.12	Safety and Radiological Protection Requirements for Veterinary Radiotherapy and Nuclear Medicine Services (resolution CNEN 291/22) - Requisitos de Segurança e Proteção Radiológica para Serviços de Radioterapia e Medicina Nuclear Veterinária (Resolução CNEN 291/22)

CNEN NN 2.05	Physical Protection in the Transport of Nuclear Materials and Other Radioactive Materials - Proteção Física no Transporte de Materiais Nucleares e Outros Materiais Radioativos
CNEN NN 2.07	Cybersecurity of Nuclear Installations - Segurança Cibernética de Instalações Nucleares
CNEN NN 6.13	Safety and Radiological Protection Requirements in Centralized and Industrial Radiopharmacy Facilities - Requisitos de Segurança e Proteção Radiológica em Instalações de Radiofarmácia Centralizadas e Industriais
	Radioprotection and Radiological Safety Requirements for Facilities and Activities involving the acquisition of Human Images for Public Safety purposes - Requisitos de Radioproteção e Segurança Radiológica para Instalações e Atividades que envolvam obtenção de Imagens Humanas para fins de Segurança Pública
	List of standards under review from January 2019 to December 2021
CNEN NE 1.10	Safety of Tailings Dam Systems Containing Radionuclides - Segurança de Sistemas de Barragem de Rejeitos Contendo Radionuclídeos
CNEN NN 3.01	Basic Radiological Protection Guidelines - Diretrizes Básicas de Proteção Radiológica
	Documents of CNEN's management system issued from January 2019 to December 2021
OI – PR - 002	Establishes the structure, organization and functioning of the CNEN Radiological and Nuclear Emergency Response System. (Ordinance PR/CNEN Nº 29/2021)
OI – PR – 002 Revision 01	Establishes the structure, organization and functioning of the CNEN Radiological and Nuclear Emergency Response System. (Ordinance PR/CNEN Nº 24/2022)
OI - DRS - 0007	Preparation of Regulatory Guides (Elaboração de Guias Regulatórios)
OI - DRS - 0006	General Standardization Plan (Plano Geral de Normatização)

OI-DRS-0003	GENERAL SUPERVISION PLAN (Rev.01)
OI-DRS-0004	RESPONSE ACTIONS FOR DETECTION / RECOVERY OF ORPHAN SOURCES
OI-DRS-0005	PROGRAM FOR INSPECTORS TRAINING IN RADIOPROTECTION AND NUCLEAR SAFETY
PI-DRS-0003	Preparation - Review of Nuclear Standards (Elaboração - Revisão de Normas Nucleares)
P-DRS-0004	Presentation (Standard format) of Nuclear Standards - Apresentação das Normas Nucleares
PI-DRS-0001	CONDUCTING REGULATORY INSPECTIONS
PI-DRS-0002	PROCEDURE FOR DELIVERY OF RADIOACTIVE MATERIAL TO CNEN HEADQUARTERS, DISTRICTS AND OFFICES
NT-SEASE-002/19	Guide for Regulatory review of Internal Hazards PSA of the CNAAA Plants (TECHNICAL NOTE Nº 2/2020/SEASE/CODRE/CGRC/DRS)
NT-SEASE-001/19	Guide for Regulatory review of External Event PSA of CNAAA Plants (TECHNICAL NOTE Nº 1/2021/SEASE/CODRE/CGRC/DRS)
NT-SEASE-002/21	Guide for Regualtory Review of Level 3 PSA of the CNAAA Plants (TECHNICAL NOTE Nº 2/2021/SEASE/CODRE/CGRC/DRS)
NT-SEASE-006/21	Guide for Regulatory Review of Seismic PSA of the CNAAA Plants (TECHNICAL NOTE Nº 6/2021/SEASE/CODRE/CGRC/DRS)

– Overview of of the process of establishing and revising regulatory requirements, including the involvement of interested parties:

1. The demand for the elaboration or revision of a regulation need to be requested by the technical area of the CNEN Directorate of Safety, Security and Safeguards (DRS) related with the theme of the regulation.

2. The request is evaluated by the Standards Committee of DRS. If approved, it will be included in the DRS Standards Preparation and Review Program.
3. A Drafting Group (GR) is created, responsible for preparing the basic text of the regulation to be elaborated or revised.
4. A Study Commission (SC) is created, responsible for preparing the draft standard from the base text.
5. The draft standard is submitted to directed/targeted consultation, being forwarded to external entities that could be impacted by the elaboration/review of this new or revised regulation, at the discretion of the SC, with a maximum period of 30 to 60 days for sending contributions.
6. The SC meets again to decide incorporating or not the suggestions and coments received in the targeted consultation.
7. At the discretion of the SC, there may be a Sectorial Dialogue, by means of a face-to-face or virtual meetings, to discuss contributions that need further depth in order to make a decision as to whether or not to accept them.
8. The draft standard is then placed for public consultation on the CNEN website on the Internet for a minimum period of 45 days and a maximum of 90 days, established in the public notice published in the Official Gazzete of Federal Government (DOU).
9. The SC meets once more to decide incorporating or not the suggestions received in the public consultation.
10. The SC prepares a report of "Opinion of Merits", concluding on the adequacy of the Draft Standard.
11. The process is forwarded to the Federal Prosecutor's Office at CNEN (PF/CNEN) for a legal opinion and comments.
12. If necessary, the SC meets to incorporate the suggestions contained in the PF/CNEN opinion.
13. The Draft Standard is forwarded to the CNEN Deliberative Committee for approval and publication in the Official Gazzete of Federal Government (DOU).

Federal Law 9.765 has been approved in 1998 and changed by Law 14.222 issued in 2021 establishing taxes and fees for each individual licensing step, as well as for the routine work of supervision of the installation by CNEN.

The Standards 1.04 – Licensing of Nuclear Installations, 1.10 – Safety in dam systems with nuclear waste, 1.13 – Licensing of Mines and Uranium Ore Beneficiation Plants, 1.14 – Reports of Nuclear Power Plants, 1.21 – Maintenance of nuclear power plants are currently under review. New standards on Nuclear Emergency Preparedness and Response and Probabilistic Safet Assessment are being drafted. The sagety guides of IAEA are being used as main references.

Federal Law 9.765 has been approved in 1998 and changed by Law 14.118 issued in 2021 establishing taxes and fees for each individual licensing step, as well as for the routine work of supervision of the installation by CNEN.

7 (2) (ii) System of licensing

- ***Overview of the licensing system and processes including types of licensed activity and, where appropriate, the procedure for relicensing.***

A) Nuclear Licensing Process (Authorization Process)

The nuclear licensing process is divided in several steps:

- Site Approval.
- Construction License.
- Authorization for Nuclear Material Utilization.
- Authorization for Initial Operation.
- Authorization for Permanent Operation.
- Ratification or rectification of Authorization for Permanent Operation every 10 years, considering the evaluation of the Periodic Safety Review (PSR).
- Authorization for Extended Operation (AOE) or License Renewal.
- Authorization for Decommissioning.
- Regulatory Control Withdrawal.

- ***Site Approval.***

In practice, the first activity to be carried out in the implementation of a power plant or other nuclear installation is the choice of the location, which must necessarily be approved by CNEN, in accordance with the regulations in force. The main standards that regulate this step are: CNEN RES-09/69 – *Rules for Choosing Site for Installing Power Reactors*, CNEN NE 1.04 – *Licensing of Nuclear Installations* and CNEN NN 3.01 – *Basic Guidelines for Radiological Protection*.

For the first step, Site Approval, site selection criteria are established in Resolution CNEN 09/69 [6], taking into account design and site factors that may contribute to violation of established dose limits at the proposed exclusion area for a limiting postulated accident. Additionally, by adopting the principle of "proven technology", CNEN regulation NE 1.04 requires for site approval the adoption of a "reference plant" for the nuclear power plants to be licensed. In that case, the applicant must submit together with the Site Approval application, in according to CNEN NE 1.04 standard, a "Site Report" which shall include additional information to that presented above:

- Physical characteristics of the site, including seismology, meteorology, geology and hydrology.
- Pre-operational environmental monitoring program.

In the site assessment process, the following factors must be considered: dimensions; local physical characteristics such as meteorology, hydrology, and area seismology; population density of the surrounding area; types of use of this area, such as industrial, residential, tourist uses or for agriculture and/or livestock; access roads and distance to the nearest population centers, also taking into account the characteristics of the reactor to be located there.

The "Rules for Choosing Sites for Installing Power Reactors", CNEN RES-09/69, require the consideration of two specific areas for the purpose of calculating radiological doses for the population: (1) "exclusion area" and (2) "low population zone". The "exclusion area" is defined as the area belonging to the concessionaire's property which surrounds the reactor and where the concessionaire has the authority to determine all activities, including removal of personnel. Low population zone is the sparsely populated area adjacent to the exclusion area. The total number of inhabitants must allow the existence of protective measures to be taken in the event of a serious accident.

In addition, the determination of these areas is based on the radioactivity released as a result of the "postulated maximum accident". This is defined as the accident resulting from a possible sequence of accidental events and whose consequences will not be exceeded by any other possible accident, except those whose probability of occurrence is so small that it can be considered almost null. Such accidents are assumed to cause damage to the reactor core, with the subsequent release of an appreciable amount of fission products. In this assessment, certain hypothetical accidents, called "Design Basis Accidents" are considered.

The "exclusion area" is determined so that the total radiation dose, for the whole body, does not exceed 25 rem and the total radiation dose, per iodine-131 absorption in the thyroid, does not exceed 300 rem for an individual situated in a point on its outer boundary line. The irradiation time is two hours, counted from the beginning of the maximum postulated accident.

Based on the characteristics of the site, considering the technical characteristics of the proposed reactor, such as maximum power level, specific safety aspects, both to prevent accidents and to minimize their consequences, such as containment and specific safety systems, and considering a previous analysis of the "Design Basis Accidents", CNEN can determine the acceptance of the site in terms of population protection.

Article 17 discusses the assessments and verifications, as well as the reassessments carried out in relation to the site.

- ***Construction License***

Before construction begins on the approved site, it is necessary to obtain a CONSTRUCTION LICENSE. In this sense, the first formal step is the submission to CNEN of an application requesting the Construction License, in accordance with the system provided for in the CNEN Standard CNEN NE 1.04, CNEN NN-1.16, CNEN NN 2.01, CNEN NN 2.03 and other complementary standards [ANNEX II.3 – CNEN Regulations].

The application for this license must be accompanied by Preliminary Safety Analysis Report (PSAR), Preliminary Physical Protection Plan (PPPF), Quality Assurance Program (QAP) and Preliminary Plan for Personnel Training.

The Preliminary Safety Analysis Report (PSAR), a basic document to allow the Project Safety review and assessment. This report, given its purpose, is quite complex and extensive, comprising several volumes with thousands of pages of technical information, presenting the design criteria and preliminary information available for the proposed reactor, along with site-specific data. This report should also discuss the various hypothetical accident situations and the expected safety features, with the aim of preventing accidents from occurring, or, if not, mitigating their effects on the public and operators.

As required, a Preliminary Safety Analysis Report (PSAR) follow the US NRC Regulatory Guide 1.70 - Standard Format and Contents for Safety Analysis Report of LWRs and the Standard Review Plan (NUREG - 0800).

The information contained in the Safety Analysis Reports (Preliminary and/or Final) must be sufficient to allow a technical review of the project and the operation plans. Typically, a Safety Analysis Report should include the following information:

I. Identification of design criteria, showing the influence of site characteristics on the project and establishing the requirements used in the main systems and components, with a view to their fabrication and safety.
II. Technical description and analysis of the project, including:
   a) Generation, transport and heat transfer, steam generation and conversion systems and their technical characteristics,
   b) Associated auxiliary equipment,
   c) Survey of data and significant parameters and their limitations,
   d) Reactivity balance and methods of its control under different operating conditions,
   e) Safety features,
   f) Normal and emergency power supply systems,
   g) Information on reliability of operating systems and equipment, etc.
III. Safety Analysis, considering the influence of the environment and the characteristics to guarantee Safety under normal conditions and in foreseen emergency conditions (analysis of accidents), with their potential consequences. The analysis must show that the safety features, incorporated into the project, are sufficient to ensure that there are no undue risks to the public and operating personnel.
IV. General information related to the operation, such as operational organization, maintenance, administrative procedures, pre-operational tests, start-up and operation, qualification criteria and personnel training programs.
V. Quality Assurance Program,
VI. Radiological monitoring program and environmental protection requirements.
VII. Emergency Plan.
VIII. Preliminary Physical Protection Plan (PPPF).

Before issuing the Construction License, which can be broken down, in practice, into authorizations and partial licenses, CNEN must reach a conclusion on the following main points:

- the installation and equipment, technical specifications and proposals referring to any of these items must jointly provide assurance that the applicant will comply with legal provisions and CNEN standards and that the health and safety of the public, including those operators, will not take risks arising from the operation of the reactor or installation.
- the applicant is technically and financially qualified to carry out the construction in accordance with applicable legal, regulatory and technical provisions.

For the construction license, CNEN performs a detailed review and assessment of the information received from the licensee in a Preliminary Safety Analysis Report (PSAR), Preliminary Physical Protection Plan (PPPF), Quality Assurance Program (QAP) and Preliminary Plan for Personnel Training. This detailed review and assessment is carried out by the technical team of the CGRC/DRS/CNEN and involve thousands of man-hours of work, usually over a period of eighteen or twenty-four months. It also requires the participation of highly qualified and specialized personnel in the most different technical fields, making specific advice still necessary in certain areas. Finally, a SAFETY ASSESSMENT REPORT (SAR) is prepared on which the CNEN's Deliberative Commission (CD) for the issuance of the Construction License is based.

The construction can then be started according to the project described in the RPAS and with the requirements and conditions that may be presented in the Construction License and approved by the CD.

During the review and analysis, if necessary, additional information is requested from the applicant, through questions and holding meetings to discuss doubtful points. Additional information submitted as a result of these requests is documented as an integral part of the RPAS in the form of an Addendum.

The Safety Assessment Report (SAR) is a summary of the RPAS review and assessment. It is normally divided in a similar way to the PSAR and presents the conclusions of the technical team that carried out the review, mainly in the following aspects:

- Site assessment,
- Compliance with the General Design Criteria adopted,
- Functional performance; system requirements and technical security characteristics,
- Design and manufacturing requirements,
- Failure analysis,
- Quality Assurance Program,
- Pre-operational and Start-up Testing Requirements,
- Radiological monitoring and environmental protection requirements,
- Need for research and development,
- Accident analysis.

Quality Assurance: before the implementation of the project and during construction, the applicant must have a Quality Assurance Program in place, in compliance with CNEN Standard NN 1.16, which consists of its own system of checks and counterchecks, comparisons, inspections, tests, adequate records, etc., to ensure the high level of quality, and, consequently, of safety, required in nuclear installations. Quality Assurance generically comprises all actions necessary to give the necessary and sufficient confidence that a product or installation will operate satisfactorily when in service.

To verify that the works are being carried out in accordance with the safety and quality requirements, and within the conditions of the granted license, a regulatory surpervision program (regulatory oversight) carried out through field inspections, audits, verifications, and reports. This program is later extended for the lifetime of the installation.

Licensee's obligations during plant construction: a) report of deficiencies in the executive project, construction, and pre-operational phase with impact on safety; b) progress report of activities; c) results of the programs of research and development (R & D) designed to solve safety problems; d) reports on equipment storage; e) audit programs on contractors; f) procedure for pre-operational tests.

- *Authorization for Nuclear Material Utilization*

CNEN Regulation concerning licencing of nuclear facilities determines that the applicant must be in possession of an authorization for nuclear material utilization to be able to receive the authorization for initial operation. According to CNEN regulation for nuclear material accounting and control, the application for authorization for nuclear material utilization must be forwarded to CNEN when the applicant requests the construction license. For the authorization of nuclear material utilization, CNEN reviews documental information provided by the applicant on the project and process data of the facility, the characteristics of the nuclear material and the proposed procedures to account and control the nuclear material in the proposed physical or chemical process.

- *Authorization for Operation*

The Licensing rules in force (Standard CNEN NE 1.04) provide for the issuance of an *Authorization for Initial Operation* and an *Authorization for Permanent Operation*. The Authorization for Initial Operation is granted by CNEN after the construction is completed and the RFAS is approved with the verification that all the supplementary safety conditions required by the CNEN inspection (Regulatory Supervision) during construction have been included in the installations. The Authorization for Permanent Operation is granted by CNEN after the approval of the test results and final verifications of the reactor's operation. Such authorization can only be granted after all inspections relating to radiological protection and nuclear safety have been satisfactorily completed.

- *Authorization for Initial Operation*

When construction of the facility has progressed to the point where final designs, information and plans for operation are complete, the applicant must file an application for Authorization to Operate, accompanied by the Final Safety Analysis Report (FSAR).

The FSAR must present, in final form, the design information, safety analysis and other information provided conceptually in the PSAR. Operation procedures, emergency, and physical protection plans (confidential) and details pertinent to the final design of the reactor itself, such as detailed containment design, definitive nuclear and thermo-hydraulic design of the core, and elements fuels and primary, secondary, and radioactive waste systems, etc.

For the authorization for initial operation (AOI), CNEN evaluates / reviews the construction status, the commissioning program including results of pre-operational tests, and updates its review and assessment of plant design based on the information submitted in the Final Safety Analysis Report (FSAR). Currently CNEN also licenses the reactor operators in accordance with regulation CNEN-NN-1.01[7]. In that case, the Licensee must submit others documents together with the FSAR to obtain the AOI: a) Final Plan for Physical Protection (FPF); b) Radiation Protection Plan; c) Fire Protection Plan; d) Commissioning Program; e) Test Procedures; f) Quality Assurance Program (PGQ); g) operating procedures manual; h) Local Emergency Plan (PEL) and i) civil responsibility insurance against damages.

Then the FSAR is reviewed and evaluated in the same manner and to the same extent and depth as the PSAR, as well as the other documents mentioned above, and additional information may also be requested when necessary for proper analysis. The additional information submitted by the applicant is also documented in the form of Addendums to the FSAR, with meetings and/or technical visits being held for clarifications and debates on doubtful points.

The CGRC is responsible to elaborate the Safety assessment Report (SAR) that consolidate the results of review carried out by technical team and then presents it to the Deliberative Committee how as a subsidy for the granting of *Authorization for Initial Operation*. This SAR must present the "Technical Specifications for Operation" that regulate the entire installation operation, and which must be part of the Authorization.

The Authorization for Initial Operation must refer to the "Technical Specifications for Operation", which establish the safety and protection measures to be imposed, and the specific conditions and operating limits that must be met to ensure the protection of health and safety of the general public, operators and the surrounding environment. It must also include all other conditions to be satisfied, such as norms, codes, criteria, and standards, inclusive.

The consensus recognizes that the safety of operation depends as much on the equipment as on the efficiency of the operators. These operating limits must therefore comply not only with technical aspects, but also with organization, administration and operational and testing procedures and all other aspects that may have some relation to safety.

Technical limits and conditions should emphasize two categories of factors: those related to the prevention of situations that could involve radiation hazards and those related to minimizing the consequences of such situations, should they arise.

The "Technical Specifications" must cover the following general items:

(a) Safety limits,

(b) Safety system adjustments,

(c) Boundary conditions for safe operation,

(d) Surveillance Requirements.

The limits and technical conditions are limit values that include the minimum and maximum operating adjustments. The establishment of specific values depends on the analysis carried out in the different systems and their interaction with the environment. Safety limits are assigned to process variables or parameters to provide protection against the uncontrolled release of radioactivity, and the adjustment of safety systems, according to these limits, is intended for the automatic protection system to act so that they are not exceeded.

Surveillance requirements include periodic tests, calibrations, and inspections necessary to ensure that the limits and conditions already considered are maintained. The maximum time intervals between the different periodic tests must be specified.

Finally, the startup and power ascension tests are closely followed by CNEN inspectors and hold points at different power levels are established.

- *Authorization for Permanent Operation (APO)*

Authorization for permanent operation is given after a complete review of commissioning test results and the solution of any deficiencies identified during construction and initial operation. The authorization establishes limits and conditions for operation and lists the programs which shall be kept active during operation, such as the radiological protection program, the physical protection program, the quality assurance program for operation, the fire protection program, the environmental monitoring program, the qualification and training program, the preventive maintenance program, the retraining program, etc.

In accordance with the Rules in force, the Authorization for permanent operation will be granted for a specified period, requested by the applicant, or established by CNEN based on the estimated useful life of the installation, if it is shorter than the requested period. In no case may the authorization to operate exceed a period of forty years.

- ***Ratification or rectification of Authorization for Permanent Operation every 10 years, considering the evaluation of the Periodic Safety Review (PSR)***

Brazilian nuclear power plants are licensed for a period of 40 years in accordance with the rule CNEN NE-1.04[5], 'Licensing of Nuclear Installations', issued by, the Brazilian regulatory board: Comissão Nacional de Energia Nuclear (CNEN).

Until the issuance of the standard CNEN NE-1.26 - *Safety in Operating Nuclear Power Plants* [9] in 1997, there was no legal basis for PSR of nuclear installations in Brazil. PSRs are conducted in accordance with paragraph 21 of standard CNEN NE-1.26 - Safety in Operating Nuclear Power Plants [9], consistent with IAEA Safety Guide No. SSG-25, 'Periodic Safety Review of Nuclear Power Plants'. It requires that "After the emission of the APO, the operating organization shall conduct, each ten years, a periodic safety review of the Plant, to investigate the consequences of the evolution of norms and standards, of operational practices, of the cumulative effects of plant structures, systems and components, of design modifications, of the operational experience analysis and of the Science and technology developments".

In accordance with standard CNEN NE 1.26 [9], item 21.2 of paragraph 21, The PSR reassessment should address, as a minimum, the following areas or safety factors:

a) physical conditions of the plant,

b) safety analysis,

c) equipment qualification,

d) aging management,

e) safety indicators,

f) incorporation of international operational experience,

g) procedures,

h) administrative and organizational factors,

i) human factors,

j) emergency planning,

k) environmental impact.

According to item 21.3 of paragraph 21 of Standard CNEN NE 1.26, the period of execution of the safety reassessment cannot exceed 18 (eighteen) months and must be divided into 3 (three) stages:

a) Survey of the current level of security to be presented in a report addressing the areas or factors mentioned in 21.2, listing for each of these the strengths and weaknesses identified in the confrontation with security standards and practices,

b) Assessment of the safety impact of identified deficiencies and proposal of corresponding compensatory measures,

c) Updating the risk management model, mentioned in section 20.

Finally, accordance to item 21.4, the reports resulting from the safety reassessment must be submitted to CNEN. The CGRC also is responsible to elaborate the Safety Assessment Report (SAR) that consolidate the results of review carried out by technical team over the PSR Reports and then presents it to the Deliberative Committee to to provide subsidies for the ratification, rectification or cancellation of the current terms of authorization for permanent operation.

Table 4 - Correlation between CNEN Standard 1.26 [9] and SSG-25

Safety Area specified in CNEN standard 1.26	Safety Factor in the SSG-25
01 – Plant Status	1. Plant Design
02 – Behavior of the Structures, Systems and Components (SSC)	2. Behavior of the (SSC) 3. Equipment Qualification 4. Plant Ageing Management
03 – Safety Analysis	5. Deterministic Safety Analysis 6. Probabilistic Safety Analysis 7. Hazard (Risk) Analysis
04 – Operational Performance and Experience Feedback	8. Safety Related Performance 9. External Operational Experience Feedback
05 – Safety Improvement Projects	10. Organization and Administration 11. Procedures 12. Human Factors 13. Emergency Planning
06 – Radiation Protection and Environment	14. Radiological Impact on the Environment

- *Authorization for Extended Operation (AOE) or License Renewal*

Authorization for Extended Operation (AOE) or License Renewal must be requested by Licensee 5 years before the commercial end of the plant. In Brazil, according CNEN standard, a nuclear power plant has authorization to operate for 40 years. This process will be regulated by the CNEN's Technical Notes NT-CGRC-007/18 - Regulatory Requirements for Long Term Operation for Nuclear Power Plants and NT-CGRC-008/18 - Regulatory Requirements for Ageing Management in Nuclear Power Plants.

- *Authorization for Decommissioning*

The decommissioning process of NPPs in brazil is regulated by two specific standandars CNEN NN 9.01 – Decommissioning of Nuclear Power Plants (issued on 21 November 2012 with changes implemented in 2017) and CNEN NN 9.02 – Management of Financial Resources for the Decommissioning of Nuclear Power Plants (issued on 26 October 2016 with changes implemented in 2017).

- *Regulatory Control Withdrawal*

Regulatory Control Withdrawal. The release of the plant from regulatory control is conditioned to the demonstration that the final state foreseen in the Final Decommissioning Plan has been reached and that no additional requirements have been established, taking into account the results of the plant's pre-operational environmental monitoring program. CNEN will issue the Regulatory Control Release for the plant after approval of the Final Decommissioning Report.

Reporting requirements are also established through regulation CNEN-NN-1.14[8]. These reports, together with a system of regulatory inspections performed by resident inspectors and headquarters personnel, are the basis for monitoring safety during plant operation.

Other governmental bodies are involved in the licensing process, through appropriate consultations. The most important ones are the Brazilian Institute for Environment and Renewable Natural Resources - IBAMA, which is in charge of environmental licensing and the Gabinete de Segurança Institucional da Presidência da República (Institutional Cabinet of the Presidency of the Republic - GSI/PR) with respect to emergency planning aspects.

B) Environmental Licensing of Angra 1, 2 and 3.

IBAMA was created by Law 7735 in 1989, it is linked to the Ministry of Environment (MMA), and has the responsibility to implement and enforce the National Environmental Policy (PNMA - Brazilian Law 6938 of 1981). The PNMA's goals are to preserve, improve and recover environmental quality to ensure conditions for social and economic development and the protection of human dignity. The PNMA established the National System for the Environment (SISNAMA), which is composed by the National Council for the Environment (CONAMA) and executive agencies at the federal, state and municipal levels.

Environmental licensing is a legal obligation required prior to the installation of any project or activity that exploits natural resources and has a significant potential to pollute and/or degrade the environment. The enforcement of environmental licensing is shared by the environmental agencies of Brazilian Municipals and States, and IBAMA at the federal government level. IBAMA is the agency tasked with the licensing of large projects involving impacts on more than one Brazilian State and activities of the oil and gas sectors on the continental shelf. IBAMA is also responsible to carry out the licensing of the environmental component of activities and projects related to prospecting, mining, producing, processing, transporting, storing and disposing of radioactive materials at any stage or using nuclear energy in any of its forms and applications.

The regulation of nuclear activities remains, as stated before, with the Federal Government. The *nuclear licensing* and the *environmental licensing* processes are independent, parallel, and complementary acts. CNEN, a Federal Organization, through the Directorate of Radiation Protection and Nuclear Safety is, the regulatory body, in charge of *nuclear licensing*, which consists of regulating, licensing and controlling nuclear activities in Brazil, enforcing nuclear safety, security and safeguards. On the other hand, IBAMA is responsible for the environmental licensing of any installation with potentially significant socioenvironmental impact and risk, including the nuclear installations.

In the environmental licensing process, possible direct and indirect impacts of a project imposed to the external environment and communities are assessed. These include: the physical aspects (geology, hydrogeology, climate, water availability), atmospheric emissions (radioactive and conventional), and generation and control of effluents, and solid waste (radioactive and conventional); the interactions with biotic system (marine and terrestrial fauna and flora) and possible incorporation (bioaccumulation, toxicity); and the socioeconomic and health implications to the human populations in the vicinity of the project. The main guidelines for the implementation of the environmental licensing are expressed in Law 6938 of 1981, Supplementary Law 140 of 2011, CONAMA Resolutions 001/86 and 237/97, and IBAMA's Normative Instruction nº184/2008 and n° 01/2016. These guidelines discipline the environmental licensing for projects with potentially adverse effects on the environment, following three main steps:

- Prior License (LP), granted at the preliminary planning stage, approving the general concept of the installation and location, evaluating its environmental feasibility, and establishing the basic requirements and conditions for the next implementation phases.
- Installation License (LI) - authorizes the construction of the facility in accordance with the approved specifications, programs and projects - including measures that are considered essential to protect the environment and human populations.
- Operation License (LO) – authorizes the operation of the facility, after successful completion of the construction and commissioning activities and the verification of the effective fulfilment of the Installation License conditions, and the effective implementation of measures to protect the environment and human populations during operation.

Among the requirements for issuing a Prior License, three technical reports should be presented by the project's proponent to provide IBAMA with a comprehensive set of information to support the decision-making process, such as:

- An Environmental Impact Study (EIA) - EIA was established by the National Environmental Policy - PNMA (Federal Act No. 6938/1981) and by the Brazilian Federal Constitution (Article 225). EIA is required for projects or activities that may potentially cause significant environmental degradation. Brazilian environmental legislation provides a guideline to an EIA that includes: technological and location alternatives of the project, environmental diagnosis of the affected areas, identification and assessment of the environmental impacts caused by the implantation and operation of the activity, definition of limits of the geographical area directly and indirectly affected by the project, definition of mitigation actions for the identified impacts, and identification of strategies for environmental monitoring in the affected area. EIA should also consider other governmental plans and programs planed to the same area, to evaluate the compatibility between projects.
- An Environmental Impact Report (RIMA) - The RIMA is a document that summarizes the information presented in the Environmental Impact Study. Contents should be presented in clear, non-technical, and accessible language to facilitate stakeholders' understanding.
- A Quantitative Risk Assessment (EAR) - The EAR is applied by the environmental agency to assess the industrial/conventional risks associated to the operation of projects and activities potentially harmful to people and the environment. The EAR also guides the implementation of risk management programs and emergency plans originated by any non-nuclear accidental event. It is important to stress that, in Brazil, the National Commission for Nuclear Energy (CNEN) is the sole agency responsible for the assessment of nuclear risk and safety. Notwithstanding, the conclusions and recommendations of CNEN are relevant to the decision-making process of the environmental agency.
- Degraded Area Recovery Project (PRAD) - The Brazilian Federal Constitution of 1988 establishes in its article 225, paragraph 2: "whoever exploits mineral resources is obliged to recover the degraded environment, in accordance with the technical solution required by the competent public agency, in the form of the law." The recovery of degraded areas from mining activities, in this context, has a unique relevance in the search for the maintenance and improvement of the environmental quality of the degraded areas, being required in the scope of environmental licensing

conducted by IBAMA.

Another important aspect for the environmental licensing process accomplished by IBAMA is transparency. Public participation is ensured by legislation, through public hearings, before to the issuing of the Prior License (CONAMA Resolution Nº 09/87). The legislation also establishes that information about any public hearing, license application and decisions of the environmental agency should be made available to the public in official newspapers and local press.

- Environmental Licensing of Angra-1, 2 and 3 Radioactive Waste Storage Facilities

The beginning of construction of Angra-1 and 2, including the radioactive waste stored on-site, occurred before the creation of IBAMA. The operation of Angra-1 started in 1981, before the current environmental regulation was established. At that time, the State of Rio de Janeiro's Foundation for Environment Engineering (FEEMA), the Rio de Janeiro environmental state agency, issued an Installation License (on September 15th 1981).

Since 1989, IBAMA is the legal authority for environmental control of nuclear installations in Brazil; and since 1997, following the publication of the CONAMA Resolution 237/97, IBAMA is also the legal authority for environmental licensing of nuclear power plants and radioactive waste storage facilities. Given this legal setup:

- The environmental licensing of Angra-1 and the Radioactive Waste Storage Facility 1 and Facility 2-A was performed through an "adaptive licensing", in accordance with IBAMA requirements, to adjust the facility to the current environmental regulations. This process defined the necessary environmental studies to be carried out and presented to IBAMA as requirements to issuing an Operation License. Subsequently, in March 2009 the report "Environmental Control Plan – PCA" was submitted to IBAMA.
- The environmental licensing of Angra-2 was performed as required by CONAMA 237/97, which involved the preparation by the facility's owner of an Environmental Impact Study (EIA) and a Report on Environmental Impact (RIMA). These documents were submitted to IBAMA for environmental impact evaluation. They also served as a basis to define environmental plans and programs that are detailed in a Basic Environmental Project (PBA). Two public hearings were performed in the period of 1999-2000. Based on the technical evaluations and inputs from stakeholders and the

public, IBAMA issued a special License for Initial Operation (commissioning) in 2000. In March 2001, Brazil's Federal Public Prosecution intervened in the environmental licensing and a Statement of Commitment (Termo de Compromisso de Ajustamento de Conduta – TCAC) that laid down a series of conditions to be met by Eletronuclear (mostly centered on the improvement of the emergency plan) was signed by IBAMA, Eletronuclear, and the Public Prosecution. In June of 2006, IBAMA issued a report (Parecer Técnico Nº 015/2006 – COEND/CGENE/DILIC/IBAMA) concluding that all of such conditions were met.

- IBAMA issued the Preliminary License No. 279/08 for Angra-3, in July 2008. In March 2009, after an evaluation of compliance of conditions of the Preliminary License Nº 279/08, IBAMA issued the Installation License Nº 591/09 for Angra- 3.
- It is noteworthy that in 2011 IBAMA started up a process to unify the environmental licensing processes of the units in operation at the CNAAA, with the exception of Angra-3 that is currently under construction. In March 2014, IBAMA issued a Joint Operating License (LO N° 1217/2014) that encompasses the operation of Angra-1, Angra-2, the Radioactive Waste Management Centre, and the Storage Facility for the replaced old steam generators. Concomitantly, the Installation License for Angra-3 was reviewed to adjust it to the Joint Operating License of the CNAAA.
- In March 2014, IBAMA issued the Combined Environmental Operation License nr. 1217/2014 for the Almirante Álvaro Alberto Nuclear Power Site – CNAAA authorizing the operation of Angra 1 and Angra 2 NPPs, as well as the Waste Management Center – CGR and auxilliary facilities for ten years.
- As already mentioned, the issuance of the combined environmental operational licence for the site in March 2014, the specific Installation License Nr.591/09 was revised again and generated a second amendment with a set of 33 new requirements for Angra 3 plant construction.
- The Operation License for Angra-1 and Angra-2 Nuclear Power Plants authorizes the operation of each one, consisting of a pressurized light water reactor and associated equipment, and may be operated at maximum nuclear thermal power of 1,876 MWt and 3,777 MWt and maximum gross electrical power of 640 MWe and 1,350 MWe, respectively. The Center for Management of Radioactive Waste, the Angra-1 Steam Generator Storage, the Transport Activity of Fuel Elements and Radioactive Materials, the Unit for Dry Storage of Irradiated Fuels (UAS), and the Units Auxiliary to the Operation and Maintenance of the Almirante Álvaro Alberto Nuclear Plant (CNAAA), located on Itaorna Beach, in Angra dos Reis/RJ, are the other structures that comprise the operation of the referred plants. It has 74 environmental conditions and programs related to the physical, socioeconomic, and biotic environments.

- The radioactive waste from the nuclear power plants are stored in four storage facilities, the Radioactive Waste Storage Facilities 1, 2 & 3 at the Radioactive Waste Management Centre (CGR) and the Storage Facility for the two old (replaced) steam generators from Angra-1;
- The project of the complementary unit for dry storage of irradiated fuel (UAS) was started by Eletronuclear in 2017 and its Environmental Installation License has been requested. Accordingly, following the "Termo de Referência" (Reference Term) of UAS issued by IBAMA in August 2016, the Simplified Environmental Report was prepared and sent to IBAMA in February 2018.
- In 2019, IBAMA authorized the operation of the Dry Storage Unit (UAS), where irradiated fuel from the Angra-1 and 2 plants will be stored. This Unit was included in the environmental license for the Almirante Álvaro Alberto Nuclear Plant (CNAAA), which encompasses the Angra-1 and 2 plants and their auxiliary structures.
- The environmental installation license for Angra-3 authorizes the installation of the Angra Nuclear Power Plant at CNAAA to generate electricity with a maximum nuclear thermal output of 3,765 MWt and a maximum gross electrical output of 1,350 Mwe, with its construction sites. The environmental license has 33 environmental restrictions.
- IBAMA is currently analyzing the issuing of a new installation license for the Angra-3 Nuclear Power Plant.

Article 7 (2) (iii) System of regulatory inspection and assessment

- *Regulatory strategies.*

The Directorate for Radiation Protection and Nuclear Safety - DRS/CNEN (ANSN) is responsible for the licensing and control all Nuclear and Radioactive Installations or activities for civilian uses in Brazil. The General Coordination for Reactors and Fuel Cycle (CGRC) is the DRS/CNEN (ANSN) branch responsible for the licensing and regulatory supervision of the Angra 1, 2 and 3 nuclear power plants (NPPs) and the research reactors (see Article 8(4)).

The Reactor Coordination (CODRE) of CGRC is responsible for the conduction of safety assessment and regulatory supervision of both nuclear power plants and research reactors, following closely the design, construction, and operation phases.

According of the Authorization Process adopted in Brazil, discussed in the item 7 (2) (ii) System of licensing, that follow the recommendation presented in the IAEA Safety Standard Series No. GSG-13, the Regulatory Authority in Brazil after the issuance of an authorization carried out a set of activities included in the regulatory supervision process (or oversight process) with the aim of verifying that the licensee conducts its activities in accordance with the "Authorization" granted and the CNEN Norms; and check for the possible existence of any condition that may result in danger for public health and safety.

The Regulatory Supervision process consists of the following subprocesses:

I. Site approval step:

1. Regulatory inspection and audits program:

   a. The selected site is inspected for the purpose of evaluating and verify the implementing of the site preparation program and environmental surveys prior to the operation (Pre-operational Environmental Monitoring Program).

   b. Soundings.

2. Review/Assessment of Mandatory Reports:

   a. Reports from the Pre-operational Environmental Monitoring Program.

II. Construction phase:

1. Regulatory inspection and audits program:
   a. Verify the implementation of the Quality Assurance Program for Construction.
   b. Pre-operational Environmental Monitoring Program.
   c. audit programs on contractors.
   d. carries out inspections in order to verify the processes used in the construction and the correct performance of the tests foreseen in the project.
   e. Storage of Material and Components.
   f. Material Specification.
   g. Personnel Qualification.
   h. Assembly.
   i. Construction test.

2. Review/Assessment of mandatory reports:

a. Report of deficiencies in the executive project, constructions and pre-operational phase with impact on safety.
b. progress report of activities.
c. results of the programs of research and development (R & D) designed to solve safety problems.
d. reports on equipment storage.

3. Control of Safety Documents Updating:
   a. Safety Analysis Report (PSAR and other documents safety relevant),
   b. Emergency Plan
   c. Preliminary Fire Protection Plan.
   d. Preliminary Physical Protection Plan.
   e. Environmental Radiological Monitoring Plan.

III. Operation phase:

1. Regulatory inspection and audits Program:
   a. Non-routine inspection - Its purpose is to investigate or evaluate accidents or incidents that have occurred and special facts or details, derived from the experience of operating other similar facilities.
   b. Routine Inspection – Its purpose is to monitor the implementation of Safety preservation and improvement programs and plans:
      - Life Extension Operation (LTO) Program - Angra 1 Power Plant,
      - Aging maintenance Program.
      - Fire Protection Plan (PPI), in compliance with the requirements of Standard CNEN-NN-2.03 Fire Protection in Nuclear Power Plants, Resolution-13/99.
      - Environmental qualification program,
      - Civil structures monitoring program,
      - Accident management program,
      - Radiological Protection Programs,
      - Probabilistic Safety Assessment Program,
      - Waste Management and Effluent Release Program,
      - Emergency plan,
      - Quality Assurance Program (PGQ),
      - Periodic Safety Reassessment (RPS),
      - Human Factors Engineering Program,

- Plant Ispection Program,
- Nuclear Fuel Integrity Monitoring Program,
- Equipment Rotation Program,
- Safety Culture Program,
- Physical Protection Plan,
- In-Service Inspection Program,
- Periodic Testing Program,
- Fukushima Response Plan.
- Periodic Safety Review Report
- Life Extension Program.
- Operational Events Reports.
- Etc.

2. Review/Assessment of Mandatory Reports:
   a. Event Report,
   b. Nuclear and Thermohydraulic Project Report,
   c. Outage Report,
   d. Monthly Operation Report,
   e. Annual Operation Report,
   f. Semi-Annual Report on Tailing and Effluent Release,
   g. Operational Radiological Environmental Monitoring Program Report.

3. Control of Safety Documents Updating:
   a. Safety Analysis Report (PSAR, FSAR and other documents safety relevant),
   b. Emergency Plan
   c. Limit Conditions for Operation
   d. Operating Manual Procedures
   e. Operational Event Reports
   f. Fire Protection Plan.
   g. Physical Protection Plan.
   h. Environmental Radiological Monitoring Plan.

4. Regulatory Review/Assessment, Inspections and Audit of Design Modification.
5. Regulatory Review/Assessment, Inspections and Audit of the Periodic safety Review.

- Overview of the regulatory inspection and assessment process with regard to the safety of nuclear installations.

- Regulatory inspection.

In this context, the inspection program is considered an important part of DRS/CNEN's regulatory activities to ensure the protection of the public and the environment. Inspections provide additional assurance that the construction and operation stages of nuclear facilities will be carried out safely and established requirements are being met.

The primary responsibility for safety rests with the Licensee (the organization operating the facility and holder of the license). DRS/CNEN's inspections and/or audits are intended to verify that the licensed organization is fulfilling its responsibility.

In case of NPPs, the regulatory inspections are composed by routine inspections performed by the resident inspectors and complemented by specific inspections or audits performed by the technical staff from the CNEN's Headquarters in according to DRS/CNEN's General Surpevision Plan.

The elaboration process of the General Supervision Plan is governed by two documents: OI-DRS-0003/2019, Rev.1 and PI-DRS-0001/2019. The document OI-DRS-0003/2019, Rev.1 - General Supervision Plan, contains the basic guidelines about types of regulatory inspections, regulatory inspections and audit program, bases for regulatory inspections and orientation to planning the regulatory inspections. The second document, PI-DRS-0001/2019 - Conducting Regulatory Inspections, is an internal procedure and its objective is disciplining the activities to be developed for the adequate planning, preparation, execution, management, and registration of regulatory inspections, within the inspection activities of the DRS/CNEN's.

In according to OI-DRS-0003/2019, Rev.1 the DRS/CNEN (ANSN)'s with the advice of each branch CGRC, DISEN, DITEC etc., a regulatory inspection and audit program is established annually for each plant. This program is revised in July/August to check its progress and rescheduling, and finally, at the end of the year, a final balance is made. The objective of the final balance is to determine the efficiency of General Supervision Plan accomplished and identify areas that need more attention in the next inspection cycle.

The inspections can be scheduled or reactive. The schedule type includes routine and specific (maintenance, radiological protection, mechanic, electrical, chemical etc) inspections. The reactive inspection (or eventual) is carried out after the occurrence of an event or a complaint (denunciation). During the outages some people from the headquarters join the resident inspection team. An inspection report with the objective, scope and findings is issued and posted to the operator, asking for corrective actions.

During 2019-2021, CGRC/DRS/CNEN conducted 30 inspections in Angra-1, 25 in Angra-2, 5 in Angra-3, 13 in UAS and 12 related to the whole plant organization. Additionally, Waste Storage and Management, Environmental Protection Program and Physical Protection are subjects covered by others departments inside the DRS which conduced 11 inspections in the period. The specialist's positions are internally revised and approved by the correspondent Division and shall be endorsed by CGRC.

- *Regulatory assessment process.*

Complementary to field activities, operation follow up is performed also based on licensee reports, as required by regulation CNEN-NN.1.14 [8]. CNEN's regulations establish the documentation, as for example, safety analysis reports, plans, and programmes. This regulatory documentation shall be submitted to the regulatory body for assessment. The safety assessments are carried out by specialists (internal or external), following specific procedures. Additional information, when needed, is requested to the operator. In case of a document does not attend the regulations, this is informed to the operator that should revise it.

The information presented in the Safety Analysis Reports and their addenda is analyzed throughout the process. Design methods and calculation procedures are reviewed, to determine whether the technical safety of the project has been analyzed by manufacturers and operators in the necessary depth. In some cases, the calculations are reproduced using computer codes different from those used by the manufacturers to compare the results.

Throughout the process, the main points evaluated by the CGRC/DRS/CNEN security analysis team are summarized below:

- Review of the site for population density and land and water uses in the vicinity, including studies of seismology, geology, meteorology, and hydrology to verify the suitability of the project, including safety devices for the site. It is also verified whether the characteristics of the site meet the provisions of CNEN Resolution 09/69 [6].
- Review of the design, fabrication, construction, testing and expected behavior of structures, systems and components related to safety and comparison, if possible, with other installations. Any deviation from accepted norms or standards must be identified and justified.

- Equipment response evaluation to various postulated transients and hypothetical accidents. Accidents are studied conservatively, considering the possible doses of radiation that could be released in the unlikely event of their occurrence. The project must be such that it does not exceed the doses contained in CNEN Resolution 09/69[6].
- Review of plans for Conduct of Operations, including operational organization, qualifications and training program for operators and technical support personnel, industrial and sabotage protection measures, and emergency planning in the unlikely event of accidents that could affect the public:
    - commissioning, pre-operational and power-up test program.
    - surveillance and periodic testing.
    - emergency planning, etc.
- Assessment of the design of radioactive effluent control systems to keep them within CNEN standards and to ensure that the facility will be operated in a manner that reduces levels as low as practicable.
- The safety assessment may further include, as appropriate, consideration of proposed research and development programs to verify design characteristics or to confirm adopted design margins. In this way, the RPAS and RFAS must identify any program in progress to resolve any security item, and also present its expected schedule.

The CNEN-NN.1.14 standard [8] stablish a set of regulatory criteria for the operational events notification and classification, and the development of associated technical reports, using the USNRC normative basis as a reference. When classified as being of safety relevance, the notification to the regulatory body must be made within 1 or 4 hours and the respective report must be submitted within 30 days. These reports present root house analysis, associated corrective actions, safety significance and lessons learned. These reports are evaluated by the regulatory body to verify compliance with regulatory requirements.

The report on abnormal occurrences shall include, at least, a narrative description, a safety assessment with the determination of the main cause of the event as well as the corrective actions and lessons learned. The rate of the event as well as the corrective actions and lessons learned. The rate of the event in the International Nuclear Event Scale - INES - is used to determine its safety significance. The Incident Report System - IRS is disseminated by CNEN to the licensee that also has agreements with International Operator Organisations for the exchange of operational experience.

CNEN also analyses some events that are considered relevant to safety, in order to verify if the Operator event analysis was well conducted, with the aid of a written procedure for the investigation of the event. This activity is done case by case and depends upon the evaluation and analysis of the event report done by the Reactors Co-ordination staff at CNEN's headquarters and the corrective actions are followed by the resident inspectors.

A planned audit is conducted, at least every two years, on Event Analysis and Operation Safety Experience Programme of the licensee and if the corrective measures required have not been implemented, unplanned reactive inspections are conducted.

Article 7 (2) (iv) Enforcement of applicable regulations and terms of licences

Enforcement powers are given by the legislation that created CNEN (Law 4118/62 with alterations determined by Laws 6189/74 and 7781/89). These laws explicitly establish that CNEN has the authority "to enforce the laws and its own regulations".

Enforcement mechanisms are included in CNEN regulations, such as the power to impose conditions, suspend activities up to withdraw a licence. However, up to now, no legal actions were required to ensure enforcement. Usually, CNEN establishes conditions which are met by the licensee in due time. CNEN monitors implementation of these conditions and whenever delays occur some new corrective actions or compensatory measures can be imposed. New evaluations are performed to ensure that safety is not compromised.

The new Law no. 14.222, issued on Octobre 15 2021 that created the ANSN includes sanctions on organizations for infractions related to the violation of nuclear and radiological safety regulations. The sanctions applied will be based on the level of damage or risk caused to individuals, property, or the environment. (Art. 12.) The infractions include failing to submit documents detailing the production and distribution of nuclear materials and neglecting to provide information about nuclear facility activities. (Art. 13(II, III).) Sanctions include fines and temporary suspension of nuclear facility functions. (Art. 14.) Organizations with the most serious infractions may have their licenses revoked. (Art. 24.)

ARTICLE 8 - REGULATORY BODY

1. Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.

2. Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.

Article 8 (1) Establishment of the regulatory body

As mentioned before (as discussed in item A.1 of Introduction, item B.5 and in article 7), the Brazilian National Commission for Nuclear Energy (CNEN) has been designated as the regulatory body entrusted with the implementation of the legislative framework related to safety of nuclear installations.

However, the Brazilian government creates in 2021 the National Nuclear Safety Authority that will assume the regulatory functions previously performed by CNEN. As emphasized in item B.5 the creation of this Authority brings some improvements:

- Full independence from regulatory activities in relation to nuclear technology promotion and operation activities
- Establishment of a new decision-making process, through a Board of Directors, composed of three directors with recognized experience in the nuclear sector, approved by the Senate, and with a mandate of 5 years.
- Includes sanctions on organizations for infractions related to the violation of regulatory requeriments.
- Updating of the values of nuclear licensing fees, to be applied in safety assessment and inspection activities, which will provide better financial support to ANSN.

Besides the law creating ANSN, two decrees were drawn up, establishing (1) link to the Ministry of Mines and Energy (on November 19th, 2021), and (2) establishing the organizacional structure of the ANSN. The ANSN will have 3 directors, who will form a collegiate body, with terms of office: A President-Director, a Director of Nuclear Installations and Safeguards and a Director of Radioactive Installations and Control (on 21st July 2022).

This new organization will enter in force only after the approval of the directors by the Brazilian Senate and is scheduled to take place in August or September 2022.

In parallel, arrangements are being implemented to the separation from CNEN, which will be encharged of promotion, research and development of nuclear subjects. While the new organization is not operational CNEN continues to answer for regulatory issues.

The technical team of this new organization will be composed of the current Directorate of Radioprotection and Safety (DRS), by the Institute of Radioprotection and Dosimetry (IRD), by the Laboratory of Poços de Caldas and by the CNEN Districts.

For this reason, the subsequent itens are related to CNEN.

Other governmental bodies are also involved in the licensing process, such as the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA, acronym in Portuguese).

8(1).1 - Legal foundations and statute of the regulatory body

CNEN authority is a direct consequence of Law 4118/62 as amended by Laws 6189/74 and 7781/89, which created CNEN. These laws established that CNEN has the authority “to issue regulations, licences and authorizations related to nuclear installations”, “to inspect licensed installations” and “to enforce the laws and its own regulations”.

8(1).2 - Mandate, mission and tasks.

CNEN’s mission is: "To ensure the safe and peaceful use of nuclear energy, develop and make available nuclear and related technologies for the well being of the population".

CNEN has a Deliberative Committee (CD), see Figure 6, that is composed of five (5) members, one of whom is the President of CNEN, the three (3) directors and an external member, representing the society. The President, as well as the other members, shall be appointed by the Executive Government, among persons of good moral character and administrative capacity in scientific or technical fields. The members of the CD shall be appointed for a period of five (5) years, provided their renewal.

The CD shall:

- Advise the formulation process of the National Nuclear Energy Policy.

- Deliberate on policies, plans and programs.
- Approve CNEN's rules and regulations of the CNEN.
- Issue the so-called administrative acts, as for example, site approval, authorization for the construction, operation and decommissioning of reactors and nuclear fuel cycle facilities.
- Make proposals on treaties, agreements, conventions, or international commitments on nuclear energy etc.

8(1).3 - Authorities and responsibilities

The information related to this topic are included in the item 8(1).1 and Article 7(2)(i).

8(1).4 - Organizational structure of the regulatory body (CNEN)

CNEN's structure is presented in Figure 13. The Organizational part of CNEN that deals with the licensing process of NPPs is the Directorate for Radiation Protection and Nuclear Safety (DRS) and performs the functions of a regulatory body.

The Directorate for Nuclear Safety and Radiation Protection (DRS) responsibilities among others are:

- Issue regulations, licenses and permits/authorizations (which must be approved by CD); monitor and control their application.
- Oversight the nuclear and radioactive facilities.
- Require and monitor the implementation of actions related to the radiological safety of workers, the public and the environment.
- Require operators of nuclear or radiological installations to perform safety demonstration studies.
- Authorize and accredit professionals to carry out activities with nuclear material or radioactive sources in nuclear or radiological installations.
- Order the suspension or revogation of radiological activities and proposes suspension or revogation of nuclear activities to the CD.
- Order the decommissioning of nuclear and radiological installations.
- Issue notifications requiring the regularization of nuclear and radiological activities and installations.
- Require and receive information from regulated agents concerning the production, imports, exports, processing, transportation, transfer, storage, distribution,

allocation and trading of services and materials subject to the nuclear authority regulation.

– require nuclear and radiological emergency plans for regulated agents; give technical guidance and collaborate with the agencies in charge of the civil defense emergency plan.

– Monitor, assist and supervise the implementation of international diplomatic compromises assumed by the Brazilian government in the areas of radiation and nuclear safety, security and safeguards.

– Apply safeguards to nuclear materials and facilities / installations.

– Provide technical support to the Deliberative Commission of CNEN.

– Gather and consolidate data on national reserves of nuclear ores and provide the Deliberative Committee of CNEN with criteria for fixing their prices for trading purposes among companies and agencies of the Federal Administration.

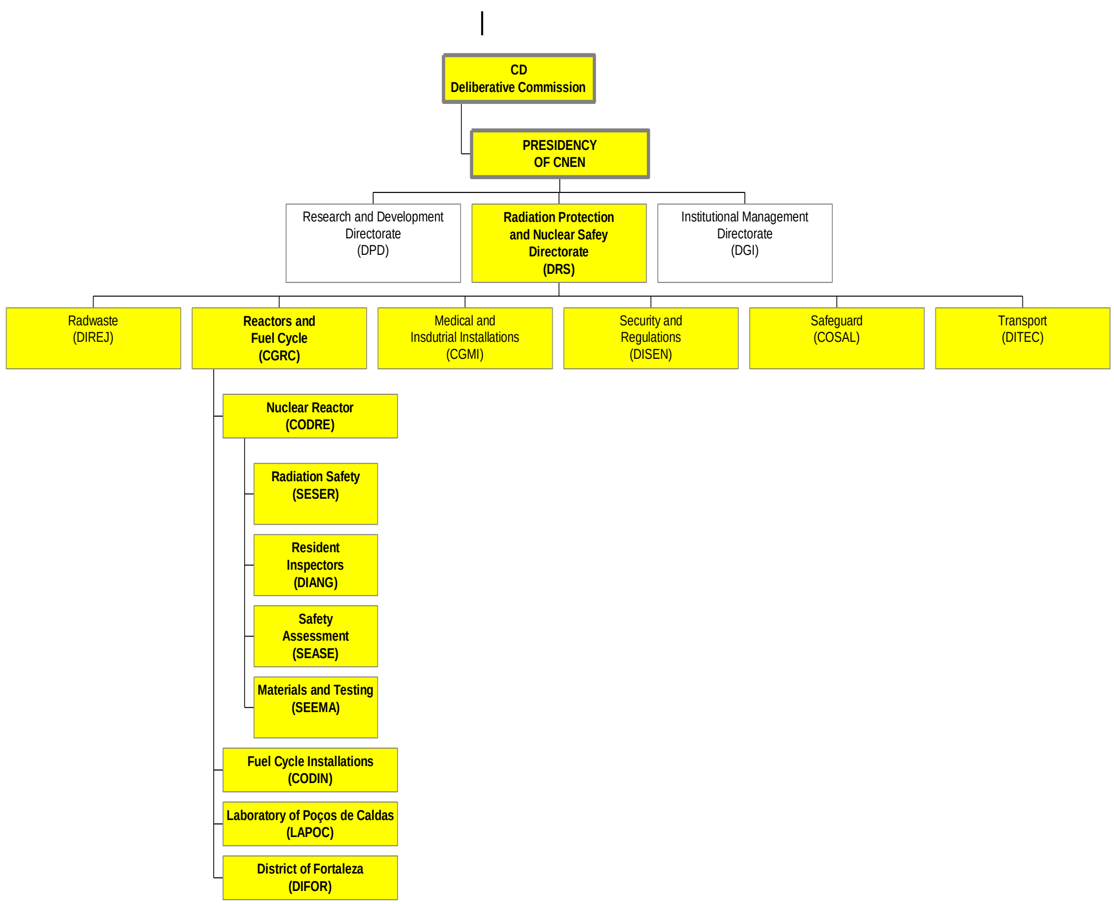

Figure 13 – CNEN Structure (simplified)

The Directorate for Research and Development (DPD) is mainly in charge of running CNEN's Researcg & Development (R&D) Institutes. Among others, they operate the research reactors, produce radioisotopes and conduct basic research in the nuclear field. The Institutes may also provide some specialized support to DRS, as TSO, in specific aspects related to the licensing process, provided there is no conflict of interest involved. DPD is in charge of the design and construction of the future Multipurpose Research Reactor (RMB) and is also working in the site selection and design of a national repository for low and medium level waste (RBMN).

The responsabilities of the General Coordination of Reactors and Fuel Cycle Facilities (CGRC) are:

- Perform licensing and control activities of nuclear Reactors and Fuel Cycle facilities.
- Monitor the compliance of nuclear installations with regulatory and technical requirements on radiation protection and safety, through inspections and assessment of the Licensee's safety performance.
- Carry out the nuclear and radiological safety assessment of nuclear reactors and fuel cycle facilities, conduct the process of elaboration of technical information related to the issuance of operation permits / authorizations.
- Issue professional licenses for reactor operators and certificates for radiation protection supervisors and qualify Independent Technical Suport Organizations (OSTI) to develop activities in the areas of nuclear power reactors, research reactors and prototypes / testing facilities and fuel cycle facilities.
- Notify the licensees about non-compliances and ask for corrective actions and propose higher enforcement action to the DRS and CD.
- Provide technical support in nuclear and radiological safety assessment of nuclear, radioactive, minerals and industrial installations, and deposits of radioactive waste.
- Coordinate the regulatory response actions to emergencies in nuclear installations.
- Provide support, if requested, to licensing processes conducted by other governmental regulatory agencies.
- Propose and implement actions aimed at the optimization of licensing, inspection and control of nuclear installations.
- Propose update and the development of new regulations.

The DRS/CNEN is composed by two main General Coordination: General Coordination of Reactors and Fuel Cycle Facilities (CGRC) and General Coordination of Medical and Industrial Installations (radiations and radioisopic applications) (CGMI), and four other units: Radiowaste

Division (DIREJ), Division of Physical Security and Standardization (DISEN/DRS), Transpot Division (DITEC/DRS) and, and Coordination of Safeguard (COSAL).

To fufill its responsibility the CGRC is supported by two main coordination: Cooodination of Reactors (CODRE) and Coordination of Nuclear Installations (CODIN), and two others units: The District of Fortaleza and The Laboratory of Poços de Caldas.

The CODRE branch of CGRC is responsible for activities related to licensing and control of the Angra 1, 2 and 3 nuclear power plants (NPPs) and the research reactors. Therefore, the CODRE is responsible for:

- Carry out safety evaluation and inspection of NPPs and Research reactors during construction, pré-operational and operational phases.
- Inspect the fabrication of NPP component.
- Follow the implementation of quality assurance programs during construction and operation of NPP.
- Examine candidates for NPP operator.
- Develop studies for evaluating accidents in NPPs.

The CODIN branch of CGRC is responsible for activities relate to licensing of Nuclear Fuel Cycle Facilities (Uranium Enrichment Plant and Fuel Fabrication Facilities, including of Uranium mining and milling facilities), including inspection of the plant activities, evaluation of operational significant events, aspects of radiological protection, management and generation of waste, among others.

The Laboratory of Poços de Caldas (LAPOC) provide support to CGRC in the following areas:

- Geoenvironmental.
- Chemical processes.
- Radioecology, radiometry, etc.

The District of Fortaleza (DIFOR) provide to CGRC in the following areas:

- Support to inspection and control related to the areas of responsibility of the CGRC.
- Provide technical support in the assessment of nuclear and radiological safety, and support to radiological and nuclear emergencies regionally.

The CGRC is also supported by Radiowaste Division (DIREJ/DRS), Division of Physical Security and Standardization (DISEN/DRS), Transport Division (DITEC/DRS) and Coordination of Safeguard (COSAL/DRS).

CODRE is composed by four divisions, in charge of the following areas: Resident Inspection (DIANG), Engineering and Materials (SEEMA), Safety Analysis (SEASE) and Radiation Protection and Meteorology (SESER). With the advice of these divisions a regulatory inspection and audit program is established annually for each installation controlled by CGRC.

DIANG is located at the plant site, makes continuous verification of the plants compliance with, for exemple, their Technical Specifications (TS), which establishes the limiting conditions for operation of each plant. It is clear that strict adherence to the TS is essential for the maintenance of the operational safety level. Additionally, DIANG makes use of a set of inspection procedures to inspect the plant periodic tests, maintenance, housekeeping, fire protection, control room activities, radiological protection, management and generation of waste, among others. The resident inspectorate also evaluates the operational events and acts as a CGRC's emergency responder in the NPP's Techical Support Center and is part of the Local Emergency Coordination Center in the city of Angra dos Reis. A technical report is prepared daily on the safety conditions of the Angra 1 and Angra 2 NPPs, including forecasting of operation and maintenance activities. A simplified daily report on the safety conditions of the plants is also prepared and sent to government organizations in the city of Angra, Rio de Janeiro and to the Federal Government. A technical report is prepared weekly on the inspection of equipment preservation at the Angra 3 NPP. Every six months, an inspection report is prepared presenting the main findings for each plant. DIANG also supports the inspection and audits performed by the headquarters specialists at the plant.

SEEMA makes continuous verification of compliance with regulatory requirements mainly in the areas of: Civil, Mechanical, Electrical and I&C, Materials and Chemical Engineering and Quality Assurance. These activities are done through the development of audits, inspections and safety assessments of the regulatory documents, submitted by the licensee.

SEASE makes continuous verification of compliance with regulatory requirements mainly in the areas of: Probabilistic safety Assessment (PSA), Termo-Hidraulic Analysis, Transient and Accident Analysis, Severe Accident, Human Factor Engineering, Core Physic, Fuel Performance and Criticality Analysis. These activities are done through the development of audits, inspections and safety assessments of regulatory documents submitted by the licensee.

SESER makes continuous verification of compliance with regulatory requirements mainly in the areas of: Radiation Protection, Radioactive Effluents Processing, Meteorology and Emergency Preparedness. These activities are done through the development of audits, inspections and safety assessments of the regulatory documents submitted by the licensee.

The four above mentioned divisions provide CODRE/CGRC with the necessary technical support in decision-making activities, licensing process, regarding the development of policies, rulemaking, procedures and administrative controls.

8(1).5 - Development and maintenance of human resources over the past three years.

Adequate human resources are provided to CNEN. A total staff of 1700 people, of which 85% are technical staff, is available at CNEN and its research institutes. Forty eight percent (48%) of the staff are university graduates, 16% having a master's degree (M.Sc.) and 15% having a doctorate degree (D.Sc.). DRS staff is about 250 people. CGRC itself comprises 69 people, 57 of which are technical.

In the period, CGRC staff registered a loss of about 4 professionals due to retirement and has received 3 new professionals, through a transfer from another area of CNEN or other governamental organization. By the end of 2021, the staff qualification shows 26 holding a D.Sc. degree, 29 holding a M.Sc. or equivalent in nuclear science or engineering and 2 basic engineering education.

8(1).6 - Measures to develop and maintain competence.

CNEN is constantly evaluating its staff needs, considering the new licensing projects and the retirement of staff.

The maintenance of the staff is still a challenge because of the high average age, about 56 years. In that context CNEN is claiming for a new public hiring process based on national contest, as required by Brazilian Legislation, to recruit new employees. Whenever a contest is held specific job description is prepared for each function and candidates are supposed to demonstrate both academic training and some experience in specific field.

Initial training and an induction course are done, including basic concepts on nuclear safety, radiological protection, legal aspects, functions, processes and roles of the regulator, PWR's technology, emergency planning, safety analysis and inspections. One week's technical visit to the NPP, tutored by DIANG, is part of the initial training. Depending on the employee function, some of them attends the NPP Systems Course. On-the-job training is used, in an individual basis and is tutored by experienced staff. National academic or technological institutions are used for complement the staff knowledge / qualification and international cooperation projects also are used for training of new staff and retraining of more experienced staff. A three-year initial evaluation is included in the recruitment process.

CGRC technical staff receives general nuclear training and specific training according to the field of work, at national and international organization, including both academic training and courses attendance, technical visits, participation in workshops, and on technical committee meetings mostly sponsored by IAEA and by the European Commission.

There is also a technical cooperation agreement with Gesellschaft für Reaktoren Sicherheit (GRS) to exchange information on the areas of operational events, PSA and severe accident.

On the area of emergency preparedness / response, CGRC is an active member of the ARGOS consortium and participate on the yearly meetings to share experience with the other international users.

The Table 3 show the set of training course and tutoring attended in the period of 2019-2021.

Table 5 – Course and Tutoring attended by CGRC/DRSCNEN's Teachnical in the period 2019 - 2021.

IAEA Workshop on Incident Reporting System (IRS), Root Cause Analysis (RCA)	February, 2019, Angra dos Reis, Brazil	3 Experts
Fundamentals Course in Physical Protection (Security) Systems (National Nuclear Security Administration (NNSA) - Department of Energy (DOE))	25 March to 05 April 2019 CNEN/Headquarters Rio de Janiro/RJ	3 Experts
Workshop on Knowledge Management	April, 2019 Angra dos Reis, Brazil	1 Expert
Training Course on ʺ "Human and Organizational Factorsʺ (ENSTTI)	18 to 25 May 2019 Brussels/Belgian	1 Expert
"Regulatory Control of Nuclear Sites: Inspection of Emergency Preparednee and Response Arrangements"	18 -25 May 2019 Madrid/Spain	1 Expert
"Regulatory Control of the Safety of Spent Fuel and Radioactive Waste Management" (ENSTTI)	21 to 25 October, 2019 Mexico City/Mexico	1 Expert
"National System for Emergency Preparedness and Response"	September 2019 Paris/France	1Expert
"International Training Course on Physical Protection Inspections at Nuclear Facilities" (IAEA)	October 2019 Obninsk/Russia	1Expert
Regulatory Control of Nuclear Sites: Inspection of Environmental and Occupational Radiation Protection (Module 1) (ENSTII)	07 -11 October, 2019 Fontenay-aux-Roses, Paris/France	1 Expert
Regulatory Control of Nuclear Sites: Inspection of Environmental and Occupational Radiation Protection (Module 2) (ENSTII)	14 -18 October, 2019 Fontenay-aux-Roses, Paris/France	1 Expert
Interregional Trainin Course on Environmental Protection Aspects for Embarking Countries (IAEA)	4 to 8 November 2019 Lemont, IL/USA	2 Experts

Advanced nuclear Energy Management School (IAEA)	18 to 20 October 2020 Moscow/Russia	1 Expert

Institution: European Nuclear Safety Training and Tutoring Institute-ENSTTI and International Atomic Energy Agency (IAEA).

CNEN started in 2013, with support of IAEA, a project related to Building Capacity through Knowledge and Quality Management (KQM) Programme. The project encompasses three major areas: assessment of key knowledge (existing and needs), development of strategy to capture and retain key knowledge needed for regulatory process of the Brazilian nuclear installations nuclear fuel cycle installations, and development and implementation of methodology (i.e., Mechanisms and tools) for identifying, capturing and disseminating lessons learned and good practices in key regulatory competence areas.

There were two workshops in CNEN's Headquarters in Rio de Janeiro, the first one was held in November 2013 and was more related to the fundamentals, concepts, definitions, strategy, tools and mechanisms of a Capacity Building and a KQM Programme. The second Workshop occurred in August 2015 more focused in practical examples, discussions and diagnosis. In both workshop the attendance was over 80 % of the staff.

Based on those considerations, CGRC proposed the creation, at the end of 2015, of a Working Group (WG) to discuss and develop a KQM Programme. In 2017, this WG has been expanded including specilaists from other areas o DRS. As a result of this new WG, DRS published an Internal Instruction and Procedure related to the definition of tools, mechanisms for the identification, capturing and retention of the knowledge.

In parallel to the IAEA initiative the CGRC participate from 2012 to 2015 in a project of the FORO Iberomerican for Regulators related to Nuclear Regulatory Competences, which led to the publication of a document together with IAEA, IAEA-TECDOC-1794 (in Spanish), *Guía para la Elaboración de un Programa de Creación y Desarrollo de Competencias de Reguladores de Reactores Nucleares.*

8(1).7 - Developments with respect to financial resources over the past three years.

Financial resources for CNEN are provided directly from the Federal Government budget. Since 1998, taxes and fees are being charged to the licensees (TLC), but this income is deducted from the Government funds allocated to CNEN.

Salaries of CNEN staff are subjected to the Federal Government policies and administration.

DRS´s budget for the period was approximately R$ 10.000.000,00. This budget is strictly to carry out CNEN's regulatory function (rulemaking, safety assessment and oversight) and does not include the costs of salaries and infrastructure which are covered by extra-budgetary resources.

8(1).8 - Statement of adequacy of resources.

From the above-mentioned item, it can be seen that the finantial resources are adequate to cover DRS needs.

8(1).9 - (Quality) management system of the regulatory body;

As mentioned in the Summary of the National Report, although CNEN has made progress in its management procedures it has for improvements to get a fully comprehensive and systematic Management Systems. Elements of quality management have already been implemented for many years and CNEN follows the Brazilian Government Documents Framework and routine processes are well mapped and described in internal procedures. These includes the receiving licenses applications, internal distribution of review tasks, review procedures, preparation of individual evaluation reports, consolidation of evaluation reports and preparation of draft resolution submitted to the Deliberative Commission. Inspection and safety assessment activities are also guided by internal procedures. Non routine activities are done in ad ad-hoc basis.

Safety culture is a subset of the wider organizational culture within an organization. Many practices which are used internationally to improve organizational effectiveness aim to promote the unity of purposes among the employees, motivating them to achieve organizational goals. The concepts of Mission, Vision, Goals and Values are often used to achieve these desired requirements.

To implement the safety and quality policies inside the Brazilian nuclear regulatory body, CNEN has issued a safety policy [10] and quality assurance policy statements [11], in December 1996, which is based on the concept of Safety Culture. In accordance with this policy, a project was launched for the development of a quality management system applicable to the main regulatory functions: rulemaking, licensing and control, review and assessment, inspection and enforcement. Soon it was recognized the importance of considering the cultural aspects inside regulatory organization. Different from operating organizations, a failure in human behavior of a regulatory staff can not directly challenge the safety of nuclear installations.

A consistent regulatory strategy, however, may have a stronger influence over plant safety performance. If an adequate set of shared values can promote attitudes and behaviors of the individuals towards organizational goals, a selected set of regulatory principles define the consistency of regulatory strategies.

Currently, the regulatory review and control activities related safety culture in Operating Organization is carried out by Resident Inspectors (verification) and by analysis of Operational Experiences (analysis of operational events reports). However, is necessary develop a regulatory process based in safety indicators, to categorize deficiencies associated with the operational safety of nuclear power plants, and so prioritizing regulatory inspection efforts or escalating enforcement actions over plant operators, in order to be consistent with the application of the concept of safety culture to regulatory bodies, warranting attention to issues proportionally to their safety significance.

Regarding CNEN verification of Safety Culture, all meetings, and activities inside the NPP site are open for CNEN resident inspectors. The inspectors have direct access to all documents, reports, control room and access to all managers and supervisors. In this way, the inspectors monitor the daily routine of the plant. In this case, the inspectors can check the attitude of workers and top management, allowing the understanding and the verification of application of the Safety Culture concepts. Other opportunity to check some aspect related to Safety Culture consists in conducting a global assessment of Reports of Operational Events. When systemic deficiencies are detected, the regulatory body requests a meeting with plant senior management.

8(1).10 - Openness and transparency of regulatory activities including actions taken to improve transparency and communication with the public.

CNEN is a governmental agency and as such is subject to Access to Information Act (Law 12.527/11), this law regulates the right of access to public information and establishes the principle of maximum disclosure of information held by public authorities, and secrecy as an exception. The exceptions are linked with proprietary information, security-related information and sensitive information.

Questions can be done in the Government Website, and it has 30 days to be answered.

CNEN makes availiable at at https://www.gov.br/cnen/pt-br all information related to nuclear activities and the national policy, the public.

Public consultation is part of the standard and regulations development process and has the objective of improving the Transparency of nuclear regulations elaboration process, allowing the participation of interested parties such as professional associations directly involved, organizations interested in its application and the general public.

CNEN published a management report annually in compliance with sole paragraph of art. 70 of the Federal Constitution, prepared in accordance with the provisions of Normative Instruction of Federal Court of Accounts (TCU) and shall be presented to internal and external control bodies and to the public for accountability.

This report is divided into three very distinct parts: the first is a presentation of the institution in terms of identification, organizational modeling and programmatic structure; the second part details the results achieved in the various program actions and finally in the third part are represented the information concerning budgetary and financial management, human resources and control.

8(1).11 - External technical support.

CNEN makes some use of its institutes as TSOs, for example, The Institute of Energetic and Nuclear Research (IPEN), the Nuclear Energy Institute (IEN), the Radioprotection and Dosimetry Institute (IRD) and the Development Center of Nuclear Technology (CDTN). These Institutes are also the main actors in the national nuclear safety research and development activities.

As an example, in the review of Angra 1 PSA, CNEN/DRS established a Working Group composed of four representatives of DRS divisions and three engineers from IPEN. In the review of aspects related to Human Factors, CNEN/DRS established a Working Group composed of six representatives of DRS divisions, one engineers from IPEN and two engineers from IEN.

CNEN/DRS also uses IRD as a TSO in regulatory inspections in radiation protection and environmental monitoring.

At the international level, CNEN/DRS has used the support of Riskaudit under an EC Technical Cooperation Project:

- **BR – EC Project BR3.01/09 (BR/RA/01):**
  - ✓ Nuclear Safety Cooperation with the Regulatory Authorities of Brazil (CNEN);

✓ November 2013 – Finalized.

- Strategy for maintaining and enhancing the capacity and regulatory capabilities of CNEN and its practical implementation.
- Safety of digital instrumentation and control (I&C) systems,
- Severe accident management (SAM).
- Emergency preparedness and response.
- Operational experience; and
- Safety of new fuels.

- **BR – EC Project BR3.01/12 (BR/RA/02):**

  - Nuclear Safety Cooperation with the Regulatory Authorities of Brazil (CNEN)
  - July 2018 – Finalized

  - Strengthened capabilities for Probabilistic Safety Analysis assessment:
    - to support CNEN in the enhancement of the most important Probabilistic Safety Assessment (PSA) regulatory issues – regulatory activities, requirements and guidance update, computer code issues.
    - to support CNEN in the reviewing process of the PSA documents to be submitted by the utility.
    - Products:
      - Technical Report of Review of selected parts of PSA.
      - PSA Review Guide.
      - PSA Regulatory Guide.

  - Enhanced capabilities for the assessment of the Deterministic Safety Analysis for Angra-2/3:
    - to support CNEN to perform an independent uncertainty and sensitivity analysis to quantify uncertainties associated with the Angra-2 Loss of Coolant Accident evaluation model with a best estimate code, in the licensing process of power-upgrade and new fuel design.

- to support CNEN in the development of a methodology for fuel design safety analysis involving specific computer codes.
- Products:
    - TECHNICAL NOTE ON REVIEW RESUL TS ON REPORT "AN ANGRA 2 LBLOCA SIMULATION MODEL FOR RELAP5MOD3.3 CODE WITH UNCERTAINTY ANALYSIS", Revision 0.
    - TECHNICAL NOTE ON AN ANGRA 2 LBLOCA SIMULATION MODEL FOR RELAP5MOD3.3 CODE WITH UNCERTAINTY ANALYSIS, Revision 2.
    - The data management (DM) code for the core wide safety evaluation of ANGRA1 and ANGRA2.

➢ Improved assessment of ageing management and long-term operation:

- to transfer knowledge and know-how to identify the appropriate parts which must be evaluated in the Periodic Safety Review (PSR) as far as long-term operation is concerned, and on the way to carry out such evaluation.
- to support CNEN in the improvement and the application of specific requirements for Brazilian NPPs based on the existing documents developed by the FORO and other existing documents in other countries.
- Products:
    - NT-CGRC-007/18 – Regulatory Requirements for Long Term Operation for Nuclear Power Plants; and
    - NT-CGRC-008/18 – Regulatory Requirements for Ageing Management in Nuclear Power Plants.

➢ Improved emergency preparedness:

- to advise CNEN on the selection of relevant information related to emergency situations, to be made available in its emergency room in CNEN Headquarters on-line and in real time, and to advise CNEN about similar computerized infrastructure used in other countries and regarding the concept and the development of the interface with the operational information available at the NPP main control rooms.
- to support CNEN to further enhance the functionalities of the ARGOS-BR code to deal with Brazilian Emergency Planning Zones (EPZs).

- Products:
    - A new function was inserted into ARGOS BR, developed during the project, to improves notably the quality and speed of answer in case of a nuclear emergency at CNAAA. This was done through creating a routine inside the system that, always a simulation of a release to the atmosphere is done, the system automatically checks out whether the dose limits established by the user for each of the site's EPZs were achieved or not. This is communicated to the user by warning colours painting the zones as the operator clicks on the EPZ button.

➢ Enhanced follow up capabilities for Severe Accident Management:

- to support CNEN in the assessment of the Severe Accident Management Programs (SAMP) for Angra-2 and 3, possibly including the capacity to review and/or revise MELCOR nodalisations used in Angra-2.
- Products:
    - 1 - Regulatory evaluation report of the Angra 2 Severe Accident Management Programs (SAMP).
    - 2 - Technical report on the MELCOR plant simulation model used for implementation/evaluation of the severe accident analysis of Angra 2.

➢ Enhanced follow up capabilities for the assessment and commissioning of systems with digital I&C in Angra-2 and/or Angra-3:

- to support CNEN in specific safety analyses, inspections, and commissioning in support of the licensing of the digital I&C systems, the man-machine interface and the information systems important to safety.
- Products:
    - NT-CGRC-012/18 – Guide for Licensing and Safety Assessment of Nuclear Reactor Instrumentation and Control Systems (Guia de Licenciamento e Avaliação de Segurança de Sistemas de Instrumentação e Controle de Reatores Nucleares: In Portuguese).

8(1). 12 - Advisory committees.

The DRS has established four Advisory Committees:

- Advisory Committees on Civil Engineer
  Has the purpose to evaluate solutions and support the licensing activities of the DRS in civil engineering, mainly for evaliuation of the civil design of Angra 3 and is composed of four representatives of DRS divisions and four engineers of TSOs.
- Advisory Committees on Radiological Protection
  Has the purpose to promote the assessments related to radiological protection actions, procedures and detection equipment used by CNEN's inspectors it also controls the individual dose from CNEN's employees. It reports to the Director of DRS. This committee also performs the licensing of Radiation Protection Supervisors, according to the CNEN's standards.
- Advisory Committees on Decommissioning
  Has the purpose to develop a draft of regulatory standard on the management of financial reserves for decommissioning of nuclear power plants.
- Reactors Operators Licensing Board
  Has the purpose to verify compliance with the standard CNEN-NN-1:01, Licensing of nuclear reactor operators, and CNEN-NE-1.06, *Health requirements for nuclear reactors operators*, evaluate and audit the training program and re-training of reactor operators and verify the ability of operators through written tests, practical-oral test, and test in simulator. It is responsible for all technical activities to support the issue of an Operator Reactor License. It also conducts assessments to verify the suitability of simulators to the standard CNEN-NN-1:01 regulatory requirements.

8(1). 13 – International Activities.

In accordance with the Brazilian Legislation, CNEN conducts international activities related to statutory mandates, international treaties and conventions, international organizations, bilateral relations, and research.

8(1). 13.1 - IAEA

CNEN actively participates in many IAEA Committees: CSS –-Commission on Safety Standards, NUSSC - Nuclear Safety Standards Committee, WASSC - Waste Safety Standards Committee, TRANSCC - Transport Safety Standards Committee, RASSC - Radiation Safety Standards Committee, EPReSC - Emergency Preparedness and Response Standards Committee, NSGC - Nuclear Security Guidance Committee and INSAG – International Safety Advisory Group.

CNEN is an active member of the IRS and IRSRR systems and contributes yearly with the presentation of events on the general meetings.

CNEN staff participates in many IAEA's Technical Meetings (12), Conferences (1), and Courses (1).

8(1). 13.2 - Bilateral Cooperation Issues and Regional Activities.

CNEN has Bilateral Cooperation Agreement with Gesellschaft Für Anlagen und Reaktorsicherheit (GRS) of The Federal Republic of Germany for the exchange of technical information and Cooperation in Regulatory and Safety Research Matters. Under this agreement three Workshops were held in the period 2013 to 2015. In 2015, CNEN started a new Project with European Commission, Project BR3.02/12 - "Support to the Nuclear Safety Regulator of Brazil" and is dedicated to the enhancement and strengthening of the nuclear safety regulatory regime in Brazil in compliance with international criteria and practices. The Consortium RISKAUDIT IRSN/GRSwas chosen by European Commission to carry out this project. This Consortium is composed of the following members: Institut de Radioprotection et de Sûreté Nucléaire (IRSN–France), Gesellschaft Für Anlagen und Reaktorsicherheit (GRS - Germany) mbH, Radiation and Nuclear Authority (STUK-Finland) and TECNATOM S.A. (Spain).

It should be mentioned that the Brazilian - Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) is a binational agency created by the governments of Brazil and Argentina, responsible for verifying the pacific use of nuclear materials in both countries.

8(1). 13.3 - International Cooperation between Regulatory Bodies.

CNEN is a member of The Ibero-American Forum of Radiological and Nuclear Regulatory Agencies (FORO). The FORO is an association created in 1997 to promote nuclear and radiological safety, and physical security at the highest level in the Ibero-American Region.

Today the FORO is composed of radiological and nuclear regulators from Argentina, Brazil, Chile, Colombia, Cuba, Spain, Mexico, Paraguay, Peru and Uruguay. The main objective of FORO is to provide an environment for the exchange of experiences and the development of joint activities related to common problems, in order to achieve the strengthening of the capacity and competence of its members. IAEA is the scientific reference organism of FORO and participate in all the technical activities.

As a consequence of the decision of the German Government to phase out from nuclear power, in 2013 a KWU Regulators Club was established by regulators from Germany, Netherlands, Spain and Switzerland with the purpose to share experience among them. The Brazilin Regulator (CNEN) joined this Club in 2014.

Article 8 (2) Status of the regulatory body

The relation amongst regulatory organizations and operators is shown in Figure 14.

8 (2).1 - Place of the regulatory body in the governmental structure

The following summarizes the relationships among the Federal Government Organization:

- MCTIC: Ministry of Science, Technology and and Comunication:

The MCTI has the following competencies: national policy of scientific research, technology and innovation; planning, coordination, supervision and control of the activities of science and technology; development policy for IT and automation; National biosafety policy; space policy; nuclear policy and control the export of sensitive goods and services. The Nuclear Energy National Commission (CNEN) is a branch of MCTI.

- SIPRON: System of Protection of the Brazilian Nuclear Program:

According to the Law nº 12.731 of November 21st, 2012, SIPRON has the responsibility, among others, of coordinating the necessary actions to permanently provide the needs of safety and security of the Brazilian Nuclear Program (PNB) and also plan as well as coordinate the necessary actions in case of nuclear emergencies which aim to protect people, workers and the environment.

- CDPNB: Development Committee of the Brazilian Nuclear Program:

To assist directly the President of the Republic on the establishment of guidelines and goals for the development and monitoring of the Brazilian Nuclear Program, through a high-level group, in order to contribute to national development and to the promotion of the welfare of the Brazilian society.

- MMA: Ministry of Environment:

This Ministry is basically responsible for the National Environment Policy. The Brazilian Institute of Environment and Renewable Natural Resources, known by the acronym IBAMA, is a Federal Agency and it is responsible for implementing the National Environmental Policy, developing various activities for the preservation and conservation of the natural heritage, exercising control and supervision of the use of natural resources, also granting environmental permits for projects of their competence. (See item 8(2).3)

- MME: Ministry of Mines & Energy:

In 2003, Law n° 10.683 defined the competencies of the MME in several areas, including electric power, as well as nuclear. The Ministry has some related companies such as Eletrobras, which controls, between other companies, Eletrobrás Termonuclear S/A (Eletronuclear) which aims to design, build and operate nuclear power plants in Brazil. Currently it operates the Almirante Álvaro Alberto Nuclear Power Station located in Angra dos Reis, with total capacity of 2007 MW.

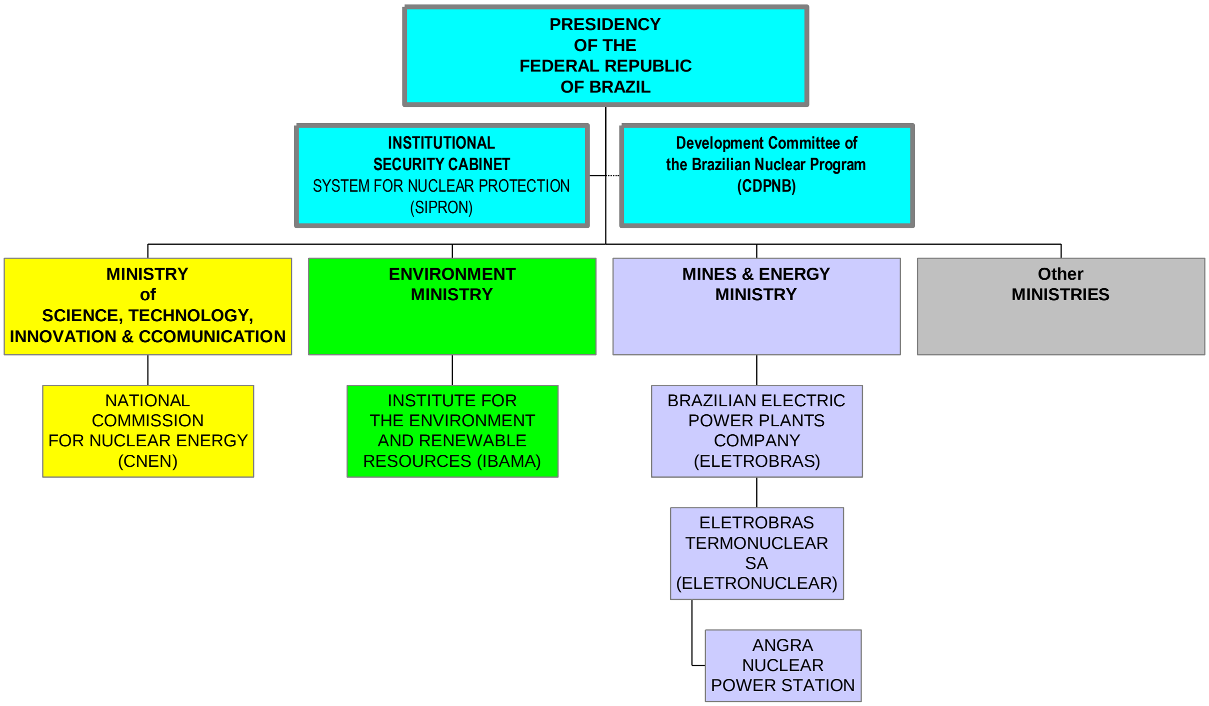

Figure 14 – Brazilian organizations involved in nuclear power plant safety

8 (2).2 - Effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.

The independence between the functions of the regulatory body (CNEN) and the organization concerned with the utilization of nuclear energy for electricity generation (ELETRONUCLEAR), is provided by the structure of the Brazilian Government in this nuclear area. While CNEN is linked to the Ministry of Science, Technology, Innovation and Comunication (MCTIC), ELETRONUCLEAR is fully owned by ELETROBRAS, a national holding company for the electric system, which is under the Ministry of Mines and Energy (MME).

The discussion and actions going on related to the creation of an independent nuclear regulatory authority (ANSN) are not based on a deficiency in the existing regulatory system but motivated by a perspective of expansion of the nuclear energy sector. The proposal is based on using the existing structure of the Directorate of Radiation Protection and Nuclear Safety (DRS) of CNEN, complemented by a governance and administrative infrastructure, adapting besides this the existing legal structure.

One of the new features in the proposed legislation is the formal inclusion of financial sanctions in order to face non compliances in a graded approach.

8 (2).3 - Other governmental bodies are also involved in the licensing process: IBAMA

The Law 7735 created IBAMA in 1989, which is responsible, as mentioned earlier, to implement and enforce the National Environmental Policy (PNMA - Brazilian Law 6938 of 1981). The structure of IBAMA is presented in Figure 15. The main organizational units involved with the regulation and control of nuclear power plants is the Directorship of Environmental Licensing (DILIC) and the Directorship of Environmental Control (DIPRO).

The Directorship of Environmental Protection (DIPRO) represents IBAMA in the CCCEN and in the COPREN, which are two multi-stakeholders' committees to act in the response of an eventual Nuclear Accident in the CNAAA.

Two divisions of the Directorship of Environmental Licensing (DILIC) carry out the environmental licensing of nuclear activities and facilities: Division of Licensing Nuclear, Thermoelectric, Wind Power and Other Alternative Sources (DENEF) and the Coordination of Licensing Mining and Terrestrial Seismic Survey (COMIP). The structure of DILIC is presented in Fig. 16.

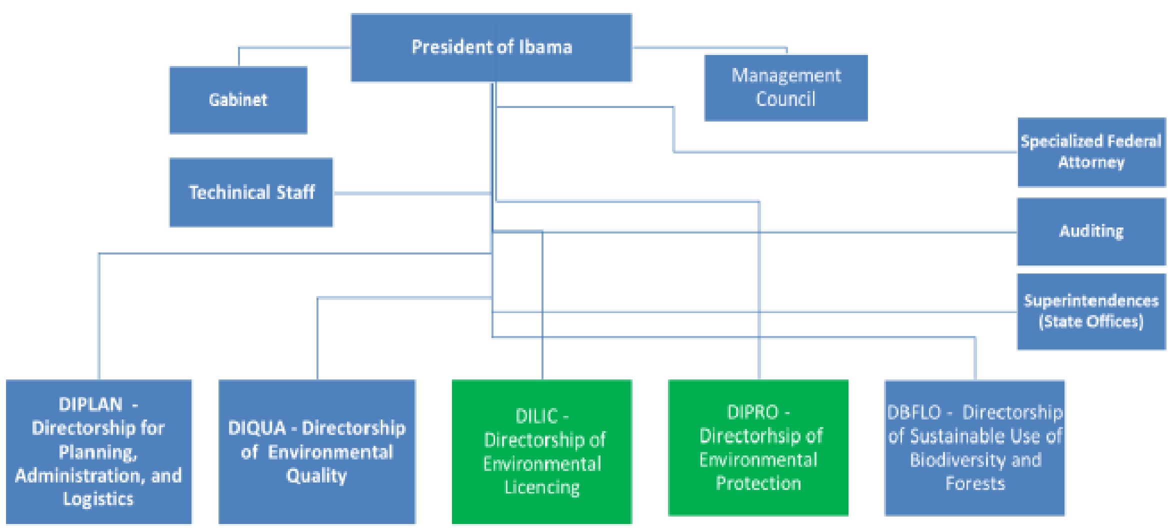

Figure 15 - IBAMA Structure

DENEF performs the environmental licensing of the Nuclear Power Plants, the Nuclear Fuel Factory, the Nuclear Research Centers (CNEN and Navy), the Radioactive Waste Repositories, the Transportation of Radioactive Materials, and, after the enactment of the Federal Law 140/2011, any other radioactive facility. Also observe that:

- With respect to Nuclear Fuel Factory, DENEF has also unified the environmental licensing of the three units in operation and issued the Operation License N° 1174/2013 to the complex that encompasses the activities of component manufacturing, fuel elements assembly, uranium enrichment, UF6 reconversion, and chip manufacturing.
- Recently, the CNEN's Directorate for Research and Development (DPD) started up the environmental licensing process for two new facilities, also under IBAMA's DENEF: 1) DENEF issued the Term of Reference to the Environmental Impact Study (EIA) and the Report on Environmental Impact (RIMA) of the Repository for Low and Intermediate Level Waste in March 2016; and 2) the Brazilian Multipurpose Reactor (in 2010). After the technical evaluation of the Environmental Impact Study (EIA) and gathering of supplementary information the IBAMA issued the Prior License (LP N° 500/2015) in July 2015.
- In February 2016 IBAMA issued the Normative Instruction No. 01/2016, which established the criteria for the licensing of radioactive facilities.

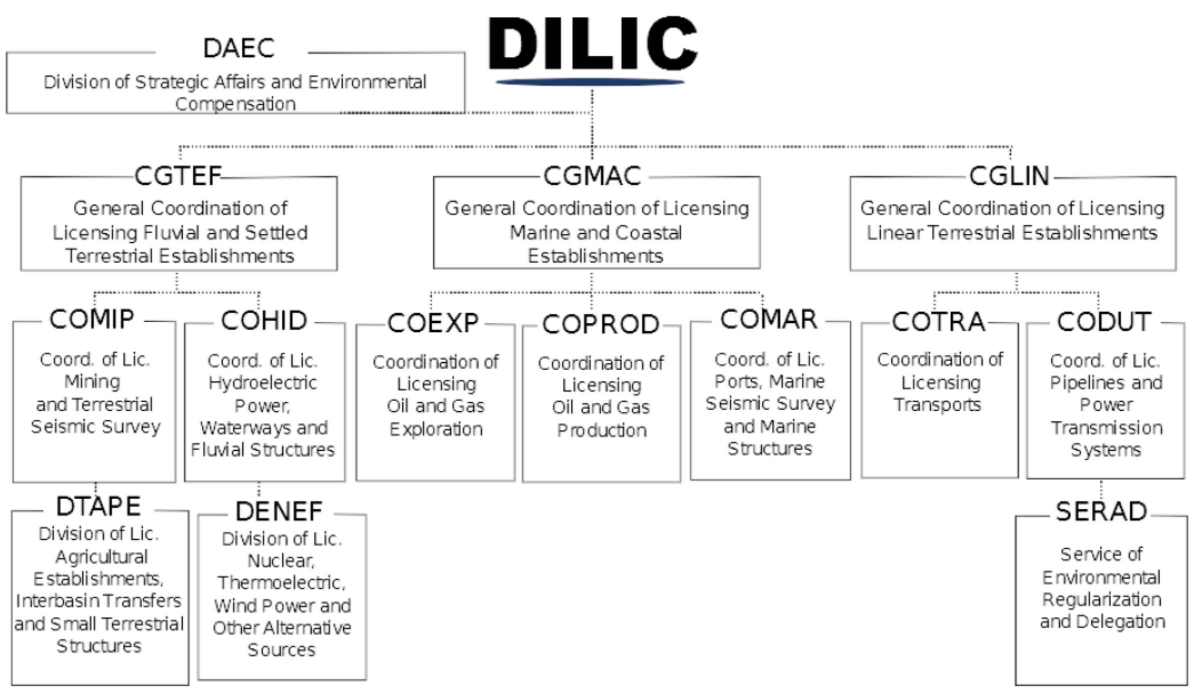

Figure 16 - DILIC Structure

COMIP carries out the environmental licensing of uranium mines in the municipalities of Santa Quitéria and Caetité and the decommissioning activities of the Ore Treatment Unit of Poços de Caldas (UTM):

- The Santa Quitéria Project consists of the exploration and processing of phosphate ore associated with uranium in a deposit owned by INB (Brazilian Nuclear Industries). In March, 2014, COMOC (current COMIP) received the Environmental Impact Study (EIA) and the Report on Environmental Impact (RIMA). After the technical evaluation of the Environmental Impact Study (EIA), the IBAMA asked supplementary information to complement the evaluation in 2015. These studies will provide IBAMA with the technical information for the decision about the Prior Licensing (LP) of this enterprise.
- The Caetité unit of concentrate uranium (URA) comprises two mines and a processing plant, whose final product is U_3O_8 in the form of ammonium diuranate (yellow cake). In April, 2015, COMOC (current COMIP) issued the Installation Licence (LI 1057/2015) of the Engenho Mine, at the Caetité site.
- The Ore Treatment Unit of Poços de Caldas (UTM), is currently in the decommissioning phase. COMOC has approved the conceptual project of the unit's decommissioning. Actually, INB has to present the executive project to be evaluated and approved by COMOC (current COMIP).

COPAH performs the environmental licensing of the Brazilian Nuclear Submarine Shipyard. In April 2010, IBAMA issued the LP 351/2010, and In December 2014, IBAMA issued the LI 1031/2014 to this project.

Article 9 – RESPONSIBILITY OF THE LICENSE HOLDER

> Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.

9.1. Formulation in the legislation (quotation) assigning the prime responsibility for safety to the licence holder

The Brazilian legislation defines the operating organization as the prime responsible for the safety of a nuclear installation.

Moreover, in according to Article 4 of the law 6.453, regardless of fault, the civil liability for nuclear damage repair, caused by a nuclear accident, is an exclusive responsibility of the nuclear facility operator. This law has been adapted to the three principles of Vienna Convention (1963):

(i) the risk of nuclear damage.
(ii) liability for nuclear damage.
(iii) the amount of insurance to cover the nuclear damage.

9.2. Description of the main means by which the licence holder discharges the prime responsibility for safety.

In fulfilling its legal obligation, the Operating Organization has established adequate safety policies, organizational structure and procedures which reflect its commitment to safety, see Article 10.

More specifically, the CNEN's Safety Policy [10] and the regulation CNEN-NE-1.26 - Operational Safety in NPP [9] define the operating organization as the prime responsible for the safety of a nuclear installation.

9.3. Description of the mechanism by which the regulatory body ensures that the licence holder discharges its prime responsibility for safety.

CNEN, through the licensing process, and especially through its regulatory inspection program, ensures that the regulatory requirements for safe operation are being fulfilled by the licensee. The licensee reports periodically to CNEN in accordance with regulation CNEN-NN-1.14 [8]. In addition, CNEN maintains a group of resident inspectors on the site, who can monitor licensee performance on a daily basis. Finally, several regulatory inspections by headquarters staff take place every year, focusing on specific topics or operational events.

9.4. Description of the mechanisms whereby the licence holder maintains open and transparent communication with the public.

See Article 16 (2) Information to the public and neighboring states.

9.5. Description of the mechanism by which the Contracting Party ensures that the licence holder of the nuclear installation has appropriate resources (technical, human, financial) and powers for the effective on-site management of an accident and mitigation of its consequences.

See Article 11.

Article 10 - PRIORITY TO SAFETY

> Each Contracting Party shall take the appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

10.1 - Overview of the Contracting Party's arrangements and regulatory requirements regarding policies and programmes to be used by the licence holder to prioritize safety in activities for design, construction and operation of nuclear installations

CNEN has issued its Safety Policy [10] and Quality Assurance Policy Statements [11] in December 1996, which are based on the concept of Safety Culture.

The main principals of the CNEN's Safety Policy are:

- The legislation and rules shall determine safety objectives and establish the features to assure their implementation.
- The responsibilities shall be clear determined, and the safety issues shall be treated by their merits without undue pressure.
- CNEN shall seek resources to performance its mission.
- The international exchange of safety information shall be encouraged by the Government.
- CNEN recognizes that the primary responsibility for safety rests with the operating organizations. Thus, CNEN should ensure that regulatory requirements are clear and contemplate a sufficient degree of flexibility to avoid undue restriction.
- The standards adopted by CNEN shall require appropriate levels of safety but without discarding the inevitable residual risk.
- Controversial topics shall be managed by CNEN in an open way. Individuals and institutions shall have the opportunity to express an opinion on them.

CNEN has established in its regulatory standards requirements to be met by the applicants or licence holders based on safety principles, defense-in-depth, ALARA concepts, quality assurance and human resources management. According to Regulation CNEN-NE-1.26 [9] the licensee shall establish an organizational structure with qualified staff and managers, to deal with technical and administrative matters using Safety Culture principles.

10.2 – Measures taken by licence holders to implement arrangements for the priority of safety, such as those above and any other voluntary activities, examples of Good Practices and safety culture achievements.

ELETRONUCLEAR is a company resulting from the merger, in 1997, of the nuclear portion of the electric utility FURNAS and the nuclear design and engineering company NUCLEN, both with almost 40 years of experience in their field of activities.

Both companies had already policies aiming the priority to nuclear safety. The organizational structure of ELETRONUCLEAR went through some modifications compared to the one presented in the previous National Report. Changings in the management of the holding company Eletrobras demanded a reconfiguration of Eletronuclear's organizational chart since 2017, when the four directorates of the company were reduced to three and still remains this way up to now. The Figure 17 shows the current situation of the company. Although it is not shown in the figure 17 bellow, the name of some areas was updated to comply with the demanding of the holding company, however keeping their original attributions.

ELETRONUCLEAR, as the owner and operator of the Angra 1 and Angra 2 plants, issued a company safety policy initially based on the INSAG 4 document, since its foundation, occurred in 1997, stating its commitment to safe operation. This policy was revised in 2004, becoming an "Integrated Safety Management Policy", and revised again in 2015, referred this time to the IAEA guideline GS-R 3.1 and the publication "WANO Traits for a Healthy Safety Culture", improving its content and expressed in an easier way to understand, as follows:

> *"We are committed to generate electricity with high standards of safety, reliability and environmental responsibility. So all of us, leaders and employees, we have to conduct our activities in an integrated manner, always giving priority to safety, which includes primarily the nuclear safety.*
>
> *Other topics are also part of our integrated safety such as quality assurance, information security, physical protection, industrial safety, health and radiological protection of occupational workers and the general population, and care for the environment.*

This was expanded into 7 principles, as follows:

> *PRIORITY: Nuclear safety is a priority. It is more important than the productivity and economy and is not to be compromised for any reason.*
>
> *PRESENCE IN THE FIELD: The frequent presence of the leaders in the field activities, the processes of communication and decision-making reinforces our commitment to safety.*
>
> *RESPONSIBILITY: The responsibility for our safety should be clearly defined and the various legal requirements met.*
>
> *TRAINING: All of us, employees and service providers, must be qualified and aware of various aspects of integrated safety necessary to carry out our work properly.*
>
> *PREVENTION: Risks to health, safety and environmental impacts must be prevented, minimized or eliminated.*
>
> *COMMUNICATION: Our communication processes, internal and external, should be transparent and efficient so that any unsafe condition identified will be promptly informed.*
>
> *CONTINUOUS IMPROVEMENT: We seek continuous improvement of our practices related to integrated management of safety."*

These principles establish the commitment and actions of the higher and middle management of the company as well as of the individuals toward safety.

To support this policy several permanent programs were created, such as, enhancement of safety culture and human performance, assessment of internal and external operating experience, self-assessments and external assessments (OSARTs and WPR), nuclear oversight committees, among others.

Strict adherence to this policy is firstly verified at the plant level by the Plant Operation Review Committee (CROU). The second and higher level of adherence to this policy is verified by the Nuclear Operation Review Board (CAON), the supervisory committee with the responsibility to review and approve all important aspects related to the plants safety, reporting to the Operations Directorate level. The members of this Committee are the Plants Managers and the Heads of Engineering, Safety, Licensing, Quality Assurance and Training, under the coordination of the Site Vice President. The CAON meets regularly four times a year and has as many extraordinary meetings as needed (on the average 8 times a year).

CAON is supported, in its plants safety oversight task, by a subcommittee, composed with members from Operations, Design and Support Engineering, Maintenance, Safety Analysis, Training and Quality Assurance. This committee reviews the operational experience reports, the Plants Safety committees meeting minutes as well as the Plants modifications documentation and takes any identified safety related issue to the CAON for scrutiny. This subcommittee also provides the CAON with a yearly evaluation of the Plants safety status.

A third safety oversight committee, Independent Safety Oversight Committee (COSIS), established at the highest company level, comprising representatives of all directorates, was created to provide independent oversight, reporting directly to the Company Board.

The nature of the subjects under the COSIS review may range from CNAAA and Headquarters performance indicators, reported events, performance audits and plant safety reviews by either national or international bodies, results and recommendations of CROU and CAON, among others. The committee also has the autonomy to set up working groups for specific investigations of matters of interest related to the nuclear power plants safety.

The creation of COSIS is also aligned with the objectives of the WANO Performance Objectives and Criteria (PO&C) and the most recent 2017 IAEA-WANO joint publication GL 2017-01, establishing that an independent oversight provides the senior leaders (if necessary through the Administration Council) a continuous perspective on Eletronuclear power plants and corporate performance compared with the industry, with main focus on nuclear safety, plant reliability and efficiency of emergency responses.

Besides the creation of COSIS, since 2021 the independent nuclear oversight function was formally established in the company by revising the atributions of the Safety Coordination, although still carrying on of the international affairs attributions, changed its name to Safety and Independent Nuclear Oversight Coordination, counting on its manager woeking directly in site area. The performed activities include, in addition to carrying out observations and inspections in the field, issuing technical reports and notifications to the supervised areas of relevant items with respect to nuclear safety on behalf of independent supervision.

Following the line of the merged companies (FURNAS and NUCLEN), a strong Quality Assurance (QA) unit was established, at ELETRONUCLEAR, from the beginning in 1997, at the level of superintendence, with the responsibility of monitoring all design, construction and operation activities and coordinating/supervising the plants nuclear and environmental licensing. This superintendence responded formally to the Technical Director at headquarters. With start of operation of the second Plant, in December of 2000, it was identified the need of a Quality Assurance unit inside the Operation organization. To meet this need the original QA superintendence was split in two units in 2003, one at headquarters, under the Technical Director and one on site, under the Operation and Production Director. This area, reorganized in 2007, keeping its previous characteristics of one unit at the Site and one unit at Headquarters, was then subordinated to a single Directorate independent of the production areas, the Planning, Management and Environment Directorate. However, in 2016, after a huge reorganization of the company's organization chart, reflecting changes in the national political situation and following a determination by the holding company, ELETRONUCLEAR reduced its directorates from four to three, excluding the Planning Management and Environmental Directorate. In this new scenario, some areas changed their subordination or were incorporated into other departments as shown in the current Organization Chart on Figure 17.

In 2011, ELETRONUCLEAR began a joint work with IAEA in the Project RLA9060 – Enhancing Operational Safety in Nuclear Installations. This project that has its additional scope funded by European Commission – Enhancement of Safety Culture, involves not only Brazil, but also Mexico and Argentine. From this work, 8 Peer Visits involving 26 Participants (among which 16 Brazilians) identified 53 Good Practices (49 for Brazil) that are under development and adjustment to be applied in a routine basis. Besides, a web platform (LASCN – Latin American Safety Culture Network) is being created by the project to sustain experience and information sharing between counterparts. As a consequence, ELETRONUCLEAR developed a Corrective Action Program which captures all inputs from deficiencies and allows a link to the associated actions. For the company, this was a step in the direction of implementing a Nuclear Oversight Process, inspired in one of those good practices observed as well as improving its communication process based on benchmarking with partners of this project.

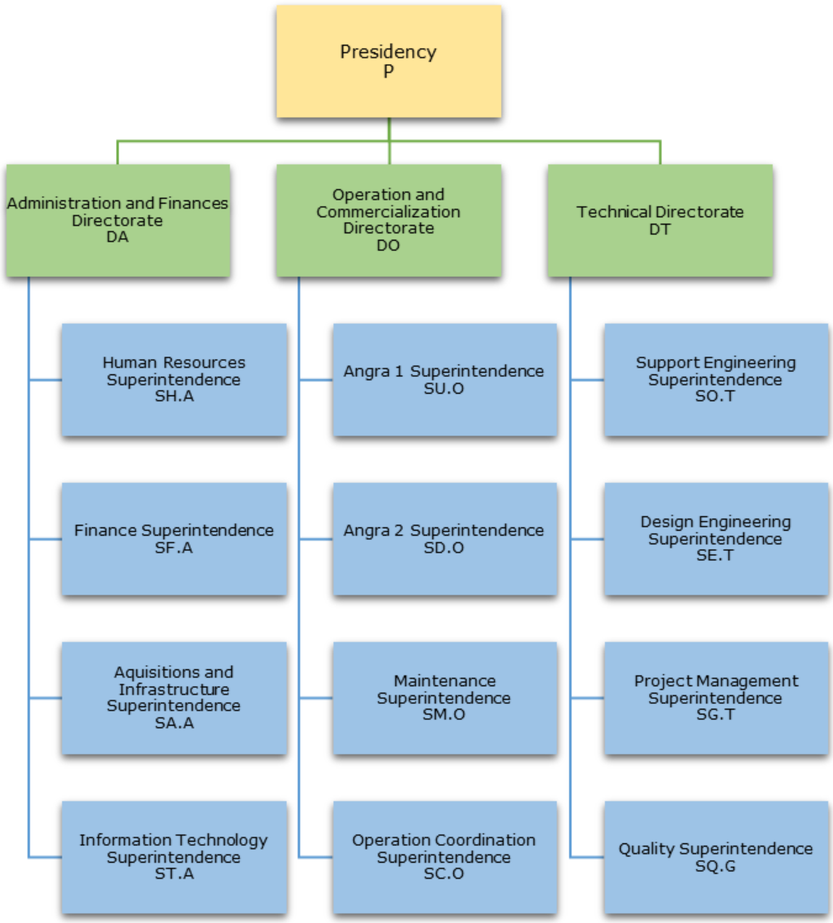

Figure 17 – ELETRONUCLEAR Organization Chart

Eletronuclear is currently using the Pendencies Management System (Sistema de Gestão de Pendências – SGP), a corporate system for items pending of corrective actions, related to several areas of the company. It stores and maintains data on pending and deficiencies items detected through several internal and external processes, providing functions that enable the planning, monitoring and recording solutions. Moreover, it provides information that enables the preparation of reports, charts and indicators, serving as a large repository of operational experience and troubleshooting.

The SGP was implemented in 2004. The software (available in the company's intranet to all employees) was built in a partnership between Eletronuclear and the Federal University of Rio de Janeiro (UFRJ). Since then and as a result of audits to which the system is submitted, it has been revised to improve efficiency and the integration of organizational units in their corrective actions programs.

The SGP has several processes as inputs. They include the CNEN's findings, WANO and OSART recommendations, Nuclear Operations Review Board (CAON) and Plant Operation

Review Committee (CROU) resolutions and internal pendencies from: Quality Assurance; PSA; Periodic Safety Review; Radiation Safety; Industrial Safety; Operating Experience and Human Performance Committees and Environmental Safety.

Monthly, the Operations Directorate demands a meeting when all pending issues, its established goals and action plans are discussed and updated. All organizational unit managers to which SGP is related are present in this meeting.

As an effort to evolve to an effective Nuclear Oversight Program, Eletronuclear took several steps to detect the processes that should be reviewed and upgraded and feed this important program. The SGP is being considered as a starting point to this project. That was confirmed through a gap analysis conducted within the IAEA Project Regional Latin America, RLA 9060.

In September 2013, it was held at the Duke Power Company, in North Carolina (USA), a technical exchange mission sponsored by the IAEA (RLA 9060) focusing on Corrective Action Program for which Eletronuclear sent an expert. On this occasion, aspects concerning the operation and management of the program at this institution were discussed as a benchmark to the upgrade of the company SGP.

Also in 2013, the RLA 9060 LASCN Project became PIANOS (Plataform IberoAmerican Nuclear of Operadotors in the area of Safety). However, due to lack of participation among members, no activities were proposed for this area and it was discontinued. Currently, the IAEA RLA 9080 Project (an updated and revised version of the original RLA 9060 Project) is focused only on initiatives in the areas of safety operation of the plants, such as: safety culture, OSART, and SALTO.

Other important safety-related initiative by the ELETRONUCLEAR Executive Board was the launch, in May/2018, of the **Top Ten Corporate Goals**. The list of the company's ten main projects and actions, updated in May 2021, are in line with its strategic positioning statement, and comprises:

1. **Strengthening the safety culture –** Encourage all initiatives aimed at the promotion and continuous improvement of the safety culture as a priority corporate reinstatement among the entire company's staff, employees and contractors, ensuring that its concept is integrated into all activities carried out in the company, in addition to independently monitoring and supervising all processes related to the safe and reliable operation of the nuclear power plants.
2. **Continuous improvement of safety and operational performance of Angra 1 and Angra 2 –** Continuously evaluate processes, projects, systems, equipment and procedures, taking as a reference the best national and international practices

of the industry, with the objective of maintaining a high standard of safety, increasing reliability and cost control.

3. **Implementation of the Spent Fuel Complementary Dry Storage Unit (UAS) –** Carry out the transfer of used fuel elements to the Spent Fuel Complementary Dry Storage Unit, according to a schedule that meets the demands of Angra 1 and Angra 2 in a timely manner.
4. **Angra 1 Life Extension** – Obtain approvals for the service life extension of Angra 1 for another 20 years (2044).
5. **Execution of the Angra 3 Critical Path Acceleration Program –** Contract the civil works and other activities of the Angra 3 Critical Path Acceleration Program.
6. **Conclusion of the Angra 3 Project –** Structuring the contracting of commercial partners to enable the conclusion of the project.
7. **Asset management with a focus on tariff review –** Systematize and optimize the immobilization/unitization of Eletronuclear's assets, in order to add value to the company's assets and due recognition in its revenue from the sale of electricity.
8. **Increase in Public Acceptance of Nuclear Energy** – Develop communication strategies to bring Eletronuclear closer to its stakeholders, making nuclear energy positive and thus strengthening the company's credibility and image.
9. **Innovation initiative at Eletronuclear –** Implement innovation initiatives at Eletronuclear, as a systematic and perennial management practice, according to the following pillars: digital transformation and knowledge management.
10. **Strengthening corporate governance –** Consolidate the corporate governance process with an emphasis on risk management in business processes, monitoring the internal control environment, corporate integrity and legal and regulatory compliance.

10.4 - Regulatory processes for monitoring and oversight of arrangements used by the licence holders to prioritize safety.

The Regulatory Supervision Process adopted by CNEN that includes the Annual inspection program for inspection and audits was discussed in the item 7(2)(iii). In addition, the CNEN has a group of resident inspectors, located at the site, that continuously check the status of each plant. This group participates in the daily meeting among NPP manages and supervisors and daily visits to Control Room to overview plant parameters, the ongoing and planned activities. This group also carried out walkdowns to verify the general status of the plant.

10.5 - Means used by the regulatory body to prioritize safety in its own activities.

Brazilian legislation defines the operating organization as the prime responsible for the safety of a nuclear or radioactive installation, including the management of spent fuel and radioactive waste. CNEN, through the licensing process, and especially through its regulatory inspection programs, ensures that the regulatory requirements for safe operation are being fulfilled by the licensee.

Therefore, to obtain and maintain the corresponding licenses, the operators must fulfill all the prerequisites established in the legislation, which are translated in the CNEN regulations presented in Annex II. In this sense, CNEN focuses its actions: on Training and qualification of personnel in safety matters to acquire the necessary technical competence; based in a conservative attitude but supported on graded approach.

ARTICLE 11 - FINANCIAL AND HUMAN RESOURCES

1. Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.

2. Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life.

Article 11 (1) Financial resources

ELETRONUCLEAR is a state-owned company of closed capital controlled by ELETROBRAS, an open capital company which holds the control of all the federal public companies of electrical energy in Brazil.

Until the year 2012, the company had as its revenue source the sale of electrical energy to its related counterpart FURNAS, generated by its plants Angra 1 and Angra 2, through a long-term contract of electrical energy supply.

From January 1st, 2013, onwards, as established by the government, the revenue of ELETRONUCLEAR due to the electrical energy generated by the Angra 1 and Angra 2 is composed by quotas from all the companies of public distribution service of the National Interconnected System – SIN. The Electrical Energy National Agency - ANEEL established the conditions for the commercialization and the calculation methodology of the annual quota to each distributing company. These quotas are proportional to the sum of consumers´ load of each distributing company.

The company has been keeping adequate resources for the operation and maintenance of the plants of Angra-1 and Angra-2, as can be seen from the examples presented in Table 4, where a detailed comparison of the executed budgets for the years 2019 to 2021 is presented:

Table 6. Comparison of ELETRONUCLEAR budget from 2019 to 2021.
Values in million R$

Items	YEARS		
	2019	2020	2021
Primary Costs			
Angra1 & 2 Personnel (salaries + benefits)	657	548	733
Angra1 & 2 Fuel	430	445	449
Other services, subcontractors and materials	464	512	825
Investments			
Angra 1 & 2 Upgradings (including engineering)	165	215	281
Angra 3 Site Maintenance and Construction	650	1.049	1.240

As it can be seen from the above Table, there was an increase in the primary costs in 2021. One of the reasons of this increase was because of the effects of the Covid 19 pandemic. Part of the costs that should have happened during 2020 was postponed to 2021. Another important impact on the primaru costs during 2021 was the realization of the first nuclear fuel transfer campaigns to the complementary unit for dry storage of irradiated fuel (UAS).

As far as Investment Costs, the program of Plant upgrades for Angra 1 and 2 has had an increase of about 30% from 2019 to 2020, and in 2021 these Investments were increased 31% when compared to the year before because of the because of the construction project of the complementary unit for dry storage of irradiated fuel (UAS). Even with this financial restriction caused by the financial impact of the suspension of Angra 3 Plant construction in such a way the investments levels on Angra 1 and 2 sustained by the company in this period of time continue to ensure a safe and reliable operation of the Plants. (see Article 6).

After the approval of the Critical Line Acceleration Plan by Eletronuclear and its holding company Eletrobras during 2020, the expenditures for Angra 3 construction have accelerated significantly especially in 2020 and 2021. With the contribution of resources from Eletrobras in the form of advances for future capital increases (AFAC), besides being able to make the minimum payments required to preserve the existing structures and to maintain the equipment and materials already purchased, the company was able to maintain its financial commitments to the main supplier abroad of services and equipment in order to avoid further delays in the project schedule. Also, the resources from Eletrobras were utilized to keep the financial obligations with the financial institutions (BNDES e CEF) up to date.

The company keeps in a Brazilian Federal Public Bank an exclusive investment fund whose use is restricted to the future financing of the decommissioning activities of the plants of Angra 1 and Angra 2 Plants, under the ownership of its holding (ELETROBRAS), as determined by the National Board of Energy Politics (CNPE).

The annual sums destined for this fund are formed from monthly contributions from ELETRONUCLEAR and have coverage in the rates structure during the same period of depreciation of the plants (3,33%/per year). In relation to Angra 1, the estimated decommissioning cost as of December 31, 2021 is, at present value, R$ 1,841 million and in relation to Angra 2, the estimated decommissioning cost as of December 31, 2021 is, at present value, R$ 1,427 million.

The main instrument to ensure the necessary financial resources in the event of a radiological emergency is the Special Fund for Public Calamities (Fundo Especial para Calamidades Públicas (FUNCAP), it is provided for emergency assistance in response actions to disasters, in according to Art. 148, paragraph I, of the Brazilian Constitution, "The Federal Government by supplementary law, institutes compulsory loans to meet extraordinary expenses resulting from public calamity, foreign war or the imminence thereof."

Article 11 (2) Human resources

Human resources are available for ELETRONUCLEAR from its own personnel or from contractors. Currently the company has a total of 1637 employees on its permanent staff and a few long-term contractors, which supply additional personnel. From this total, 604 have a university degree, 805 are technicians and the remainder 228 administrative personnel.

Before getting to this number, in the review period, ELETRONUCLEAR had a great reduction in its staff employees resulted from the personnel reduction imposed by the holding company Eletrobras to all its subsidiaries, through an Early Retirement Program. About 1000 employees joined this program and left the Company since 2014.

Once the Retirement Program was announced, CNEN asked to ELETRONUCLEAR to present the actions that would be taken to face the losses of experienced employees. The Program was discussed with CNEN and meetings between high level managers were done in a regular basis.

The most significant losses occurred in the Eletronuclear Headquarters staff with a reduction of about 40% of its experienced personnel from engineering, commercial and administrative areas. The Operation and Commercialization Directorate was the least affected numerically (less than 20% losses) and had the additional possibility of replacing lost personnel in the operating plants by personnel hired and trained for Angra 3. Managerial positions were fulfilled with the regular substitution planning.

In order to minimize the impacts caused by the loss of experienced employees that joined the retirement program, it was launched in 2014 the Substitutes Preparation Program – PPS providing information to minimize the risk of human performance factors arising from unplanned outputs.

The Criticality Matrix Database, the basis of the Personnel Management Simulator, which identifies the degree of impact caused by the exit of each of the company's employees, has been updated and this management tool is available to all management staff. This matrix is currently being revised.

The construction of the Leadership Pipeline with participation of representatives of all levels managerial was performed. In 2018, an Assessment of Managers was carried out by an external consultancy. In 2019, the Leadership Succession Program Development took place.

In early 2018, a working group was created to take care of the knowledge management (KM) process, with the objective of re-evaluating the tools used in the Replacement Preparation Program (PPS). Throughout 2018, this group interviewed all managers and mapped all KM practices performed at ELETRONUCLEAR without HR support. The objective is to create procedures to regulate these practices, to create evaluation mechanisms aiming at a better effectiveness, if necessary, and to identify that other practices would be effective according to the specificity of each area of the company. Also in 2018, the design of a KM policy for the company was started, as well as a specific one for the Angra 1 NPP Long Term Operation (LTO) Project.

In 2019, the document "Guidelines for Knowledge Management at Eletronuclear" was approved by the company, with the objective of encouraging the actions on this topic, in addition to supporting the culture´s consolidation in the company. A market study is currently being done to hire a external consultancy in knowledge management. Some goals include: the definition of the KM strategy, application of educational actions and knowledge transfer tools accordingly with the critical knowledge and skills raised in our workshops. The hiring forecast for this consultancy is in 2022, June.

In 2021, Eletronuclear carried out an innovative action for new leaders, called the Talent Bank. This Program deals with the identification, valuation, evaluation, development and movement of potential leaders of the Company in order to develop functional capacity and meet the immediate and future needs of organization.

In 2016, in order to replace the personnel lost in areas were own personnel is required in accordance to CNEN and Labor Ministry guidelines, ELETRONUCLEAR was authorized to promote a public examination with the purpose of occupying the vacancies left in three specific job positions in the company: occupational health physician, field operator and security specialist.

Nowadays, ELETRONUCLEAR is authorized to promote another public examination with the purpose of occupying the different types of vacancies at the company, focusing on the following qualifications/functions: Engineer, Nuclear Operator, Technician, Analyst/Administrator, Nuclear Safety Specialist, Finance Professional, Physicist, Lawyer, and others.

The company raised the need to hire 484 (four hundred and eighty-four) people in vacancies to service the Company's operational and corporate activities. According to the needs, identified by the Boards and their schedules, mainly related to the pre-operational actions of the Angra 3 Plant, 261 vacancies would be to 2022, 183 vacancies to 2023 and 40 to 2024.

The deadlines programmed above were established based on the duration of the technical-operational training and certifications of the professionals who will be allocated to the operation and maintenance of the Angra 3 Plant, which are in line with the Colenco Power Engineering Ltd benchmark, which indicates the parameter of 4 years of training.

However, the currently Eletronuclear's total staff (approved in SEST-10,499/20, of April 23, 2020) is 1,796 vacancies. In this way, Eletronuclear was allowed to publish in public examination, only 140 vacancies. At this moment, Eletronuclear is trying to negotiate with the Brazilian government to authorize the occupation of the other necessary vacancies.

The Organizational Climate Survey, implemented in 2010, had the objective to analyze the employee`s perceptions of their work environment, about aspects like communication, leadership and that sort of thing. Comparing the result of the first survey conducted in 2010 (when the favorability index was 65,51%), the level of satisfaction has been increasing and in 2015 the result has achieved 68,81%. This instrument helped the Human Resources area to monitor the internal atmosphere of the organization and address plans to interfere more directed in some specific points.

Climate surveys are carried out every 2 years. According to the value of the Favorability Index (IF) the researched assertions are grouped into "Favorability Classes", in order to facilitate the analysis of results and subsequent formulation of the Action Plan to Improve the

Organizational Climate. A climate result is considered high, if the value is greater than or equal to 85%.

In 2018, Eletronuclear ranked 2nd of the best grades for the organizational climate survey, behind only Furnas. The Eletronuclear´s level of satisfaction was 75.8%, above the CMDE target (70%) and above the general average of Eletrobras companies (71.16%). According to the Favorability Class, this score (75,8%) reflects an average result.

In 2020, the last survey, Eletronuclear ranked 2nd place too about the best grades for the organizational climate survey, behind only Eletronorte. The Eletronuclear´s level of satisfaction was 79.65%, above the CMDE target (72%) and above the general average of Eletrobras companies (77.66%). According to the Favorability Class, this score (79,65%) still reflects an average result, but it is possible to have good expectations for the next survey and its easy to realize this.

Eletronuclear continues to keep an agreement with the Brazilian Coordination for Improvement of High Level Education Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES) to provide scholarships to graduate programs in public or private institutions that have courses in the nuclear area. However, due to budget cuts in the Federal Government, which directly impacted development institutions in Brazil, the bidding agreement signed between ELETRONUCLEAR and Capes is currently inactive.

The Human Performance Program was implemented in 2007 and since then, it has been increasing in terms of actions and areas. The goal of the Program is to systematize actions in order to promote the improvement of employees working at Eletronuclear so as to reduce human errors and error-related events. One of the basic methodologies is the reduction of human errors through the comprehension of the reasons why the errors occur and the conscience and perception of emotional and behavioral factors with also the use of error prevention tools.

The human resources representatives at Human Performance Program are the Psychologists from the Eletronuclear permanent staff. They participate in the initiatives from this program so as described below:

- Basic trainings applied to all new employees including disciplines as error theory, error precursors, and error prevention tools.
- Application of the Human Performance Module inside the Outage Training to an average of 1500 contractors from Angra 1 and Angra 2 NPPs over the last three years, before their respective refueling outages.

- Application of Team Work Training for operator, chemical and maintenance areas. This training was structured to develop skills and attitudes for a good relationship, communication and integration of the team.
- Attendance of daily safety dialogue from maintenance area. The main objective is to draw attention to the error precursors and reinforce the errors prevention tools. Besides that, some subjects as leadership, motivation, conflict resolutions can be discussed as well.
- Behavioral aspects are observed on training operators in order to give them emotional support and develop necessary skills for the exams.
- Participation in simulators training to follow-up behavioral aspects (teamwork, leadership, communication, decision-making processes, error precursors, etc.) for the operator's staff from Angra 2.
- Participation in the plants Human Performance Committees. In committees, it is discussed the strategies to reduce the human errors and the effectiveness of the initiatives. One of the contributions of the psychologists is the development of the newsletters covering topics such as communication, teamwork and motivation.

Since 2009, the psychologist staff of Eletronuclear has been included in the Human Performance and Safety Culture Committee, being also part of the root-cause analysis group, working effectively at the plants Angra 1 NPP and Angra 2 NPP analyzing all kind of events, even those that are not at first related to human errors. The goal is to verify if the event is related to human error and, if so, determine the causes of the problem and how they should be treated, seeking to avoid repetition or recurrence of events in the future. In 2015, 52 events occurred in Angra 1 and 63 in Angra 2 were analyzed. In 2018, the ELETRONUCLEAR Psychology Team won the "Human Being Prize", sponsored by the Brazilian Association of Human Resources, and considered the case "The work of Psychology in Human Performance" the best HR practice performed among public sector companies in the city of Rio de Janeiro.

Activities related to qualification, training and retraining of plant personnel are performed by the Training and Simulator Department of ELETRONUCLEAR, which reports to the Site Superintendent.

Four main facilities are available for training in the Plants personnel residential village, located at about 14 Km from the site: a general training center, a full scope simulator facility for Angra 2, a new full scope simulator facility for Angra 1, and a maintenance training center. One Interactive Graphic Simulators (IGS) is available to support classroom training.

These facilities have been expanded in 2010 with the construction of two new blocks (~700 m^2) for classroom and mechanical, electrical and I&C maintenance labs training to support identified needs of better practical maintenance training and additional classroom space for the Angra 3 personnel.

As reported in the previous Brazilian National Reports, before the installation of the full scope simulator for the Angra 1 plant, in 2015, its operators have done their simulator training abroad, in simulators of similar plants.

The Angra 2 full scope simulator is available on site for operator training since beginning of 1985. This simulator was originally used to provide external training services until start of training of the first group of Angra 2 operators, in 1995. The first group of Angra 2 control room operators was licensed in the beginning of 2000.

This simulator has undergone periodical partial upgrading of the hardware, basically simulations servers, at about every 10 years, as well as adaptation of the models and control room panels to take in account changes in the Angra-2 plant.

A major software and hardware upgrade of Angra 2 full scope simulator was developed and implemented between 2009 and 2013, involving substitution of all computers and most of the software (executive program, instructor system, some mathematical models, database and data transfer programs).

In the period under review (2019-2021), the replacement of Angra 2 full scope simulator interface system was completed and the training department had upgraded the turbine and feed water control system of the Angra1 simulator, replacing the simulated systems by a simulation of the Ovation® platform, which is already mounted in Angra1 Nuclear Power Plant. The simulated solution was a simulated Ovation® 3.2-based Distributed Control System (DCS) utilizing the WE-SIMIX® Simulation Software. The re-qualification, training programs performed for the Angra 1 power plant operators, allowed 49 operator licenses to be renewed. For Angra 2, in the same period, 74 operators completed the training requirements for license renewal.

The process for acquisition of the Angra 3 full scope simulator, which will feature the same digital instrumentation that will be installed in the Plant as well as a separate module that allows simulation of severe accident, was resumed. The international bid process for the supply of the simulator is going on, and soon the contract shall be signed.

Part of the future Angra 3 operators were trained in the Angra 2 simulator, taking advantage of the similarity between the Angra 2 and 3 plants. These operators were licensed for Angra 2 and since then has been acquiring practical control room experience in Angra 2 before going to Angra 3.

A final simulator-training period will be applied when the new Angra 3 simulator is available to allow these operators to familiarize themselves with the Angra 3 computerized control room, which is the most important difference between the two plants. Also, a new group comprising of experienced engineers and experienced field operators is going to be licenced for Angra 3. Their initial training will be done in the Angra 2 simulator, and the last part of their training will be done at the new Angra 3 simulator.

The first group of 14 Angra 3 operators have completed their initial training using the Angra 2 simulator and passed the written, oral and simulator examinations obtaining their licenses for Angra 2.

Simulator training load is at least 60 hours per year for each individual. The composition of control room teams is specified in plant administrative procedures. The minimum control room team comprises a Shift Supervisor (who must hold a current Senior Reactor Operator - SRO license), a Shift Foreman (also a SRO), a Reactor Operator (who must hold a Reactor Operator – RO license) and a Balance of Plant Operator (also a RO). Although not required by CNEN, all Angra 1 Shift Supervisors are graduated engineers with five years of academic education.

The requirements for organization and qualification of the Angra 1 and 2 staff are established in Chapter 13 of the respective FSAR. Implementation and updating of these requirements is subject of CNEN audits of the licensee training and retraining program and examination of new operators to comply with the regulations CNEN-NN-1.01[7] and CNEN-NE-1.06[12].

According to regulation CNEN NN 1.01[7], besides the Control Room shift personnel, the Head of the Operation department must also hold an SRO license. Additionally, Radiation Protection Supervisors must also hold a special license issued by CNEN, according to regulation CNEN-NN-7.01 [13].

Aside from the requirements of the regulations, it has been a permanent policy of the Operation and Production Directorate to occupy important management positions at the plants with licensed or former licensed operators. In particular, the Plant Manager, the Deputy Plant Manager, the head of Operation Department and the heads of Technical Support and Maintenance for both Plants are currently licensed SRO. Furthermore, key engineers belonging to Technical Support and Outage Planning are receiving SRO training and certification with the dual purpose of acquiring a better knowledge of the operation processes and improving of interfaces between these areas and operations.

Specialized training is also provided for personnel belonging to the different plant areas. Maintenance technicians follow qualification and re-qualification programs tailored to their field of activity. Chemistry and radiological protection technicians follow extensive on-the-job training on a yearly basis aimed at a continuous updating of basic concepts learned during their initial technical training. The fire brigade and security personnel are trained according to the requirements established by related CNEN regulations.

Since the last report, a Human Factors Simulator was installed. It comprises a large room with several interconnected equipments, like pumps, valves, piping, a tank, etc., that simulate a system of a real plant. It is possible to simulate actual work done at the plant, like operating a pump, isolating part of the system for maintenance, etc, and thus to verify the use of the human factors tools, like double check, adherence to procedures, etc. Also, it is possible to verify the interaction between personnel belonging to different areas, like Operation, Maintenance and Radiological Protection, since during the simulations each person plays the same role it does during their actual work at the plant. With this simulator, has been possible to identify and to correct some deficiencies in the human factors area, and thus to increase the safety of the plant operation.

Technical visits and reviews of ELETRONUCLEAR training programs and training center by experts from the International Atomic Energy Agency (IAEA), the Institute for Nuclear Power Operation (INPO) and the World Association of Nuclear Operators (WANO) continue to provide valuable contribution to the identification and implementation of good practices of the nuclear industry for enhancing the quality of the training activities.

Regulatory review and control Activities

CNEN monitors the adequacy of the human resources of the licensee through the evaluation of its performance, especially through the analysis of the human factor influence on operational events. The training and retraining program is also evaluated by CNEN within the licensing procedure and through regulatory inspections.

In the specific case of reactor operators, CNEN has established regulations related to their licensing process [7] and their medical qualification [12]. CNEN conducts written and practical examinations for Reactor Operators (OR) and Senior Reactor Operators (SRO) before issuing each individual authorization. It should be mentioned that the licenses of OR and OSR have a validity of two years, after that period the operators should undergo a license renewal process. Similarly, CNEN has a certification process for the qualification of Radiation Protection Supervisors (SPR) by issuing licenses with a validity of five years.

In the period of 2019-2021, CNEN has issued a total of 49 licenses renewals for Angra 1, and 74 licenses renewals for Angra 2.

The standard CNEN-NN-1.01 – Licensing of Nuclear Reactor Operators also establishes and consideres some criteria for inactive or active licences. This licensing process represents a substantial demand on CGRC's manpower, especially when we consider the possibility of increasing the number of operating plants.

Article 12 - HUMAN FACTORS

> *Each Contracting Party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation*

12.1 - Regulatory requirements and organizational issues

The Brazilian nuclear regulation was and is still strongly influenced by the model used in the *United States Nuclear Regulatory Commission*, particularly with regard to stages of the licensing process. One consequence of this influence was the incorporation into PSAR and FSAR of the so called human factors engineering (Chapter 18). The NUREG-0711, Revision 3, Human Factors Engineering Program Review Model, has been adopted as a reference for the safety evaluations, taking into account the technological differences between Westinghouse and Siemens/KWU (AREVA) designs.

According to the chapter 18 (Human Factors Engineering) of NUREG-0800 (Standard Review Plan, Revision 3, December 2016), "The submittal should address all 12 elements described in NUREG-0711, Human Factors Engineering Program Review Model" and "Acceptance criteria for HFE design methodology are provided in NUREG-0711. NUREG-0711 references NUREG-0700, "Human-System Interface Design Review Guidelines," which provides detailed acceptance criteria for HFE design attributes."

Following the Table 1 (Acceptance Criteria Sources) of NUREG-0800 (chapter 18), NUREG-0711 is used in major control room modernization, control room modification and "changes resulting from plant modifications, procedure changes, equipment failures, justifications for continued operations, and identified discrepancies in equipment performance or safety analyses", as well as evaluations of important human actions and workload evaluation. In these last cases, Attachment A and Attachment B of NUREG-0800 (chapter 18) define methodologies that complement NUREG-0711.

The human factors engineering approach to be presented in PSAR and FSAR is composed by the following topics, in accordance with NUREG-0711 (the twelve elements of the HFE program's review model):

1. Human factors engineering program management;
2. Operating experience review;

3. Functional Requirements Analysis and Function Allocations.
4. Task Analysis.
5. Personnel Qualification and Quantification (Staffing and Qualification).
6. Treatment of important Human Actions (Human Reliability Analysis).
7. Human – System Interface Design.
8. Procedures Development.
9. Training Programs Development.
10. Human Factors Verification and Validation.
11. Design Implementation.
12. Human Performance Monitoring.

The Regulatory Framework related to Human Factors is based in the following main documents (among others referenced in the NUREG-0711 that must be used):

1. NUREG-0700, Rev.2, Human-System Interface Design Review Guideline, May 2002, (U.S. Nuclear Regulatory Commission).
2. NUREG-0711, Revision 3, Human Factors Engineering Program Review Model, 2012, (U.S. Nuclear Regulatory Commission).
3. NUREG-0737, Supplement 1, Requirements for Emergency Response Capability, 1989, (U.S. Nuclear Regulatory Commission).
4. NUREG-0800, Standard Review Plan (SRP).
5. NUREG/CR-3331, A Methodology for Allocating Nuclear Power Plant Control Functions to Human and Automated Control, 1983, (U.S. Nuclear Regulatory Commission).
6. NUREG/CR-4227, Human Engineering Guidelines for the Evaluation and Assessment of Video Display Units, 1985.
7. NUREG/CR-5439, Human Factors Issues Associated with Advanced Instrumentation and Controls Technologies in Nuclear Plants, 1990.
8. NUREG/CR-5908, Vol.1, Advanced Human-System Interface Design Review Guideline, (U.S. Nuclear Regulatory Commission), 1994.
9. Regulatory Guide 1.97, Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident, Rev.3, (U.S. Nuclear Regulatory Commission), revision 4, June 2006.

10. NUREG/CR-6751 - The Human Performance Evaluation Process (HPEP): A Resource for Reviewing the Identification and Resolution of Human Performance, (2001).

12.2 - Human factors in the design.

- Angra 1

Concerning the human factors engineering design considered in the Angra 1 Plant, being an early Westinghouse, type PWR, with two-loop, was designed at a time when human factors were not formally and systematically taken as a prime issue in nuclear safety. Following the accident at Three Mile Island, in 1979, and still before beginning of operation, a critical review of the Angra 1 plant design with respect to man-machine interface was undertaken. This resulted in numerous modifications in the control room, including the installation of the Angra 1 Integrated Computer System (SICA), which encompasses a Safety Parameter Display System (SPDS) and a Critical Safety Function (CFS) monitoring program.

The Federal University of Rio de Janeiro in a partnership with the applicant developed the SICA. The hardware and software of this Integrated Computer System is upgraded in 3 to 4 years intervals, for better equipment performance and increase of features, such as number of monitored parameters, frequency of data acquisition, among others.

At the same time, plant emergency operating procedures were greatly improved in their format, which now incorporate double columns, the left one with the expected action and the right one with actions to be taken in case of inadequate response.

A new layout of the control room was implemented considering ergonomic aspect and operational experience.

The Angra 1 Plant has a new simulator recently installed. Since 2015, this simulator has been used for training of the operators to be licensed, as well as the requalification of operators of the plant operation staff. The acceptance of this simulator was submitted to CNEN and all documentation for qualification were based in the standard ANSI/ANS 3.5- Simulators for Operators Training.

- Angra 2

The family of German PWRs, to which Angra 2 belongs, was designed giving great importance to HFE safety and operational aspects. The most important feature is known as the "30 min rule", by which the plant I&C is designed to meet the requirement of automatic accident control for the first 30 minutes, to allow sufficient time to the operators to plan their subsequent manual actions for accident control.

Considerng the operational aspects, repetitive and routine operations have been automated to relieve operators of boring tasks and so reducing the possibility of human errors. The long operational experience of these plants, as well as the first 15 years of operation of Angra-2, confirm the effectiveness of their HFE.

Among the improvements of the man-machine interface that have been introduced relative to the Angra 2 original design, the most important was the addition of a Integrated Computer System (SICA) for extension of the scope of the plant Safety Parameter Display System (SPDS) and for monitoring of the Critical Safety Functions (CSF). This was done subsequently to the plant commissioning.

This system was further improved, with a substantial increase in the number of monitored variables, following the replacement of the Angra 2 plant process computers. This improved version was also installed in the Angra 2 simulator. The acceptance of this simulator was submitted to CNEN and all documentation for qualification were based in the standard ANSI/ANS 3.5- Simulators for Operators Training.

12.3 - Methods and Programmes

The basic requirements concerning human factors and organizational issues important to safety for the Brazilian Plants are established in the different chapters of their Final Safety Analysis Reports (FSAR). Under "Conduct of Operations" and "Administrative Controls" the plants organization structure, qualification and training program requirements for plant personnel, types of procedures required, etc., are established. The consideration of human factors in the design is treated in the FSAR I&C chapter, as for instance, implementation of automation to help and relieve operators from performing repetitive tasks or for allowing adequate time for complex actions as well as the design of the Man-Machine-Interface of the Main Control Room.

For Angra 1 and Angra 2 plant an additional chapter “Human Factor Engineering” was prepared **and incorporated in the FSAR**, which details the several aspects of human factors taken into account in the design of this plant.

These basic requirements contemplate the Brazilian Nuclear Regulations and the regulations of the Country, supplier of the plant, when no specific Brazilian regulation exists. Complementation of these requirements, to take into account newer knowledge or experience, is achieved by internal programs for enhancement of safety culture and human performance, feedback from internal and external operational experience as well as from Regulator requests.

As reported in previous National Reports a safety culture (SC) enhancement program based on an IAEA supported in-house SC self-assessment was developed beginning in 1999-2000 and has become a permanent program at Eletronuclear S.A. Training on SC concepts is provided since then on the New Employee initial training program and refreshed yearly in the in the periodic retraining for plant access. In 2019 Eletronuclear created a procedure to the company´s SC Program encompassing all SC initiatives throughout the company, and initiated a 5 steps SC self-assessment based on IAEA and WANO guidelines.

Since 2007 the Human Performance Program has been improved and can be considered a key role in terms of reinforcement of safety culture in the company. In the beginning the objective was to train every employee in the human performance fundamentals on the use of error prevention tools. After this, the retraining has been developed under the responsibility of the immediate leader. This approach was chosen to allow the involvement in all the levels of the company with the principles of Human Performance. For the new employees and contractors the basic training continues being conducted by the psychological and technical professionals, to provide uniform guidance related to Human Performance. As of 2009, the company's team of psychologists became part of the event's root cause analysis group and intensified its participation in human performance committees. These committees, in turn, were renamed "human performance and safety culture committees" in 2018, with the inclusion of representatives of the safety coordination, belonging to the presidency, on their staff.

In response to a CNEN requirement of establishing a Human Factor Engineering program for Angra 1 following the American licensing guidelines of NUREG-0711, Human Factor Engineering (HFE) Program Review Model, and was incorporated in this program a new FSAR chapter (chapter 18), as established in NUREG-0800 Standard Review Plan. Then, an evaluation of the Angra 1 HFE was developed along 2011 and 2012. The expertise for developing this program has been provided through a Cooperation Protocol between Brazil and the European Commission. This work was completed providing an overall review of the Angra 1 HFE aspects, in particular of the Main Control Room. No major discrepancy was found. Some upgrade recommendations have been issued for displays in the main control room. As required, a FSAR chapter 18 was prepared and has been sent to CNEN.

As already informed in the previous National Report, for Angra 2, CNEN requirements concerning HFE evaluation were basically the same reported above for Angra 1. That is, the preparation of a chapter 18, in accordance to NUREG 0800 following NUREG 0711. Although Angra 2 was designed following basically German standards, it was agreed in the licensing process to adopt the above NUREGs for itemization and format, with the contents and criteria from the actual plant design documentation. The developed chapter 18 was approved with a series of conditions, most of them fulfilled before criticality and some for later compliance.

These last requirements have been incorporated in a HFE verification program using the Angra 2 full scope simulator and analytical evaluations the results, obtained by comparing the required and available times for manual operator action for a set of critical transients/accidents, resulted in no operator overload, indicating the adequacy of the Angra 2 HFE design, including the main control room Man-Machine Interface (MMI).

The above mentioned HFE verification program is not yet concluded, as there are still CNEN open questions concerning the human reliability analysis developed for the Angra 2 level 1+ PSA and operator behavior in case of beyond design events including severe accidents. Work is being done on both fronts; the actions involved however are of long duration, such as developing a Level 2 PSA and the respective human reliability analysis, which were recently concluded.

The main finding in the field of HFE in the recently completed Angra 2 PSR was, as for Angra 1, the lack of a systematic approach for treating these aspects in the plant modifications process.

CGRC audit periodically the following programmes:

- Qualification Program for Engineering and Technical Support Staff;
- Implementation of the Job and Task Analysis Training based on the Systematic Approach to Training (SAT);
- Instructor Qualification and Managers Training Systematization.

In the case of Angra-2, the subjects related to the Cognitive Task Analysis (using the Angra-2 simulator to obtain the time spent to perform operational tasks) and Human Reliability Analysis (HRA) has been analyzed by CNEN, according to the following standards “Time response design criteria for safety-related operator actions”(ANSI/ANS 58.8 – 1994), “Good Practices for Implementing Human Reliability Analysis” (NUREG-1792, USNRC, 2005) and “Evaluation of Human Reliability Analysis Methods Against Good Practices” (NUREG 1842, USNRC, 2006).

The standard CNEN-NN-1.01 – Licensing of Nuclear Reactor Operators[7] requires the qualification of the simulators used in the training of nuclear reactor operators. Such qualification is evaluated by CNEN. Angra 2 has a specific simulator installed in the Training Center near the plant. The training of the Angra 1 operators has been performed at the Almaraz plant simulator (TECNATOM, Spain) that was adapted to this task, until May 2015. Since then, the entire Angra 1 Operator's retraining program has been performed in the new simulator in Mambucaba Training Center.

Severe Accidents Procedures are presupposed in the Standard CNEN-NE-1.26 – Operational Safety in Nuclear Power Plants[9]. This kind of procedure requires firstly an analysis of the design vulnerabilities to the severe accidents to be performed by means of a Probabilistic Safety Assessment (PSA) coupled with a Human Reliability Analysis (HRA). This requires in turn the elaboration of the FSAR chapter 19 - Severe Accidents for Angra 1, 2 and 3, according to the review and acceptance criteria described in the NUREG-0800 (March 2007) and NRC Regulatory Guide 1.200 (March 2009).

Regarding Angra-3, the PSAR chapter 18 was evaluated by CNEN and yielded several findings when compared to the acceptance and review criteria of the NUREG-0711 and German Standards. The use of digital technology implies in several new safety issues compared to the technology utilized in the past. In relation to the computerized control room it is much more integrated with the instrumentation and control systems. This leads to the necessity to investigate carefully the influence of the digital architecture on the staff behavior (human actions) during the operational events occurring in the control room.

The CNEN review activities aim to verify that accepted HFE principles are incorporated during the design process and that the human-system interfaces reflect a state-of-the-art HFE design.

After the requirements in relation to the Chapter 18 of the PSAR, Eletronuclear and FRAMATOME presented to CNEN the implementation process of the Human Factor Program in the Angra-3 design, according to the NUREG-0711, Rev 3.

Taking in to account the HFE program, Angra-3 has Angra-2 as reference plant considering the process systems and Olkiluoto 3 (Finland) considering the Digital I&C and Main Control Room.

The HFE program will be conducted through a Comitte with Eletronuclear and FRAMATOME professionals, during the design phase (Eletronuclear with the expertise in the Operation, Maintenance, Training acquired in the plant of reference Angra 2 and FRAMATOME wit hthe expertise in the HFE in plants with Digital I&C).

The Human Factor Program and all methodologies to each item of NUREG-0711 Rev3 and consequently FSAR Chapter 18 are developed by FRAMATOME, revised by Eletronuclear. The methodologies are implemented by profesionals of FRAMATOME and/or Eletronuclear depending on the activities proposed.

12.4 - Self-assessment of managerial and organizational issues by the operator.

Self-assessments, including organizational aspects, are performed for all main plant areas, on a regular schedule and in preparation for the external reviews, OSART or WANO Peer Review (WPR) every three years, for each plant (see Article 19(7)), where the managerial and organizational aspects at plant management level are also evaluated.

The first WANO Corporate Peer Review was requested by Eletronuclear to evaluate managerial and organizational aspects of the Company as a whole, focusing on the level and adequacy of the alignment between the company headquarters in Rio and the plant specialists at the site, about 200 km away, in Angra dos Reis. This Corporate WPR was performed in July 2007 with a follow up mission in 2009.

As a consequence of the Post Fukushima Action Plan, and following a new schedule established by WANO for this type of Peer Review, a second WANO Corporate Peer Review was held in 2014 with subsequent follow-up mission in 2018. The results showed that there is the need to improve the existing communication within the corporate levels, in order to guarantee a better alignment of targets, and to promote a more efficient resource allocation on programs and projects. It was developed an action plan with many important initiatives and some other actions were taken in order increase the company's horizontal process view.

The final report also showed that senior leaders acknowledged that the monitoring and oversight organisation should use independent nuclear safety assessments more effectively. As a result, an Independent Nuclear Safety Oversight Committee (COSIS) reporting to the Executive Board was created, see Article 10 for more details. A program implemented by the company to enhance management skills was developed and identified as strength.

Other important initiative involving ELETRONUCLEAR was the creation of the Latinamerican Independent Nuclear Oversight project, involving Brazil, Mexico and Argentina, by an independent initiative of their main operator companies. The so-called "Lat-iNOS" project has already performed three independent safety review missions, one in each country, counting on experienced safety revisors, following WANO and IAEA guidelines and an agenda defined by the three countries. This initiative was positively mentioned by the last WANO Corporate Peer

Review Follow-up mission and evolved to a formalization process intended to be forwarded to IAEA this year.

In 2019, motivated by suggestions coming from both internal audits and demands from the Regulator CNEN and international organizations, Eletronuclear began its Safety Culture Self-Assessment, the first one done by company´s own resources since 2002. Although review missions like IAEA OSART and WANO Peer Reviews have already included safety culture assessments in their review scopes, this independent initiative of also aimed to align with the IAEA SRS 83 guide, which had not yet been used by the organization. The safety culture self-assement is currently in its third step of individual interview with of managers and non-managers of the organization, including contractors. The two previous stages, survey and document evaluations, were concluded, and helped the planning of the third and future steps, considering the findings in the area of managers in the field and work environment. Other areas for improvement may still emerge from the processes of interviews, focus groups and field observations still to be carried out this year. In addition, an IAEA Independent Safety Culture Assessment (ISCA) mission is scheduled to take place in October this year and will provide another critical look at Eletronuclear's safety culture, helping the company to promote and continuously improve it within the organization.

12.5 - Feedback of experience in relation to human factors and organizational issues.

The feedback of experience with respect to human factors and organizational items is performed mainly through the evaluation of operational events where there is the presence of human and organizational failures and periodic audits performed in the training and requalification system of licensed and non-licensed personnel.

12.6 - Regulatory review and control activities.

Organizational aspects have been addressed by CNEN using the HPEP method. In the Operational Experience area, CNEN has evaluated operational events to identify programmatic causes to determine whether a deficiency in a program, policy or practices for managing work activities allowed barriers to fail. Angra-1 and Angra-2 operators retraining program, which are approved and audited by CNEN in function of requirement in the standard CNEN-NN-1.01[7], incorporates this operational experience.

For the review of Operational Events involving Human Failures, CNEN has adopted the review process described in the NUREG/CR-6751 - The Human Performance Evaluation Process

(HPEP): A Resource for Reviewing the Identification and Resolution of Human Performance, (2001).

The Regulatory Framework related to nuclear power plants simulators is based in the following requirements included in the Articles 81, 82 and 83 of the Standard CNEN-NN-1.01 (Resolution CNEN/CD No. 170 of April 30, 2014) and ANSI/ANS-3.5-2009, "Nuclear Power Plant Simulators for use in Operator Training and Examination", which is adopted by CNEN to assess compliance with Article 82 of the Standard CNEN-NN-1.01:

> *"The request of the acceptance of a simulator, as mentioned in Article 81 should be made by the operator organization at least six (6) months in advance by means of an application containing the following information:*
>
> *I - statement that the simulator features meet the training plan submitted to CNEN.*
>
> *II - Detailed description of the simulator, specifying, if any, the main differences to the unit for which it will be used, and*
>
> *III - detailed description of the tests and their results that prove the similarity of the simulator to the unit for the utilized scenarios. "*

The ANSI/ANS-3.5-2009 requires performing the following simulator tests associated with their respective requirements and criteria (items 3.4 and 4.4 of the Standard):

1) Verification tests.
2) Validation tests and
3) Performance tests. In addition, the standard requires the physical fidelity tests (3.2.1 and 4.2.1) and capacity test of the simulator instructor station (items 3.3 and 4.3).

Validation tests required by paragraph 4.4.2 of ANSI/ANS-3.5-2009 are performed to compare the results of the simulation models with the installation data. Criteria for meeting the requirements of these tests are described in items of section 4.1 of ANSI/ANS-3.5-2009, in particular the items 4.1.3.1 - Steady State, 4.1.3.2 – Normal Evolutions and 4.1.4 – Malfunctions. The scope of the tests must meet the set of events listed in item 3.1 - Simulator Capabilities, in particular the items 3.1.3.1 - Operation Steady State, 3.1.3.2 - Normal Evolutions and 3.1.4 - Malfunctions. To document the results of these tests the pattern described in Appendix A.4 of ANSI/ANS-3.5-2009 must be followed.

The ANSI / ANS-3.5-2009 defines four types of performance tests in 4.4.3:

1) Operability Test.

2) Simulation test based on specific training scenarios.

3) Reactor Core Performance Test and 4) Post-Event Tests; and

4) Post-Event Tests.

CNEN has carried out periodic audits for the renewal of licenses for Angra 1 and Angra 2 operators, including the use of simulators in the biennial retraining. Particularly, the use of Severe Accident Management Guides (SAMGs) has been verified, which will be used in the Angra 1 and Angra 2 Technical Support Centers, next to the control room.

Angra 1 and Angra 2 operators receive training in these guides, provided in the corresponding module of the Biennial Retraining Program for each plant. Severe accident scenarios are included, where the curves obtained with the calculations of the simulation with severe accident code are used as input data in the guides and evolution of the accident. In the simulator, only the evolution of accidents until the entry conditions in the SAMGs are trained.

ARTICLE 13 - QUALITY ASSURANCE

> *Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation.*

13.1 - *Overview of the Contracting Party's arrangements and regulatory requirements for quality assurance programmes, quality management systems, or management systems of the licence holders*

The requirements for a quality assurance program in any nuclear installation project in Brazil are established in the licensing regulation CNEN-NE-1.04 - Licensing of Nuclear Installations [5]. Specific requirements for the program are established in a specific regulation, Quality Assurance for Safety in Nuclear Power Plants and Other Installations, CNEN-NN-1.16 [14] and with the Standard CNEN-NE-1.26 Operational Safety in Nuclear Power Plants [9].

The Quality Assurance Programmes (QAP) shall cover the activities that influence the quality of items important to safety, developed during the management of different phase in the life cycle of the facility: siting, design, construction, commissioning, operation, life extension and decommissioning.

As mentioned at the beginning of Article 12, the Brazilian nuclear regulation was and is still strongly influenced by the model used in the United States Nuclear Regulatory Commission (USNRC) then the Quality Assurance Program (QAP) was incorporated into the Chapter 17 of PSAR and FSAR. In accordance the set of regulation mentioned Iin the paragraph above the applicant for a Construction License (CL) must describe his Quality Assurance Program (QAP) and QAP of his main contractor for construction in the Preliminary Safety Analysis Report (PSAR) and the applicant for Operanting Autorization (OA) must describe his Quality Assurance Program (QAP) and QAP of his main contractor for Operation.

However, for the initial phase of operation, Authorization for Initial Operation (IOA), the QAP shall be presented as part of the Final Safety Analysis Report (FSAR), and for the phase of permanent operation, Authorization for Permanent Operation (APO) the QAP shall be presented as a single document.

13.2 - Status with regard to the implementation of integrated management systems at nuclear installations

(See Article 10.2)

13.3 - Main elements of a typical quality assurance, quality management or management system programme covering all aspects of safety throughout the lifetime of the nuclear installation, including delivery of safety related work by contractors

The standard CNEN-NN-1.16 [14] consists of four sections, embeds s the 18 BR described in 10 CFR 50 Appendix B. Section 1 presents the objective and scope; section 2 presents some elementary principles and section 3 presents definitions and abbreviatures used in the text. The Section 4 is formed by 13 subsections that embeds the 10 CFR 50 Appendix B and presente the requirements for quality assurance systems and programmes and is divided in:

4.1 - Quality Assurance Systems: Obligations and Responsibilities; Basic Guidelines; Language; Procedures, Instructions and Drawings; Management's Evaluation.

4.2 - Quality Assurance Program.

4.3 - Organization: Responsibilities, Authorities and Communications; Organizational Interfaces; Personnel Selection and Training.

4.4 - Documents Control: Documents Preparation, Review and Approval; Issuance and Distribution of Documents; Control of Changes to Documents.

4.5 - Design Control: General Requirements, Design Interfaces, Design Verification, Design Changes.

4.6 - Procurement control: general requirements, evaluation and selection of suppliers, control of purchased services and items.

4.7 - Control of items: identification and control of items, parts and components; handling, storage and delivery.

4.8 - Process control.

4.9 - Inspection and testing control: inspection programme; testing programme; calibration and control of measuring and test equipments inspection and testing status, and operational status of items.

4.10 - Non-conformance control: general requirements.;

4.11 - Corrective actions.

4.12 - Quality assurance records: preparation of records; receipt, storage and preservation of records.

4.13 - Audits: general requirements, programming.

ELETRONUCLEAR has established its quality assurance program in accordance with the requirements mentioned above. The corresponding procedures have been developed and are in use. The programs provide for the control of activities which influence the quality of items and services important to safety as: design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, commissioning, operation, maintenance, repair and training. The quality assurance programs are described in Chapter 17 of the FSAR of each unit.

The Quality and Environment Superintendency (SQ.T), reports to the Technical Directorate (DT) and is responsible for the establishment and supervision of the ELETRONUCLEAR's Quality Assurance System.

The Quality and Environment Superintendency (SQ.T), is responsible for the coordination and performance of internal and external audits in order to verify compliance with all aspects of the quality assurance program. A comprehensive system of planned and periodic internal and external audits is established and documented. Audits are performed according to written procedures, including checklist as appropriate. In the case of internal audits, people involved with activities being audited have no involvement in the selection of the audit team. Audit reports are distributed to, and formally analyzed by the audited organizations.

The Quality and Environment Superintendent (SQ.T) also takes part of the Nuclear Operations Review Board – NORB (or, in Portuguese, "Comitê de Análise de Segurança – CAON"), which is a collective body under the coordination of the Operation Coordination Superintendency (SC.O) whose purpose is to examine, follow-up and analyse issues concerning Angra 1 and 2 operational safety and to make recommendations for safety improvements. In the same way, the Quality and Environment Superintendency participates in the Plant Operation Reviews Commission (or, in Portuguese, "Comissão de Revisão de Operação da Usina – CROU"), which are collective bodies under each respective unit manager with the responsibility to review and analyze, on a closer basis, questions related to the operation of the units.

The Project Quality Assurance Program for the Complementary Dry Storage Unit (or Independent Spent Fuel Storage Facility) was evaluated by audits and surveys during all phases, including construction, erection, commissioning and operation. Revisions of the Eletronuclear's and main contractor's Quality Assurance Program were performed and submitted to the Brazilian regulator body authority before the activities they referred, as request by applicable Brazilian nuclear license regulation.

13.4 - Audit programmes of the licence holders

The Quality and Environment Superintendency (SQ.T), is responsible for the coordination and performance of internal and external audits in order to verify compliance with all aspects of the quality assurance program. A comprehensive system of planned and periodic internal and external audits is established and documented. Audits are performed according to written procedures, including checklist as appropriate. In the case of internal audits, people involved with activities being audited have no involvement in the selection of the audit team. Audit reports are distributed to, and formally analyzed by the audited organizations.

13.5 - Audits of vendors and suppliers by the licence holders

The Brazilian standard CNEN-NN-1.16 (2000) requires the control of purchased items and services. Item 4.6.2 indicates that the capability of external providers to provide items or services in accordance with procurement documents must be assessed during supplier selection. As appropriate, according to the Brazilian standard CNEN-NN-1.16 (2000) item 4.6.2.2, the use of supporting documents of the current quality of the supplier and source evaluation of the technical capacity and of the supplier Quality Assurance System are acceptable forms of supplier evaluation. During the period of 2019 – 2021 we have performed 872 documental evaluations of suppliers and 27 supplier audits (in 2019: 301 documental evaluations and 14 audits; in 2020: 253 documental evaluations and 06 audits; and in 2021: 318 documental evaluations and 07 audits).

13.6 - Regulatory review and control Activities

13.6.1 – Guidance for Regulatory review

CNEN has a specific standard NN - 1.16 – "Quality Assurance for NPP and other Nuclear Installations which establishes strong requirements for the operator and main contractors. QA Programs are evaluated before starting the main phases of a project (construction, commissioning, operation, decommissioning) and audits are performed along these different phases.

CNEN review the QA Program of ELETRONUCLEAR and main contractors.

13.6.2 – Regulatory Audit of Licensee QAP

Audits and inspections performed by CNEN verify that quality assurance requirements are being implemented and that the quality assurance has been effective as a management tool to ensure safety.

CNEN performs two types of audits: QA System audit and Process Audits. The former is related to QA System its framework, premisses, policies and organization structure. The latter are audits in specific processes like maintenance, surveillance, design modification, radiation protection, and so on.

CNEN audits the QA Systems of ELETRONUCLEAR, the main contractors and in a specific case this audit is extend to other supplier.

CNEN has monitored closely the quality assurance activities of Angra plant, trying to focus more on results than on the formalities. From the beginning of 2000, special audits where carried out where quality aspects were discussed directly with the plant management, rather than with the QA group. These audits have identified some problems related to the lack of a grading system for the findings, both from CNEN inspections and ELETRONUCLEAR internal QA audits, a consequent lack of prioritization of their resolution, and a consequent long time for the closing of minor problems.

Every process audit related to the CNEN annual program take care of QA aspects, including check of the operator internal audits in that process, and their results.

CNEN required ELETRONUCLEAR to establish and implement a system for management of corrective actions as an additional license condition at the time of the renewal of the Authorization for Initial Operation (AOI). This system is already implemented by Eletronuclear, so called Pendencies Management System ("Sistema de Gerenciamento de Pendências – SGP) and can be accessed from the corporate Intranet and is subjected to audit by Quality Assurance. More details of this System are described in Article 10.

ARTICLE 14 – ASSESSMENT AND VERIFICATION OF SAFETY

Each Contracting Party shall take the appropriate steps to ensure that:

i. Comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of operating experience and significant new safety information, and reviewed under the authority of the Regulatory Body;

ii. Verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.

14(1) – Assessment of safety

14(1).1 - Overview of the Contracting Party's arrangements and regulatory requirements to perform comprehensive and systematic safety assessments

A comprehensive safety assessment is a requirement established by the licensing regulation in Brazil according CNEN NE 1.04, CNEN NE 1.26, CNEN NN 9.01 and others complementary standards [ANNEX II.3 – CNEN Regulations]. There are three main steps in the Licensing Process in Brazil: 1) Site Approval, 2) Construction License and 3) Authorization for Operation. However, in practice, this threes steps are divided in several stages, as described in Section 7 (2) (ii) A): 1) Site Approval, 2) Construction License, 3) Authorization for Nuclear Material Utilization, 4) Authorization for Initial Operation, 5) Authorization for Permanent Operation, 6) Ratification of Authorization for Permanent Operation every 10 years, considering the evaluation of the Periodic Safety Review (PSR), 7) Authorization for Extended Operation (AOE) or License Renewal, 8) Authorization for Decommissioning, and 9) Regulatory Control Withdrawal.

The standard CNEN NE 1.04 [5], Licensing of Nuclear Installations, establishes the licensing process for nuclear facilities to be applied to the activities related to location, construction and operating of such facilities. Licensing regulation CNEN NE 1.26, Operational

Safety in Nuclear power Plants [9], requires that a Periodical Safety Review (PSR) be performed for each operating nuclear power plant at 10-year intervals. The licensing regulation CNEN NN 9.01, Decommissioning of Nuclear Power Plants [ANNEX II.3 – CNEN Regulations], Establishes the basic nuclear safety requirements to be met during the planning and implementation of the decommissioning of nuclear power plants, which constitutes a step in the licensing process.

The CNEN NE 1.26 standard, *Operational Safety in Nuclear power Plants* [9], the objective of this Standard is to establish the minimum requirements necessary to ensure that the operation of nuclear power plants is maintained without undue risk to the health and safety of the population as a whole and to the environment. Therefore, this standard establishes requirement for:

- Technical Specifications.
- Plant Commissioning.
- Operating Organization Structure.
- Management and personnel involved in the operation of plant.
- Operating Instructions and procedures.
- Maintenance, Test, exams, essays and periodic inspections.
- Management of the reactor core and handling of fuel elements.
- Design modifications.
- Radiological Protection.
- Effluents and radioactive waste management.
- Emergency preparedness.
- Quality assurance.
- Physical protection of the plant.
- Fire protection,
- Records and reports.
- Risk management, and
- Periodic safety Review.

The CNEN NN-1.16 standard [14], Quality Assurance for Nuclear Power Plants, determines the requirements to be followed in establishing and implementing Quality Assurance Systems for Nuclear Power Plants and also for radioactive facilities as applicable. It determines the way in which the Quality Assurance Program should be prepared and submitted to CNEN. It applies to activities that affect the quality of items important to safety, developed in the management of the undertaking and to each of its various stages: site selection, design, construction, commissioning, operation and decommissioning.

The CNEN NN-1.14 standard [8], Nuclear Power Plants Operating Reports (Resolution CNEN 016/01 – 29.11.2001 issued in Official Gazette D.O.U.: 05.01.2002), establishes the program requirements of significant events notifications and of the nuclear power plant operating reports required by the National Commission of Nuclear Energy (CNEN):

- Routine Reports:
  - Initial Operations Report.
  - Nuclear and Thermohydraulic Project Report.
  - Monthly Operation Report.
  - Annual Operation Report.
  - Semi-Annual Report on Tailings and Effluent Release.
  - Operational Radiological Environmental Monitoring Program Report; and
  - Outage Report.
- Event Notification; and
- Event Reports.

The CNEN NN-1.17 standard [ANNEX II.3 – CNEN Regulations], Personnel Qualification and Certification for Non- Destructive Testing of items in Nuclear Facilities (Resolution CNEN 02/96 issued in Official Gazette D.O.U.: 19.04.1996, first edition and Resolution CNEN 15/99 issued in Official Gazette D.O.U.: 21.09.1999, Rev.1), establishes the requirements for personnel qualification as well as the process for certification of qualification regarding activities of Non-Destructive Testing (NDT) of items important to safety of nuclear facilities. Applies to personnel intended to perform activities of NDT of items important to safety. It specifies the level of qualification, education, training, and experience required, as well as physical ability of the candidate determined by the Employer Organization. It specifies the authority responsible for issuing the certificates, its validity and revalidation as well as individual records that should be maintained. Presents the requirements that individuals must meet to be submitted for qualification and certification for NDT activities by the method of helium leak.

The CNEN NE-1.18 standard [ANNEX II.3 – CNEN Regulations], Preventive Conservation in Nuclear Power Plants (Resolution CNEN 09/85 issued in Official Gazette D.O.U.: 04.09.1985), establishes the requirements for preventive conservation during construction and operation of nuclear power plants. It determines its applicability to the work of any individual or organization who participates in activities related to items important to safety, during construction and operation of NPPs. It presents not only the general requirements for preventive conservation, but also specifies the responsibility, planning, procedures and instructions as well as establishes specific requirements applicable to the control of the facilities, materials and equipment that are considered important to safety and to the inspections that should be performed.

The CNEN NE-1.21 standard [ANNEX II.3 – CNEN Regulations], Maintenance of Nuclear Power Plants (Resolution CNEN 03/91 issued in Official Gazette D.O.U.: 28.08.1991), Determines the organizational and administrative requirements applicable to the set up and implementation of a maintenance program for nuclear power plants, without specifying the technical details of such maintenance. It specifies the Operator responsibility for the establishment and implementation of the plant preventive or corrective maintenance program in order to preserve its performance during its lifetime, as foreseen in the project, as well as a program for the organization, purchasing, receiving and storage of materials, items and spare parts. It establishes controls of the organizational structure and the responsibilities, the criteria for selection and training of maintenance personnel and administrative controls providing a scope of administrative and technical procedures of such maintenance. It specifies the maintenance workshops and the procedures to be performed for replacements and repairs of defective items.

The CNEN NE-1.22 [ANNEX II.3 – CNEN Regulations], Meteorological Programs in Support of Nuclear Power Plants (Resolution P.DExl-04/89 issued in Official Gazette D.O.U.: 08.08.1989), establishes the minimum requirements for meteorological programs in support of nuclear power plants, suitable for obtaining and applying information and reliable data for: acceptable evaluation of radiological and environmental consequences for both operational conditions and accident situations; planning and implementation of protective measures for workers, general public and the environment, in emergency situations. It applies to activities concerning the determination of atmospheric parameters such as basic meteorological information and classification of atmospheric stability for the site, construction and operation phases of nuclear power plants. Specifies the general provision and installation of meteorological instruments for measurements of meteorological parameters and determines the accuracy and maintenance of instrumentation systems as well as the protection, restoration, monitoring, reduction, storage and period of data recording.

The CNEN NE-1.28 standard [ANNEX II.3 – CNEN Regulations], Qualification and Performance of Independent Technical Supervision Bodies in NPPs and other facilities (Resolution CNEN 15/99 issued in Official Gazette D.O.U.: 21.09.1999 and Ratified in Official Gazette D.O.U.: 11.10.1999), Establishes the requirements demanded by the National Commission for Nuclear Energy - CNEN - to qualify an entity as Independent Technical Supervision Body (ITSB), for a specific area of activity in NPPs as well as in other nuclear and radioactive facilities as appropriate. It regulates the independent technical supervision when specified by the designer or the system responsible person. It applies to the qualification of an ITSB in activities that influence the quality in the construction, metal-mechanics, electrical, electronics, instrumentation & control, operation and maintenance areas as well as to the acting of the Independent Technical Supervision Body.

The CNEN RES-09/69 standard [6], Standards for the selection of sites for NPPs construction (Resolution CNEN 09/69 issued in Official Gazette D.O.U.: 31.07.1969), these standards apply to requests for CNEN approval of sites where nuclear power reactors are intended to be constructed.

14(1).2 - Safety assessments within the licensing process and safety analysis reports for different stages in the lifetime of nuclear installations (e.g. siting, design, construction, operation).

An overview of Safety assessments within the licensing process and safety analysis reports for different stages in the lifetime of nuclear installations in Brazil is discussed in the Articles 7 (2) (ii) System of licensing and 7 (2) (iii) System of regulatory inspection and assessment.

As required, a Preliminary Safety Analysis Report (PSAR) and a Final Safety Analysis Report (FSAR) were prepared for the Angra 1 and Angra 2 NPPs. The FSARs followed the US NRC Regulatory Guide 1.70 - Standard Format and Contents for Safety Analysis Report of LWRs. These reports were reviewed and assessed by CNEN, and extensive use was made of the US NRC - Standard Review Plan (NUREG - 0800).

For the Angra-2 plant, the licensing process was started in accordance to the German licensing procedure. Such process foresaw a series of partial approvals. For each step, a large amount of the actual design and licensing data has been supplied, for analysis, to the Brazilian licensing authorities. No comprehensive licensing document such as a PSAR was adopted in this procedure. This approach turned out not to be practical. At that time CNEN had already licensed Angra-1, along the line of US NRC procedures. It judged that to use two different approaches for licensing would be too time and resources consuming. Accordingly, it requested to have a FSAR following USNRC Regulatory Guide 1.70, to be able to use the Standard Review Plan methodology as done for the first plant. Preparation of an FSAR for Angra-2 was a major task, which involved extensive adaptation and revision work internally and extensive exchange of information with CNEN. Along the licensing period, CNEN has submitted approximately 800 requests for information, which were answered by ELETRONUCLEAR. Through such a review, optimization of safety calculations, clarification of limit conditions of operation, and other relevant matters have been addressed. As far as applicable, the FSAR has been revised to incorporate the modifications derived from these improvements. On the basis of this revision ELETRONUCLEAR was granted the Authorization for Initial Operation (AOI).

During the period covered by this report, January of 2019 to December of 2021, a Construction License was issued for the Spent Fuel Complementary Dry Storage Unit of CNAAA – UAS, in 2019, an Authorization for Initial Operation for the same facility was issued in 2020 and a Ratification of Authorization for Permanent Operation was issued for Angra 1 Unit, in December 2019. The ELETRONUCLEAR submitted to CNEN, in 2019, the documentation associated with long-term operation of Unit of Angra 1, as part of the process of Authorization for Extended Operation (AOE). The ELETRONUCLEAR submitted to CNEN, in 2021, to comply with requirements in paragraph 21 of CNEN standard CNEN-NE-1.26 [9] and IAEA SSG-25, the documentation related the Preparation for 2nd PSR project of Angra 2 and 3rd PSR project of Angra 1.

In relation to Research and Development Reactors, a Ratification of Authorization for Permanent Operation was issued for the Research Reactor IPEN/MB-01, in November 2019 and a Partial Construction License was issued for The Nuclear-Electric Generation Laboratory (LABGENE), a land-based prototype reactor, designed by Brazilian Navy. The Directorate of Research and Development of CNEN submitted, in December 2018, the Preliminary Safety Analysis Report of Multipurpose Reactor (RMB), as part of the of The Construction License process and this document is under regulatory evaluation to enable the issuance of the Construction License.

Each Plant Modifications has to be assessed to verify the maintenance of the Design Basis and Quality Requirements.

14(1).3 - Re-evaluations of hazard assumptions (e.g. according to international best practice, using deterministic and probabilistic methods of analysis).

14(1).3.1 - Fukushima "Stress-Test"

As soon as the magnitude of the accident occurred in March was identified, in 11th 2011 at the Fukushima Daiichi Nuclear Power Station in Japan, the Board of Directors of Eletronuclear decided in March 16th 2011 to constitute a technical committee, coordinated by the Presidency, counting on senior staff members of all company's Directorates, with the responsibility of following the accident evolution and measures taken to control it, to follow the recommendations from international organisms related to nuclear, environmental, industrial, and radiological safety, as a consequence of the accident and also to help the Executive Board on nuclear safety related matters, resulting from the event.

On April 19th 2011, Eletronuclear contributed to the World Association of Nuclear Operators Significant Operating Experience Report (WANO SOER 2011-2) issued in March 2011, including the results of the recommended verifications regarding Angra 1 and Angra 2 NPPs capability, to face beyond design basis accidents, with emphasis on station black out, flooding and fire hazards.

CNEN evaluated the preliminary information about the accident occurred at the Fukushima Daiichi Nuclear Power Station in Japan and on May 13th 2011, the Commission issued a document Nr. 082/11-CGRC/CNEN formally requiring Eletronuclear to develop a preliminary safety assessment report, including a specific set of technical aspects, taking in to consideraton the Fukushima accident. These included:

1. Identify the major design differences between Fukushima and Angra Units;
2. Identify possible external initiating events (extreme) and the internal potential cause a common mode failure;
3. Control of concentrations of hydrogen in the containment;
4. Ensuring electricity supply emergency power;
5. Fulfillment of the requirements of station blackout;
6. Service water system, cooling chain;
7. Procedures for severe accidents;
8. Access to buildings and controlled area of the reactor after an severe accident
9. Development of Probabilistic Safety Analysis Level 1, 1 and 2;
10. Performance of "stress tests"
11. Emergency planning

Eletronuclear provided to CNEN a technical report, in July 2011, with a preliminary evaluation of the above listed topics.

Along the second half of 2011 ELETRONUCLEAR's technical committee, referred above, developed an Action Plan with describing initiatives to be developed in relation to the site and NPP's to respond to the Fukushima event. This plan, named Response Plan to Fukushima, was approved by the Executive Board of the company in November 2011 and shortly, thereafter, submitted to CNEN and revised in January 2013, in the light of new obtained information.

It had 56 initiatives, comprising studies and projects, divided into three main areas of evaluation: protection against risk events, cooling capacity, and limitation of radiological consequences. Some of these actions were already in progress, as part of Eletronuclear's continuous safety improvement programs.

The action plan included studies and projects to be accomplished mostly by 2016, with an estimated investment of about US$ 150 million. ELETRONUCLEAR has invested R$ 65 million by the end of 2018. However, there will be a delay in the finalization of some of the initiatives, ending in 2022, due to restrictions in the multiyear budget of investments for Angra 1, Angra 2 and Central Infrastructure, considering the Company's current situation.

On September 2011, in Madrid, Spain, the Foro-Iberoamerican (FORO), an Association of Iberoamerican Radiological & Nuclear Regulatory Authorities created in 1997 on the initiative of its member states, owners of NPPs, decided to conduct a re-evaluation of their NPPs in response to the Fukushima Daiichi accident, equivalent to the Stress Tests (STs) Assessments (EU stress test), carried out under the leadership of ENSREG. In this first technical meeting, CNEN together with CSN (Spain), ARN (Argentine) and CNSNS (Mexico) have defined the scope and methodology to be applied in the “FORO - Stress Test” (In Spanish).

On January 2012, CNEN, issued a letter Nr. 012/12-CGRC/CNEN requiring formally to Eletronuclear to develop a complementary assement in according to “FORO - Stress Test” specification.

The performance of the Stress Tests for Angra 1 and Angra 2 was completed in March 31st, 2012. Based on the results mobile equipment to provide additional means to withstand a prolonged Blackout, comprising diesel generators, diesel driven pumps, compressors and associated connection fixtures, were specified and purchased. This equipment is presently stored close to the Plants.

The “REPORT ON THE STRESS TEST ASSESSMENT OF THE UNITS OF THE ALMIRANTE ALVARO ALBERTO NUCLEAR POWER STATION FOR THE CONDITIONS OF THE FUKUSHIMA ACCIDENT” - DT-006/12, issued on March 29th 2012, encompasses the two units in operation at Angra site. The evaluations have been performed engaging specialists with deep knowledge of the site characteristics and specialists in the design and dynamical behavior of each plant.

According to procedure adopted by FORO, Brazil, Argentine, Spain and Mexico carried out a Cross-Peer-Review on the produced National Reports (Action Plan). On June 2012, in Buenos Aires, Argentina, those countries (Argentina, Brazil, Mexico and Spain) held a technical meeting dedicated to discuss the results of the Cross-Peer-Review and submit the results to the scrutiny of other FORO Member Countries without nuclear power plants (Chile, Uruguay, Peru and Cuba). Finally, the joint review conducted by experts appointed by the member countries resulted in a final report (in Spanish). This report is composed of the assessment carried out in each nuclear power plant and the regulatory position regarding these assessments, as well as the implementation schedule of the improvements arising as a result of the Licensee’s evaluation made by or at the request of regulatory body.

The Final Report was approved by the FORO Plenary and presented at the Second Extraordinary Meeting of the Nuclear Safety Convention dedicated to the lessons learned from Fukushima.

On June 2014, in Mexico City, Mexico, experts appointed by the member countries of the FORO (Argentine, Brazil, Mexico, Spain, Uruguay, Chile, Peru and Cuba) held the Third Technical Meeting dedicated to follow-up and verify the status of implementation of improvements included in the National Reports (Actions Plan).

The ELETRONUCLEAR Fukushima Action Plan Structure, focused on three main Areas of Evaluation: Protection against Risk Events, Reactor and Fuel Pool Cooling Capacity, and Mitigation of Radiological Consequences, as shown in Figure 18.

Eletronuclear has also carried out a strong exchange of technical information participating and/or collaborating with many different Brazilian organizations (government, regulator, technical support organizations, vendors, service providers and other stakeholders) involved in maintaining and enhancing nuclear safety, and efforts made to achieve and maintain or strengthen a high level of nuclear safety in these organizations.

In addition Eletronuclear participated and in certain instances led discussions through the media and directly with the several organizations, including governmental and public in general through seminars and open meetings. Besides, international organizations, such as GDFSuez, FRAMATOME, Westinghouse, Rosatom and others were invited to discuss with Eletronuclear professionals aspects related to the Fukushima event and improvements needed.

Monitoring of ongoing initiatives in other nuclear power plants, together with other international organizations, indicates the adequate alignment of actions undertaken by Eletronuclear in response to the accident at Fukushima Daiichi NPP's to what has been practiced by the nuclear industry worldwide.

An Extraordinary National Report of Brazil, following the Guidance for National Reports specially issued by the officers of the Convention on Nuclear Safety was prepared and presented to the Extraordinary Meeting in Vienna in August 2012. More details about actions immediately taken by both CNEN and Eletronuclear due to the event can be found there.

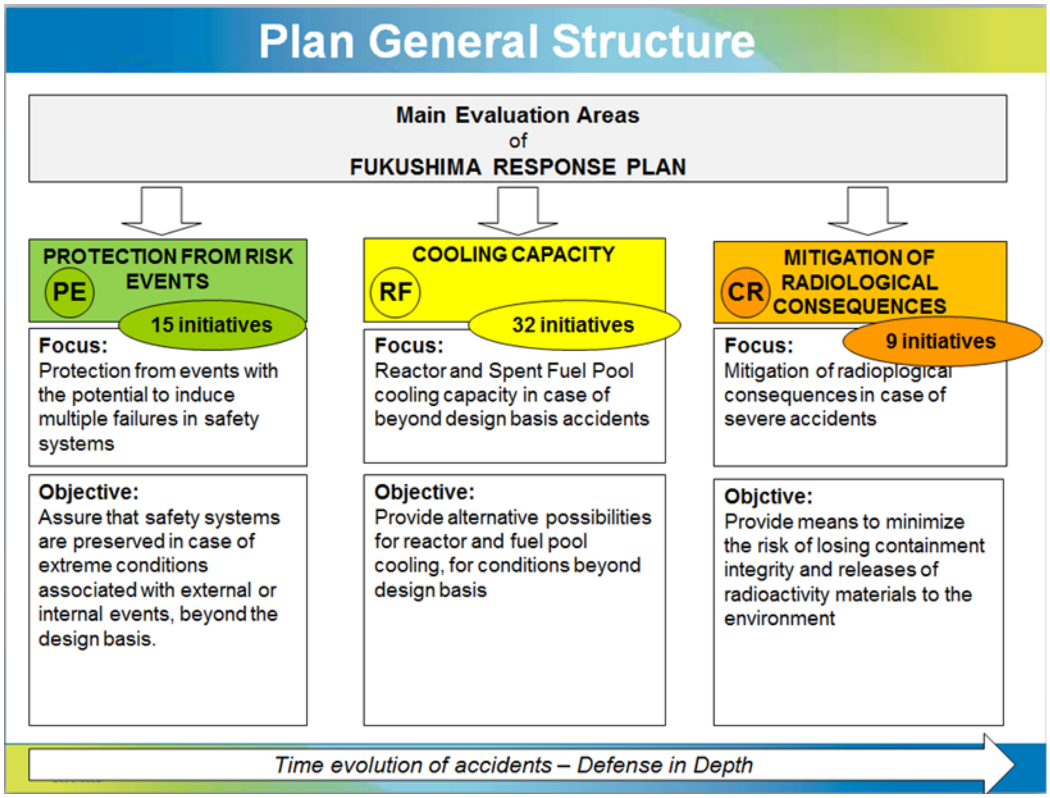

Figure 18 – ELETRONUCLEAR Fukushima Action Plan Structure

The item B.2.4 and ANNEX V show the status of completation of Fukushima Response Plan util December 2021.

14(1).3.2 – Vienna Declaration

14(1).3.2.1 - New nuclear power plants are to be designed, sited, and constructed, consistent with the objective of preventing accidents in the commissioning and operation and, should an accident occur, mitigating possible releases of radionuclides causing long-term off site contamination and avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions.

The principles regarding the design and construction of nuclear power plants in Brazil are embedded in ARTICLE 7, paragraph 1, item III of The Law no 6.189, December 1974, that modifies LAW 4.118 of Aug 21, 1962 and Law 5.740 of Dec 1 , 1971, which create respectively, National Nuclear Energy Commission (CNEN) and others Companies, and stipulates that the Construction Permit and authorization to operate nuclear facilities shall be conditioned among other things to adaptation to new conditions tha are indispensable to the safety of the installations and to the prevention of risk of accident risk arising from its operation.

Based on this requirement, the new plants to be implemented in Brazil will be designed, located, built and operated in accordance with updated international standards.

Although new plants are not scheduled, these concepts are being incorporated into the draft standard for Severe Accidente Management Program (SAMP) being developed by CNEN, as a part of the EC Project, with the support of STUK (Finland), GRS (German) and CNS (Spain), and it incorporates new concepts like Design Extension Condition and distinguishes between new design and operating plants. For future plants, the project shall include in their design basis the condition of accidents leading to core melt. Their systems and procedures must be capable to keep core cooling, to maintain the integrity of the containment and to minimize the release of fission products into the environment while keeping stable the long term plant conditions.

14(1).3.2.2.- Comprehensive and systematic safety assessments are to be carried out periodically and regularly for existing installations throughout their lifetime in order to identify safety improvements that are oriented to meet the above objective. Reasonably practicable or achievable safety improvements are to be implemented in a timely manner.

DRS/CNEN carries out a set of activities in its regulatory control process as described in Articles 7 and 14 in order to obtain reasonable warranty that the design basis or licensing basis are adequate to promote the plant safety and protection of the public and environment. To accomplish with this objective CNEN relies in the systematic review provided by RPS and, regular peer reviews from IAEA and WANO are also part of the operator strategy. Through the RPS, the operational experience, improvements and updates implemented in norms and standards used in licensing are evaluated to identify possible gaps and necessary improvements in safety aspects of NPPs.

14(1).3.2.3.- National requirements and regulations for addressing this objective throughout the lifetime of nuclear power plants are to take into account the relevant IAEA Safety Standards and, as appropriate, other good practices as identified inter alia in the Review Meetings of the CNS.

The standard CNEN-NE-1.04 - Licensing of Nuclear Installations [5] requires in the item 6.5 Technical Standards and Codes that: 6.5.1 Items must be designed, manufactured, assembled, built, tested, and inspected according to standards compatible with the technical importance of the safety function to be performed. 6.5.2 In applying the requirements of section 6.5.1, Brazilian updated codes and standards should be adopted. In the absence of appropriate Brazilian standards, Codes, Guides and Recommendations of the IAEA should be used preferably, and in their absence, international standards or standards of technically developed countries, provided that such standards and regulations are accepted by CNEN.

In addition, IAEA safety documents and international standards / rules, as USNRC rules, are used as the basis of the development of national standards.

For exemple, in the development process of the new draft standard for SAMP, mentioned above, was used the following documents: **Safety of Nuclear Power Plants: Design,** *IAEA* Safety Standards Series No. NS-R-1 and its successor SSR–2/1, **Design of Reactor Containment Systems for Nuclear Power Plants,** *IAEA* Safety Standards Series No. NS-G-1.10; **Radiation Protection Aspects of Design for Nuclear Power Plants Safety Guide,** *IAEA* Safety Standards Series No. NS-G-1.13, 2005; **Deterministic Safety Analysis for Nuclear Power Plants Specific Safety Guide,** *IAEA* Safety Standards Series No. SSG-2, 2010; **Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants Specific Safety Guide,** *IAEA* Safety Standards Series No. SSG-4, 2010; **Safety of Nuclear Power Plants: Operation, IAEA Safety Standards Series No. NS-R-2; Severe Accident Management Programmes for Nuclear Power Plants Safety Guide,** *IAEA* Safety Standards Series No. NS-G-2.15, 2009; **Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants,** *Safety Standards Series No. NS-G-2.2,* 2000; **Recruitment, Qualification and Training of Personnel for Nuclear Power Plants,** *Safety Standards Series* No. NS-G-2.8, 2002 and **WENRA harmonization Issue: Emergency Operating Procedures and Severe Accident Management Guidelines,** 2005

14(1).4 - Overview of periodic safety assessments of nuclear installations during operation, including references to appropriate standards and practices and illustrations on how new evidence is taken into account (e.g. in the light of operating experience, and of other significant new safety information).

The Periodical Safety review (PSR), as informed above, is required by the paragraph 21 of CNEN standard CNEN-NE-1.26 - Operational Safety in Nuclear power Plants [9]. CNEN consider that the 14 Safety Factors stablished in the Specific Safety Guide SSG-25 – Periodic Safety Review for Nuclear Power Plants, are sufficient to cover all safety aspects of the Plant.

The Table 4 in the Article 7 show the correlation between Safety Areas of item 21 of CNEN Standard CNEN-NE-1.26 and Safety Factor of IAEA SSG-25.

14(1).4.1 - Overview of periodic safety assessments of Angra 1.

The first Brazilian Periodical Safety Review (PSR) was performed for Angra-1 in the 2004-2005 period, following the requirements of CNEN Standard NE 1.26 and the guidelines of the IAEA Safety Guide NS-G-2.10. Good practices and opportunities for improvement have been identified, for which action plans have been developed and executed.

The second Brazilian PSR was performed for Angra 1 in 2014 based on CNEN Standard CNEN-NE-1.26 – Safety Operation in Nuclear Power Plants and the guidelines of the IAEA Safety Guide SSG-25 - Periodic Safety Review for Nuclear Power Plants, issued in March 2013.

The evaluation, covering the period from January 1st 2004 to December 31st 2013 was held between July 2013 and July 2014 by a multidisciplinary team of Eletronuclear and Tecnatom, company hired for this purpose. Six (06) evaluation areas have been established for 14 Safety Factors (FS). In order to evaluate these FS assessments generated 33 evaluation reports.

It is noteworthy that the evaluations, studies and implementation made after Fukushima event were widely considered along the holding of the second RPS Angra 1.

These six main areas encompass all items of IAEA Safety Guide SSG-25 and the items of the standard CNEN - NE 1.26 [9], that are: plant design; systems, components and structures condition; equipment qualification; ageing; safety analyses (deterministic and probabilistic); risk analysis (hazards); plant performance; operational experience (national and international); organization and administration; human factors; procedures; emergency preparedness; and radiological impact in the environment.

Good practices, deficiencies and opportunities for improvement have been identified, for which action plans have been developed.

The main deficiencies identified were related to documentation updating, full completion of the Environmental Qualification program, completion of the planned PSA scope, timing for conclusion of the evaluations of the Operational Experience Program and lack of a process for immobilization of contaminated lube oil, none of them of high safety significance.

The main conclusion of the PSR were, that in these 10 years, the Angra-1 plant continued to operate within an acceptable safety level, fulfilling the standards and keeping current important functions for operational safety, meeting the operating conditions to complete their lifetime. For all the scope evaluated, no deficiencies that could hinder the continued safe operation of the plant were identified.

This year (2022), Angra 1 will start the third PSR wich will cover the period from January 1st 2014 to December 31st 2023. For this PSR it was developed and submited to CNEN the basis document based on INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Standards Series No. SSG-25 – Periodic Safety Review for Nuclear Power Plants, IAEA, Vienna (2013), INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Standards Series No. SSG-48 – Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants, IAEA, Viena (2018).

14(1).4.2 - Overview of periodic safety assessments of Angra 2.

As reported in previous National reports, because of problems independent of plant performance involving the Public Ministry, the Angra-2 Plant had been operating with an Authorization for Initial Operation (AOI), renewed yearly. In June of 2011, after approximately 10 years of operation, Angra-2 an Permanent Authorization for Operation (AOP) was issued. One of the requirements conditionings of this License, is the reinforcement the application of the standard CNEN-NE-1.26 [9], was the performance of the first Angra-2 PSR. The final Angra-2 PSR report, including the plant global safety assessment, was delivered to the Regulator on end of November of 2012, covering the 2001 - 2010 review period, however, the evaluations, studies and implementation made after the Fukushima event were widely considered.

The assessments were performed by a multidisciplinary company team from design and support engineering, safety analysis, operations, maintenance, radiation protection and quality assurance, led by a Board appointed committee. About 10 man/years were necessary to complete this work. Having available the experience acquired with the performance of the Angra-1 PSR, being Angra-2 a fairly new plant with a modern documentation system and having available the plant design knowledge (ELETRONUCLEAR was considered the plant architect engineer), led to a substantially lower effort than the required for the first Angra-1 PSR, which was a turnkey plant delivered in the early eighties.

The detailing of the work followed the guidelines of the IAEA guide NS-G-2.10. A check was done against the draft of the new revision of this Guide, DS 426, later issued as Safety Guide SSG-25.

The 13 Safety Factors (SF) of the NS-G-2.10 guide have been assessed, as for the Angra 1 PSR, plus an additional one, Severe Accident Management, included as a consequence of the lessons learned from the Fukushima accident. This work resulted in 33 individual assessment reports and one final PSR report containing the summary of the assessments and the Plant global evaluation.

Strengths and weaknesses of each SF have been identified. The weaknesses have been subdivided in Deficiencies and Improvement Opportunities. The Deficiencies have been classified from 1 to 5 in accordance to their decreasing importance to safety. The impact to safety of each individual Deficiency as well as of the whole set of Deficiencies on the operation of the plant over the elapsed assessment period as well as for the subsequent operation of the plant have been evaluated.

No class 1 deficiencies, those classified as with high safety importance, have been identified. The final conclusion of the first Angra-2 PSR was that the plant operated safely along its first 10 operation years and that no relevant safety problem was identified that could impact the subsequent operation of this plant.

Action plans have been developed and submitted to CNEN for elimination of the 14 deficiencies identified, which were basically: lack of procedure (checking of fire penetrations) or poor compliance with some existing safety related documentation procedures, need to encompass the several ageing management activities in a systematic ageing management program in accordance to the latest IAEA guidelines, development of immobilization processes for contaminated lubricating oil and residual mud from systems clean up and long permanence time of quality assurance corrective action requests.

The PSR for Angra-2 was evaluated by CNEN and some requests were issued. The main conclusions were related to the preparation of an Integrated Ageing Management Program, update the Severe Accident Guides considering specific data from Angra-2 Probabilistic Safety Assessment, Reestructure the FSAR's Chapter 18 in accordance with updated version of NUREG 0711 and NUREG 0800.

In 2021, Angra 2 started the second PSR which will cover the period from January 1st, 2011, to December 31st 2021. For this PSR it was developed and submitted to CNEN the basis document based on INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Standards Series No. SSG-25 – Periodic Safety Review for Nuclear Power Plants, IAEA, Vienna (2013).

14(1).5 - Overview of safety assessments performed and the main results of those assessments for existing nuclear installations including the summary of significant results for individual nuclear installations and not only according to their type and generation.

14(1).5.1 - Angra 1.

14(1).5.1.1 - Overview of Deterministic Safety Analysis of Angra 1.

In the eighth report review period an extensive scope of new deterministic safety assessments have been performed for the Angra 1 NPP, for the licensing of the Steam Generator replacement project. The whole Safety Analysis chapter of the Angra 1 FSAR, covering the plant transients and accidents, was revised. A new LB-LOCA analysis was performed, consisting in the development of a realistic evaluation model for the LB-LOCA, using the Westinghouse methodology that encompasses the WCOBRA/TRAC code with the ASTRUM methodology for uncertainty calculation. It was included in the FSAR the evaluations of Modes 3, 4 and 5 for Uncontrolled Boron Dilution and a new section related to Anticipated Transient Without Scram (ATWS).

ELETRONUCLEAR has also submitted to CNEN approval the documentation relative to the use of a new fuel design (Westinghouse 16x16 Next Generation Fuel – 16NGF, jointly development by Westinghouse, Korea Nuclear Fuel-KNFC and Indústrias Nucleares do Brasil) and a power uprate of 6.3%. All this major design changes required additional safety analyses. The evaluation process carried out by CNEN was finalized in 2009. The first reload (one third of the core) of this new fuel was done in the 2014 refueling outage.

In the current review period (2019 – 2021) a contract was signed between ELETRONUCLEAR and WESTINGHOUSE to reevaluate or reanalyze the entire Chapter 15 of the Angra 1 FSAR and also include a new accident as requested by NUREG 0800 (Feedline Break – FLB). These evaluations or reanalyzes are part of the Long-Term Operation program (LTO). This analysis will incorporate:

- 18 Month Fuel Cycles
- MRP-227 (Materials Reliability Program for Pressurized Water Reactor Internals Inspection and Evaluation Guidelines)
- Thermal Conductivity Degradation (TCD)
- Upflow Conversion to avoid Baffle Jetting
- Optimized Zirlo cladding

New methodologies will be incorporated for the LOCA and Rod Ejection accidents. For LOCA the new Full Spectrum LOCA methodology (FSLOCA) will be used and for Rod Ejection the new 3D Rod Ejection methodology will be used to address U.S. Nuclear Regulatory Commission (NRC) regulatory guidance provided in Regulatory Guide (RG) 1.236.

14(1).5.1.2 - Overview of Probabilistic Safety Analysis (PSA) of Angra 1.

Although a full Probabilistic Safety Assessment (PSA) was not a formal licensing requirement at the beginning of the licensing of Angra 1, a preliminary level 1 study was performed in 1983/85 for Angra 1 using generic plant data. This study indicated a strong contribution of the reliability of the Emergency Diesel-Generator system to the total risk, which supported the decision to install two additional Diesel-Generator sets at Angra 1. Additionally, the surveillance interval of seven check valves of the High-Pressure Safety Injection (HPSI) system was reduced, to increase system reliability, and therefore reduce this system contribution to the total risk.

On January 31, 1992, CNEN issued the Regulatory Guide for the elaboration and use of an Angra-I Probabilistic Safety Assessment (PSA). This Regulatory Guide as part of the licensing requirements included in the terms of the Authorization for Permanent Operation (APO) of Angra 1 ussued in 1994.

A new study was concluded in 1998 (Rev. 0) and revised in 2000 (Rev. 1), consisting of a detailed Level 1 PSA, for the Angra-1 plant, in accordance with the methodology described in NUREG/CR-2300, “PRA Procedures Guide”. This study has been evaluated by CNEN, with the assistance of IPEN specialists, and several new requirements were sent to ELETRONUCLEAR in the period 2003-2009.

This PSA, for Angra-1, has suffered several partial and full revisions, being presently in its revision 5, issued in December 2020, with the purpose of periodic update of data, incorporation of relevant plant changes, as well as to fulfill CNEN requirements. The periodic update contemplates new plant data and changes in the plant hardware and procedures, such as modifications associated with the steam generators replacement, as well as advances in modeling, as for example the incorporation of a state of the art model for analysis of the behavior of the pump seals in case of total loss of cooling, new modeling of ECCS valves and main control room cooling, and a reevaluation of the PSA human reliability analysis using state of the art EPRI HRA Calculator. It can be stated that several important findings, leading to upgrading of plant hardware and operational procedures, arose from this second PSA study.

The implementation of hardware and/or procedural measures, originated from the results of the Angra 1 Level 1 PSA study, led to a considerable reduction of the calculated Angra 1 Core Damage Frequency (CDF), down to the range of low 10-5 per reactor.year.

The major routine application for this PSA is Configuration Risk Management (CRM), which consists of the identification of the allowable plant configurations for on-line maintenance planning, based on evaluation of the risk rate and the weekly cumulative risk resulting from the different plant configurations associated with the maintenance program.

Another routine application is the screening and, when relevant, the evaluation of the impact on the overall plant risk, of all proposed plant modifications.

As a further application, the Angra-1 Level 1 PSA has been used to support the development of the Maintenance Rule (MR), which consists in orienting the maintenance program to emphasize maintenance of the components that have more influence on the plant risk, in accordance with the NUMARC 93-01 Revision 2.

In early 2006, a reprogramming of the planned PSA studies for both plants, based on CNEN requirements and recommendations of the Angra-1 PSR, was performed, based on more realistic evaluation of the timing and available resources. The scope, for both plants, included PSA Level 1+, including fire and internal flooding at power, shutdown and low power states, as well as a Level 2 PSA, involving development of eight major studies. This scope was later extended to include an External Events PSA.

The main PSA development activities for the Angra 1 plant performed to date within this program were:

- Extension of the existing level 1 study to level 1+; completed in December of 2006;
- Model improvements for the above PSA study, including pump seal LOCA, review of reliability of high pressure safety injection valves, evaluation of reliability of the control room air conditioning; completed in 2008;
- Preparation of the revision 0 of the Angra 1 Fire PSA, performed jointly with EPRI, using the state-of-the-art methodology of EPRI TR-1011989 (NUREG/CR-6850), EPRI/NRC-RES "Fire PRA Methodology for Nuclear Power Facilities"; started in February 2007 and completed in August 2010.
- Issuing of the Angra 1 level 1+, internal events PSA 3rd overall revision in 2012;
- Issuing of revision 1 of the Angra 1 Plant Fire PSA study, in beginning of 2013, incorporating refinement of rooms modelling which is being applied in the revision of the Angra 1 Fire Hazard Analysis, to evaluate the associated risk reduction of each of the proposed modifications to improve the Plant fire protection;

- Angra 1 Fire PSA currently the subject of a broader revision led by the plant designer (Westinghouse) in order to obtain better modeling and results more adherent to the actual plant state;
- Issuing of the Angra 1 level 1+, internal events PSA 2nd, 3rd and 4th and 5th overall revisions in 2010 – 2020 period;
- Issuing of the Angra 1 Low Power and Shutdown PSA in 2021,
- Issuing of the Angra 1 Level 2 PSA in 2022,
- Continuing the development of the Angra 1 Seismic and Other External Events PSA for issuance in 2022,
- Implementation of an on-line Risk Monitor system (RiskWatcher®) available to the operation team in the Control Room by the end of 2022.

14(1).5.1.3 - Overview of Severe Accident Management of Angra 1.

Development, under a contract with Westinghouse, of Severe Accident Management Guidelines (SAMG) for Angra 1, based on the Westinghouse Owners Group (WOG) SAMG methodology. The revision 0 of these SAMG was completed in end of 2009. The process of verification, validation, training and integration into the Emergency Planning framework (see Article 19(4), for more details) was recently completed.

In that case, the Angra 1 SAMG have been developed adapting the generic Westinghouse Owners Group (WOG) SAMG to the specific details of the Angra 1 Plant. This is the usual approach for Westinghouse designed Plants and for other type of Plants that have developed generic guidelines. It is justified by the fact that the generic strategies of the WOG SAMG were developed and validated for the Westinghouse designed PWR.

For the validation process of of Angra 1 specific SAMG it were used ten (10) Angra 1 specific calculated severe accident scenarios to perform a table top exercise for verification of the full applicability of the developed SAMG to Angra 1.

In 2016, after the completion of the stages of development, training and preparation for implementation of the Angra-1 Severe Accident Management Guidelines (SAMG), version in Portuguese (action from the ELETRONUCLEAR Fukushima Response Plan), the SAMG of Angra-1 was incorporated in the Plant Operation Manual (MOU) and, in the period covered by 2016 and 2018, three drills were realized involving and integrating severe accidents and the emergency plan.

In 2020, under a contract with Westinghouse, the Angra 1 SAMG was updated based on the PWROG-16059-P PWROG Severe Accident Management Guidance for International Plants.

Some of important issues that were addressed in this update were:

- Post-Fukushima upgrades
- Other Operating Modes (Shutdown, refuelling)
- Spent Fuel Pool iniciated accidents
- Severe accident mitigation systems (Passive Hydrogen Recombiners)
- Integration of important improvements from the new consolidated PWROG SAMG (TSC support guides; improved guide fluidity; specific guides for I&C and BO)

The figure bellow shows the new structure of Angra 1 SAMG.

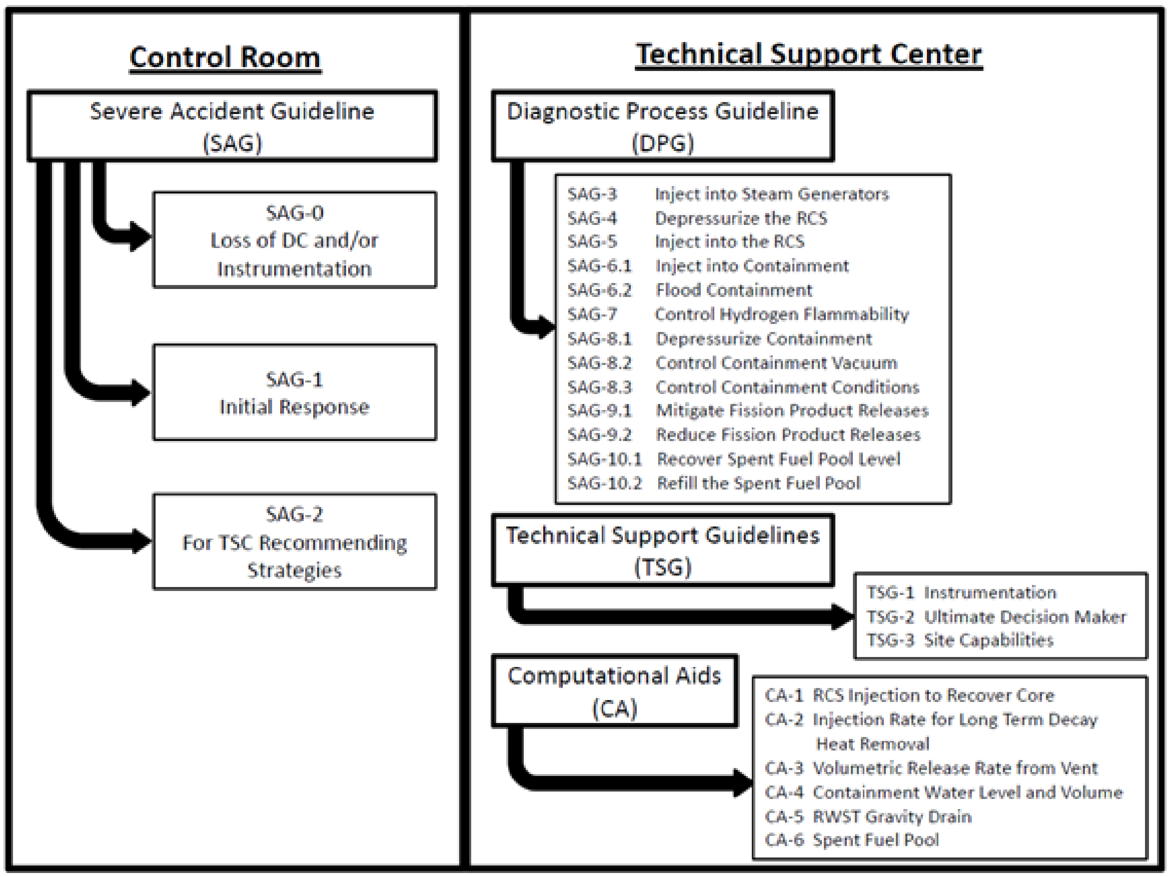

Figure 19 - new structure of Angra 1 SAMG

For the validation of the Angra 1 SAMG, the high-level scenarios were a Large Loss of Coolant Accident (LOCA) and na Extended Loss of AC Power (ELAP); from these initiators four different scenarios were generated for individual tabletop exercises.

After the Angra 1 SAMG validation, team training, guidelines translating and revision and Operating Revision Comission approval, in the beginning of 2022, the updated Angra 1 SAMG were officially incorporated in the Angra 1 Operating Manual.

14(1).5.2 - Angra 2.

14(1).5.2.1 - Overview of Deterministic Safety Analysis of Angra 2.

The safety assessment, with the purpose of demonstration of the adequacy and safety of the plant design bases, included both, the deterministic and probabilistic approaches, complementarily, to safety analysis. The deterministic approach followed the traditional western methodology of using qualified, internationally accepted, conservative computer codes and assumptions for the analysis of a large set of postulated events, established in national / international guides and regulations, ranging from minor transients to a large loss of coolant accident (LOCA).

An exception to the above-mentioned conservative approach was the Angra 2 large break LOCA Analysis which was performed following the “best estimate” methodology approach using of a “best estimate code” of the RELAP5 MOD2 family, coupled with uncertainty evaluation. This analysis was evaluated by CNEN with the assistance of two international consultants, the German institute GRS (Gesellschaft fur Anlagen und Reaktorsicherheit) and the University of Pisa. The verification and acceptance of these analyses was performed through independent calculations done by the CNEN with the support of the University of Pisa.

For the Angra 2 also, a major scope of deterministic safety assessments, covering plant transients and accidents, has been performed in the previous review period, to support the licensing of a 6% increase of Angra 2 power, together with a fuel design change (HTP - high thermal performance fuel with M5 cladding). Reanalysis of the LB-LOCA with uncertainty quantification was part of the assessment.

14(1).5.2.2 - Overview of Probabilistic Safety Analysis (PSA) of Angra 2.

For the Angra-2 plant, a preliminary evaluation of the core melt frequency, as well as the probabilistic analysis support for development of Accident Management countermeasures and other evaluations, requiring probabilistic insight, have been done taking the German Risk Study (RS), as well as PSA results of German sister plants, as a basis, and adapting their models for the main design differences between these plants and Angra-2. The validity of this approach is based on the similarity of the plant designs all belonging to the standard 1300 MWe German PWR design.

The estimated Angra 2 core damage frequency (CDF) for internal events, obtained from this approach was on the range of mid10^{-6} /reactor.year, compatible with the CDFs for 6 German sister plants, all in the 1 to 3 x 10^{-6} /reactor.year range.

The at-power specific Level 1^{+} PSA for Angra 2, considering internal events and flooding, was developed during 2005 and 2008 by an external contractor. Revisions of this study have been incorporated in the previously mentioned PSA development program. To date, three revisions of this study have been performed. The Regulator also requested to increase the set of Level 1 PSA studies for Angra-2 to include Low Power and Shutdown (LPS), Internal Fire and External Events as well as a Level 2 PSA.

The main PSA development activities for the Angra 2 plant performed within this program were:

- Conclusion of revision 0 of the Level 1^{+} PSA of Angra-2 by an external contractor, in mid-2008;
- Conclusion of revision 1 of this PSA, performed internally, in mid-2009, with implementation into the model of the identified required modifications;
- Revision 2 of this PSA was completed by end of 2013, and revision 3 by end of 2015;
- Conclusion of the development of application of the Angra-2 Risk Monitor, using the above PSA model, for Configuration Risk Management of on-line maintenance of this plant. The Angra-2 risk monitor is being routinely used by the operation and maintenance planning group;
- Support to the development of the Reliability Centered Maintenance Program (RCMP) for the Angra-2 Plant. The development of this program is presently completed and it is being applied.
- The referred scope of PSA studies requested by the Regulator was finalized using a contract signed with plant supplier AREVA, in December 2015.

Some of the main insights resulting from the Angra 2 level 1+ PSA for internal events and flooding were:

- The existing procedure of Feed and Bleed from the secondary side for the beyond design event of total loss of feedwater is too complicated resulting in a too large probability of human error and failure of the procedure;
- Connecting the bus bars of the 4 redundancies of the two existing Emergency Diesel 1 (large Diesels) and 2 (small Diesels) power supply nets, in such a way that in case of failure of a Diesel 2 of one or more redundancies, the bus bars of these redundancies are fed by the corresponding Diesel 1 bus bar redundancies, is an effective risk reduction measure. This feature already exists in the German plants of the Angra-2 family but was not implemented at this plant;
- Provision of double secured power supply for some critical secondary side valves, required for DBA and BDBA accident control will contribute effectively to risk reduction.

The CDF values obtained for the Angra 2 plant in PSA revisions 1 and 2 were in the low 10-5 per reactor.year, which, when compared to the CDF of its German sister plants, was almost one order of magnitude higher.

After completion of revision 3, which incorporated in the PSA model the above referred safety features, installed in the Plant in the meantime, the corresponding CDF was reduced to 3.3×10^{-6} / reactor.year, in the same range of its sister plants.

Similarly to Angra 1, this PSA has been used routinely for maintenance planning in order to ensure a safe plant configuration during maintenances, to evaluate the risk impact of plant modifications, to support the Reliability Centered Maintenance program and eventually to support justifications to exceptions to the Technical specifications, as for instance extended emergency Diesel unavailability times during the 10 years revision of this equipment.

CDF results and insights from the recently completed scope of PSA studies (fire, shutdown, seismic/external events and level 2 were :

- The CDF for internal fire yielded a very low 3.7×10^{-7}/year, indicating that the consistent physical separation of Plant redundancies (4x50%), as well as the existing fire detection and extinguishing systems provide a fire protection design study;
- The CDF for external events (excluding seismic) of $1{,}2 \times 10^{-5}$/year is dominated by loss of Ultimate Heat Sink (UHS) due to intake water blockage from organic material (48,5%) and from the combination of Loss of Offsite Power (LOOP) and of UHS, caused by strong wind and organic material (35%). This is consistent with the CNAAA site characteristics;

- The CDF for seismic PSA yielded a value of $1.1x10^{-5}$/year, which seems to be high for a low seismicity country as Brazil. This study still needs further refinement as it was based on a preliminary Probabilistic Seismic Hazard Analysis and still used conservative assumptions in case of lack of some detailed equipment or building data. The evaluation of building and equipment fragilities indicated that the plant can withstand earthquakes with a PGA of up to 0,4g, (design Safe Shutdown Earthquake, PGA= 0,1g), indicating existence of substantial margins against seismic events;
- The CDF for shutdown, $4,5x10^{-5}$/year, is one order of magnitude higher that of its sister plants. This can be tracked down to large differences in reliability data for residual heat removal system valves, between the Angra-2 Level 1 Internal Events PSA used as reference and the corresponding reliability data considered in Germany. Some procedures available in German Plants, during outage work performance, are still to be implemented in Angra-2;
- The Level 2 PSA study yielded a Large Early Release Frequency (LERF) of $3,5x10^{-8}$/year, indicating that the existing features for mitigation of Severe Accidents (passive H_2 recombiners and sturdy Primary and Secondary Bleed and Feed) are efficient in avoiding early releases.

Another important general insight arising from the ELETRONUCLEAR PSA development program is that to have a usable PSA model in accordance to up-to-dated methodology takes considerably longer than expected, even without any unforeseen problems and with available support from experienced consultants.

14(1).5.2.3 - Overview of Severe Accident Management of Angra 2.

The development of Severe Accident Management Guidelines (SAMG) for Angra 2 started in April 2011, supported through a Cooperation Agreement with the European Commission. The completion of the work, including calculations, documentation, assessment, training and integration with Emergency Planning was completed in December, 2015. All generated documentation was submitted to CNEN, which also participated in the training courses and exercises. For more details see Article 19.4.

In the case of Angra 2 no generic SAMG were available for the German PWR design, therefore the corresponding SAMG required use of results from specific Angra 2 levels 1 and 2 PSA plus additional specific MELCOR SA calculations for development of the strategies and computational aids.

14(1).6 - Regulatory review and control activities.

All technical documents submitted to CNEN by the licensee go through a process of safety assessment by CGRC. The result of this process is documented on technical reports, which contain the review findings. These findings may accept the document, require further information, identify non-compliance with regulations or require further action by the licensee.

The Regulatory technical activities related to nuclear power plants and research reactors licensing are carried out by the CGRC, as specified in Article 8. In particular, these include:

- Carrying out safety evaluation and inspection of NPP and research reactors during the construction, pre-operational and operational phases, in order to qualify for CNEN's licenses.
- Following the implementation of quality assurance programmes during construction and operation of NPPs.
- Inspecting the fabrication of NPPs components.
- Examining and licensing candidates for nuclear reactor operators.
- Developing studies for evaluating accidents in NPPs.

To perform these tasks, CGRC:

- Analyzes the geographical, demographical, geological and meteorological data of the site submitted for approval by the applicant.
- Assesses the installations by analysis and control of the projects, including a detailed investigation of the normal operational state, and of the equipment and safety systems in case of accidents. This analysis with its occasional stipulation of specific conditions, constitutes the basis on which the construction license is granted.
- Supervise and conduct inspections of the construction, controlling conformity with the project analyzed, and observance of the conditions stipulated.
- Assesses the quality assurance programs of the organizations involved in planning, construction, and operation of the respective installations.
- Effects controls, in order to verify the adequate application of Quality Assurance Programs (QAP).
- Effects controls to verify the various processes used in construction, and the accurate execution of tests scheduled in the project.
- Supervise the commissioning stages, and the pre-operational tests, comparing the analysis of the results with the conditions stipulated in the construction license.
- Grants the operation license for nuclear power stations.
- Issues the licenses for qualified plant operation personnel.

- Supervises the operation of nuclear installations, analyzing eventual technical modifications.
- Analyze, supervise, and inspect all decommissioning stages.
- Establishes ecological and biological procedures and systems for radiation measurement in the vicinity of nuclear installations, aiming at a collection of data in pre-operational and post-operational stages for future comparison of cause and effect.
- Regular inspection programmes for research reactors in operation.
- Written and oral examination to qualify operators for power plants and research reactors.

14(1).6.1 - Periodic Safety Review of Angra 1.

At the end of 2021, the ELETRONUCLEAR (ETN) submitted to CNEN to comply with requirements in ART. 19 of Authorization for Permanent Operation Ratified issued in December 2019, and paragraph 21 of CNEN standard CNEN-NE-1.26 and IAEA SSG-25, the documentation related the Preparation for 3rd PSR project of ANGRA 1. The base document, PA-RPS 01 - Base Document of the 3rd Periodic Safety Review of ANGRA 1, submitted by ETN, was based on INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Standards Series No. SSG-25 – Periodic Safety Review for Nuclear Power Plants, IAEA, Vienna (2013), INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Standards Series No. SSG-48 – Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants, IAEA, Viena (2018).

CNEN carried out regulatory assessment of aspects included in the Basis Document to verify its technical suitability and consistency. In according to Basis Document, the 3rd PSR of Angra 1 schedule is:

ID		Deadline
MP1	Definition of the Normative Basis of the 3rd RPS	November 30rd, 2021
MP2	Pre-meeting for the presentation of the 3rd RPS to CNEN	January and February, 2022
MP3	Agreement between CNEN and ELETRONUCLEAR, and start of the 3rd RPS	June 1st, 2022
MP4	Plant information cut-off date (freeze)	June 30rd, 2022

MP5	Approval of Safety Factor reports (1-14), to be submitted to the LTO Program Executive Committee from ETN	August 30rd, 2023
MP6	Submission to CNEN of the results of the Safety Factors reviews	September 30rd, 2023
MP7	Presentation to the Executive Committee of the LTO Program the final version of the Final Report, including the Integrated Implementation Plan for Safety Improvements (PIIMS) of the 3rd RPS of Angra 1	November 30rd, 2023
MP8	Submission to CNEN of the Final Report, including the PIIMS of the 3rd RPS	December 23rd, 2023

14(1).6.2 - Periodic Safety Review of Angra 2.

The ELETRONUCLEAR submitted to CNEN, in 2021, to comply with requirements in paragraph 21 of CNEN standard CNEN-NE-1.26 and IAEA SSG-25, the documentation related the Preparation for 2nd PSR project of Angra 2.

CNEN carried out a preliminary assessment of aspects included in the Basis Document to verify its technical suitability and consistency. In according to Basis Document, the 2nd PSR of Angra 2 simplified schedule is:

ID		Deadline
1	Pre-meeting for the presentation of the Basis Document of 2nd RPS of Angra 2 to CNEN	July 2021
2	Plant information cut-off date (freeze)	December 2022.
3	Approval of Safety Factor reports (1-14)	February, 2023
4	Presentation to CNEN the Preliminary Plan for Safety Improvements of the 2nd RPS of Angra 2	June 2023
5	Submission to CNEN of the Final Report, including the PIIMS of the 2nd RPS of Angra 2	October 2023

14(1).6.3 – Deterministic Safety Analysis of Angra 1.

In 2017, CNEN evaluated the request to change the technical specifications regarding the hot runner factor inspection methodology in the heat flow. CNEN's evaluation process generated requirements, which are in Eletronuclear's response action plan to be met.

At the end of 2021, CNEN evaluated the operator request to change the technical specifications (PAET) regarding the electric hydrogen recombiners replacement by passive autocatalytic hydrogen recombiners for design basis accidents.

CNEN evaluated the documents that had been presented with the technical basis for this modification, where the number of passive autocatalytic recombiners required for LOCA DBA at ANGRA NPP Unit 1 were determined and justified. CNEN's evaluation process generated requirements, CNEN's evaluation process generated requirements which were attended satisfactorily by the operator of them were attended by the operator, ELETRONUCLEAR. Based on the analyses presented, the regulatory body approved the PAET.

14(1).6.4 – Deterministic Safety Analysis of Angra 2.

A fuel oxidation problem has occurred in Angra 2 unit. As it is a multidisciplinary event, with possible consequences in the safety analysis, the oxide layer measurement tests were monitored by CNEN, with a multidisciplinary team, including deterministic analysis technicians. The refueling report, including the insertion of oxidized elements, was evaluated by CNEN and after answering CNEN's questions about possible safety consequences, the refueling was approved

14(1).6.5 – Probabilistic Safety Analysis (PSA) of Angra 1.

In 2019 a regulatory workshop was carried out to clarify important points contained in the operator's responses to the requirements of technical advice issued by CNEN, aiming at the process of application and use of PSA Level 1. In these meeting was also verified the documentation of the operator supporting PSA Level 1 as well as the Quality Assurance action on this documentation. From 2020 to 2021, regulatory inspections have been suspended due to quarantine imposed by Covid-19.

From 2019 to 2022, the results of the Human Reliability Analysis in the Level 1 and Level 2 PSA report entered a final reevaluation phase. The clarification of important points of this revaluation are also part of the regulatory inspections to be carried out in 2022 PSA oversight plan.

The Revision 5 of the PSA Level 1 was delivered to CNEN by the end of 2020. The regulatory reviewed and concluded that in general, APS Level 1+ meets the criteria of completeness, adequacy and coherence, consistency, clarity, and traceability in accordance with ETN application plan, some applications can be considered. This review is not exhaustive, and the detailed review is in progress in consequence of the 3rd PSR.

Following Revision 5 of APS level 1 the following APS were delivered to CNEN:

- LP&SD Final Report under review by the regulator.
- Level 2 PSA Interim Technical Report under review by the regulator.
- Seismic PSA Interim Technical Report under review by the regulator.
- Fire PSA Interim Technical Report reviewed by regulator.

The ELETRONUCLEAR will complete the PSA Level 2 for the operation at full power, including internal events, internal fire, internal flooding, seismic events and other external hazards and PSA for low power and shutdown modes, based on Revision 5 of PSA Level 1, joint The 3rd PSR of Angra 1.

From 2019 to 2021, technical meetings were carried out between CNEN and Eletronuclear to clarify some questions related the application and use of PSA Level 1, as well as to monitor the development of other PSA's parts.

During the period from 2015 to 2018 the CNEN with support of the European Commission, in the Support to the Nuclear Safety Regulator of Brazil project, generated a draft vesion of a Regulatory Guide for the Development, Application and Use of PSA for Brazilian Nuclear Installations. This preliminary version was reviewed CNEN Experts and now this document is in administrative procedure for issuance.

Regarding the safety analysis, it is worth noting that in 2019, ETN incorporated Chapter 18 Human Factors Engineering and Chapter 19 Probabilistic Risk Assessment and Severe Accident into the RFAS review of December 2019.

14(1).6.6 – Probabilistic Safety Analysis (PSA) of Angra 2.

From 2018 until 2021 CNEN carried out the preliminary review of PSA project (PSA Level 2 for the operation at full power, PSA for Low Power and Shutdown modes, PSA Fire, PSAs

External Events and Seismic PSAs). The preliminary review generated a set of technical advice with additional requirements request that are in the process by the operator. From 2020 to 2021, regulatory inspections have been suspended due to quarantine imposed by Covid-19.

14(1).6.7 – Severe Accident Assessment of Angra 1.

From 2019 to 2021, regulatory inspections were carried out to clarify important points contained on the operator's responses to the requirements issued by CNEN, aiming at the process of the Fukushima lessons learned implementation. Although some commitments assumed by the operator have been implemented, such as installation of fittings to connections form mobile equipment and upgrade of Severe Accident Management Guides, there are pending implementations such as the pump seal for severe accident conditions, filtered containment venting system and others.

Development, under a contract with Westinghouse, of Severe Accident Management Guidelines (SAMG) for Angra 1, based on the Westinghouse Owners Group (WOG) SAMG methodology, was forwarded for CNEN assessment. The revision 0 of these SAMG was started at the end of 2009.

According the CNEN requirements, the SAMG has been revised to implement the modifications derived from the plan to incorporate the lessons learned from the accident at Fukushima to make Angra 1 station even safer. Angra 1 SAMG's was impacted by the replacement of the electrical recombiners by Passive Autocatalytic Recombiners (PARs) and other implemented lessons learned after Fukushima accident, as well asthe transition criteria from EOP to SAMG considering a spent fuel pool event.

To attend the requirements of CNEN an upgrade of these SAMG were improved and completed at the end of 2020 by the operator, supported through Westinghouse project, based in the PWROG-16059 (12/2016) report.

The main SAMG upgrade items for Angra 1 plant performed were:

- The Angra 1 SAMG were updated incorporating the lessons learned from the events in Fukushima, such the guides to I&C/DC total loss and equipments, connections and procedures for alternative mitigations actions (FLEX) are all available.
- shutdown states and spent fuel pool accidents.
- new transition criteria from the EOP to SAMG considering the fuel pool accidents.
- PAR installation.
- Support guides to Technical Support Center (TSC).

- Specific guides to instrumentation assessment.
- Important design modifications like the pump seal for severe accident conditions and the filtered containment venting system have been planning for implementation in the future outages. The pumb seal modification, for example, will be executed in the Angra 1 next outage and the Westinghouse company were contracted to design the Angra 1 filtered containment venting system.

The new SAMG of Angra-1 was incorporated in the Plant Operation Manual (MOU) in the period covered by 2020 and 2021. The process of verification, validation, training, and integration into the Emergency Planning framework was recently completed.

14(1).6.8 – Severe Accident Assessment of Angra 2.

From 2016 to 2018, CNEN has been following its process of implementing the actions of the Fukushima plan, requiring them to be completed as soon as possible. Examples of pending implementations include containment filtration venting, installation of mobile equipment connections, severe accident containment atmosphere sampling system, review of severe accident management guides.

In 2017, Eletronuclear proposed to CNEN a response to compliance with the condition of CNEN Resolution No. 200. This Resolution conceded the Angra 2 Permanent Operation Authorization. This condition requires that the Angra 2 Severe Accident Management Program (SAMP) be reviewed within the period established. Eletronuclear's proposed only to review the Severe Accident Management Guides (SAMG). CNEN clarified that in addition to the SAMG review, the entire program should be updated in accordance with the necessary modifications and implementations due to the action plan in response to the Fukushima accident. For example, the requirement for revision of the Emergency Operating Procedures implied by these modifications, the elaboration of the Operating Procedures for mobile equipment, filtered containment venting system, installation of fittings to connections for the mobile equipment, post-accident sampling system, as the SAMGs update.

According the CNEN requirements, the SAMG of Angra 2 has been revised to incorporate the lessons learned from the events in Fukushima.

A draft of a new standard regulatory had been developed considering the lessons-learnt from the accident at Fukushima with the requirements to development of a Severe Accident Management Program. This draft is in process of assessment.

The development of Severe Accident Management Guidelines (SAMG) for Angra 2 had been initiated in April 2011, supported through a Cooperation Agreement with the European

Commission. The completion of the work, including calculations, documentation, assessment, training, and integration with Emergency Planning was completed in December 2015. All generated documentation was submitted to CNEN, which also participated in the training courses and exercises. For more details, see Article 19.4.

In the case of Angra 2 no generic SAMG were available for the German PWR design, therefore the corresponding SAMG required use of results from specific Angra 2 levels 1 and 2 PSA plus additional specific MELCOR SA calculations for development of the strategies and computational aids. These requirements were attended by ELETRONUCLEAR.

CNEN required a SAMG update in order to implement strategies for spent fuel pool. These must have the transition criteria from EOP to SAMG considering a spent fuel pool event as well the specific guides concerning the spent fuel pool accidents. ELETRONUCLEAR implemented these requirements in April 2021.

Article 14 (2) - Verification of safety

Article 14 (2).1 - Overview of the Contracting Party's arrangements and regulatory requirements for the verification of safety.

The item 4.2 of CNEN Standard CNEN NN-1.14, *Nuclear Power Plants Operating Reports* (Resolution CNEN 016/01 – 29.11.2001 issued in Official Gazette D.O.U.: 05.01.2002) requires the operating organization to submit the Nuclear and Thermohydraulic Project Report (RPNT) to CNEN for each authorization request for initial loading or reloading of the reactor core, including any revisions to the RPNT, including during the burn cycle. The RPNT must contain a minimum of information that demonstrates that the safety limits, established in the technical specifications, will not be violated during the reactor burn cycle. The analytical methods used to determine the operating limits of the nucleus must be those previously reviewed and approved by CNEN. A summary of the methodology used, as well as its references, must be presented in the RPNT.

The item 11 of CNEN Standard CNEN NN-1.26, Operational Safety in Nuclear power Plants [9], require that Operating Organization establish procedures for modifications to structures, systems, and components. The Design modifications can be of two types: technical alterations (change) or modifications. The modification does not involve unassessed safety problems. The technical alteration involves unassessed safety problems and must have prior authorization from CNEN.

The CNEN Standard CNEN NE-1.25 - In-service Inspection in NPP, establishes the minimum requirement applicable for in-service inspections in nuclear power plants and it applies to individuals and organizations that perform these inspections. It establishes that the operator is responsible for setting up and implementing pre-service inspection programs and in-service inspection and may delegate entirely or in part this task to other organizations, however remaining responsible for them before CNEN.

Furthermore, it must, before each shutdown, submit a proposal comprising the scope of inspection activities in service and confirm that the results of final inspection are satisfactory. It specifies the requirements for verification of in-service inspection activities, to access the results of tests, examinations, or assays, establishing the nature of corrective actions, as appropriate, for pressure testing, items repair and replacement, methods, techniques, and tools used for the qualification of non-destructive tests operators and inspections in service activities records.

Article 14 (2).2 - Main elements of programmes for continued verification of safety (in-service inspection, surveillance, functional testing of systems, etc.).

During the period of January 2019 to December 2021, that correspond to the ninth review cycle of CSN, considering the Angra 1 and Angra 2 NPPs in Brazil, in operation, the principal safety verification objective went to follow the activities conducted under the current Authorization for Permanent Operation (AOP), to confirm that the systems, structures and components (SSCs) are being inspected, maintained, tested, and operated in accordance with its last version of FSAR.

Angra 3 is in interrupted construction phase then the principal safety verification objective for activities conducted under the current Construction License is to confirm that systems, structures and components (SSCs) are being preserved in accordance with the Preservation Program implemented by ELETRONUCLEAR.

On the regulatory side, to verify the safety of the operating plants CGRC makes use of two levels of surveillance. The first is a continuous inspection of activities carried out by the division of Resident Inspection. These on-site inspectors have procedures to verify the execution of several activities such as periodic tests, maintenance actions, control room activities, fire protection and housekeeping, work control, evaluation of operational events, etc. and to report any deviations. The second is the yearly Inspection and Audit Program to be implemented by the headquarters divisions of CGRC. This inspection program may be complemented along the year as necessary. All inspections and audits are documented on Inspection Reports. For more details about

Eletronuclear informed CNEN of its intention to submit a life extension request for the Angra 1 plant. After technical meetings, it was initially decided to follow the USNRC regulations.

On the utility side, the main elements for continued verification of safety are:

- Existence of a structured permanent safety oversight process at plant, site and corporate level.
- Verification of strict adherence to the safety limits, limiting conditions of operation, repair times, system operability criteria and surveillance requirements established in the technical specifications (see Article 19(2));
- Verification of strict adherence to the ISI program.
- Verification through PSA tools of the allowable risk for the online maintenance plant configurations (see Article 14(1)).
- Verification of the adherence to the predictive and preventive maintenance program.
- Follow up and periodic evaluation of a comprehensive set of performance and safety indicators (see Article 6).
- Verification of how safety problems from internal and external operational experience affects the safety of the Brazilian plants (see Article 19(7)).
- Obtain periodic feedback of external comprehensive peer reviews (WANO, IAEA), see Article 19(7).

Article 14 (2).3 - Elements of ageing management programme(s).

Eletronuclear decided for the implementation of an Ageing Management Program (AMP) at Angra-1, following the requirements defined by 10 CFR 54, US License Renewal Rule, which embodies a systematic and comprehensive approach for the ageing management of systems, structures, and components (SSCs) important to safety. The US ageing management approach is also consistent with the principles of the IAEA guidelines on the implementation of ageing management programs for nuclear power plants. Such decision complies with CNEN's (Brazilian Regulatory Body) recommendations.

Eletronuclear also decided to carry out the Angra 1 plant life extension licensing process and began technical meetings with CNEN. Technical meetings were held between CNEN and ETN to define applicable regulatory requirements and the use of the US model was decided using references 10CFR54, NUREG-1801, NEI-95-10 and IAEA Safety Guides.

As part of the LTO licensing process, an Integrated Plan Assessment (IPA) and an Integrated Ageing Management Program are under development. ETN hired the designer of the Angra 1 NPP (Westinghouse) to develop and start implementing Life Extension licensing activities. Regular meetings are held between the plant designer ETN and NEN to present the status of the development of this project.

In addition, the implementation of this program will support the application for a Licensing Renewal Process of Angra-1, planned to start at the second half of 2019. As part of the regulatory requirements accorded with CNEN, in 2020 and 2022 the LRA was update with Operational Experience Internal and External and the main Angra 1 modification and activities were incopred in the LRA. The LRA revision 1 (May 2020) and revision 2 (April 2022) was delivery to CNEN.

The AMP is being implemented, with the assessment of Westinghouse, in four different phases:

1) Pilot Program (concluded in 2010);
2) Time-Limited Ageing Analyses (TLAA) review (concluded in 2013);
3) Integrated Plant Assessment (IPA) (started 2015 conclusion in 2019);
4) Implementation of the commitments (on going).

Time limited ageing analyses comprise existing safety analyses involving time limited assumptions as defined in US-NRC rule 10 CFR 54.3 and in IAEA Safety Reports Series No. 57. TLAA include environmental qualification in accordance with US-NRC rule 10 CFR 50.49, “Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants”.

Integrated plant assessment consists of a demonstration that passive long-lived structures and components in the scope of the ageing management programme for long term operation have been identified and that the effects of ageing on the structural integrity and on the functionality of such structures and components will be managed to maintain the current licensing basis during the period of the plant operation.

Implementation of the commitments is on going during the implementation phase.

An Independent Review was contarcted from an Eorupean consulting company (RESCO) and ints recommendations were implemented into the License Renewal Application which was revised and subimitted to CNEN in 2022.

For Angra 2 NPP, ETN contracted the original designer (Framatome) to develop and start implementing an Integrated Ageing Management Program. The work is being further developed by an ETN dedicated Team.

In parallel, Eletronuclear has improved at Angra 1, a set of initiatives, including studies, assessment and plant modifications, as shown below:

- Replacement of components to eliminate Copper-alloy in the secondary system;
- Readiness assessment for the implementation of an AMP (Framatome, 2002-2003).
- Ageing management assessments in the scope of the 1st Periodic Safety Review - PSR (2005).
- Identification of Alloy 600 parts and welds in the Reactor Coolant System and its connections (2007).
- Replacement of Reactor Pressure Vessel Internals Split Pins (2008).
- Replacement of Steam Generators (2009). Substitution of material tubes: Alloy 600 to Alloy 690.
- Weld overlay at the pressurizer surge line, spray line, safety valve lines, and relief valve line (2010).
- Replacement of the Reactor Pressure Vessel Closure Head (January 2013).
- IAEA Pre-SALTO Mission at Angra 1 (November 2013 and 2018).
- Implementation of inspection and maintenance programs for safety related concrete structures.
- Development of the Environmental Qualification Program for Electrical and I&C Equipment.
- Development an Integrated Plant Assessment (IPA) producing Scoping and Sreening, Ageing Management Reviews and Ageing management Programs (Contractor: Westinghouse).
- Contracting the Mechanical Stress Improvement Process (MSIP) and Weld Overlay for Stress Corrosion Control at Reactor Pressure Vessel and Safety Injection Nozzles (in course).
- IAEA TSM at Angra Site (October 2016).

Upon the invitation, two peer review mission on safe long-term operation (SALTO) was provided to review programmes / activities of Angra Nuclear Power Plant Unit 1 (“the plant”). The design lifetime of this Westinghouse plant is 40 years. The plant was commissioned in 1985.

Brazilian regulatory authority CNEN issued a 40-year-period license untill 2024 for the plant in accordance with the rule CNEN NE-1.04[5].

The target of the plant is to follow US NRC requirements for licensing renewal and be consistent with the IAEA recommendations for long term operation (LTO). The mission reviewed completed, in-progress and planned plant activities related to long-term operation (LTO) including activities involving the ageing management of systems, structures and components (SSCs) important to safety and revalidation of time limited ageing analysis (TLAA).

The main conclusion of two Pre-SALTO Mission to Angra 1 were commitment of the plant management to improving plant preparedness for LTO. In addition, the Pre-SALTO teams noted that the Technological Obsolescence Management implemented by Eletronuclear as a good practice.

The Pre-SALTO team also recognized that the plant approach and preparatory work for safe LTO, generally followed the IAEA Safety Standards and international practices.

The plant implemented an obsolescence programme. This programme includes proactive strategy, focus on SSCs important to safety, procedures to manage obsolescence and organizational arrangements for the implementation. The prograrnrne consists of two processes:

- RAPID - Readily Accessible Parts Inventory Database. It is a virtual warehouse and the database has information of about 100 organizations and plants worldwide. Part of this database is the Obsolete Items and Replacement Database (OIRD) with information if some organization has already solved a problem of equal or similar obsolescence;
- PKMJ contract, providing engineering consulting service to solve problems related to obsolescence - Engineered Obsolescence Solutions (EOS) and set of licenses for the use of software necessary for proactive management of obsolescence.

The plant strengthened the cooperation with Westinghouse. Main obsolesense and reliability items were discussed. Several contracts were awarded to Westinghouse, including preventive maintenance and tests, digital control rod systems position indication, replacement of I&C cards for the reactor protection system (implemented during outage lPI9), I&C cards replacement for the control rod system (planned during outage lP 20, March, April 2014) and other modifications planned for outages IP 27 till IP31. Spare parts and services can be contracted directly from Westinghouse because the SSCs was designed and manufactured by this company, which makes the procurement easier and quicker. In addition, the plant strengthened its cooperation with its syster plant Krsko NPP in Slovenia.

The plant achieved good results in prioritization of materials for maintenance and modifications. Daily operation focus meetings and monthly outage meetings prioritize purchasing of materials based on safety and reliability needs.

ELETRONUCLEAR also receives PEER Reviews missions from IAEA, WANO and INPO in a regular basis, as can be seen in Table 7 – International Technical and Review Missions, Article 19(7).

Article 14 (2).3 - Arrangements for internal review by the license holder of safety cases to be submitted to the regulatory body.

The answers and information to be sent from the licensee to the Regulator follow steps defined in internal procedures to verify the technical consistency and completeness of the answers, notably in the processes of Project Modifications of the unit and changes in the Technical Specification, whose procedure involves several instances of safety analysis.

Article 14 (2).4 - Regulatory review and control activities."

In the period of January 2019 to December 2021, CGRC performed 84 inspections and audits. Out of this total, 34 were at Angra 1, 27 at Angra 2, 6 at Angra 3 and 19 on the common site. In relation to Spent Fuel Complementary Dry Storage Unit of CNAAA – UAS, CGRC performed 14 inspections and Audit.

A technical cooperation is under way with the IAEA (IGALL) to establish improvements to the applicable regulatory requirements and to obtain an associated technical support. Another technical cooperation finished on 2017 with Eurpean Community (GRS, TECNATOM and IRSN) to develop regulaltory requirements for Life Extension and Ageing Management. As result of these cooperations two technical notes were developed with applicable regulatory requirements. The implementation of these technical cooperations will support CNEN for a Licensing Renewal process of Angra 1, planned to starts in 2019.

Technical cooperation with the IAEA within the IGALL project started in 2016, through Workgroup 4, specifically for regulators. Since then, a series of technical meetings have been held, for the elaboration of guides and general recommendations to be used by the member countries. These guides and recommendations, in addition to the USNRC references initially established, were used in the preparation of two technical notes with regulatory requirements to be followed by Eletronuclear during the preparation of the documentation associated with a request for an extension of the life of the Angra 1 NPP.

A Technical Note was also generated with a regulatory guide to be used by CNEN technicians in the evaluation of the documentation that would be submitted.

At the end of 2019, CNEN received the documentation associated with the LTO request for the Angra 1 plant and a supplement to this documentation in May 2020.

Since 2018, annual regulatory audits have been carried out in the development of the Angra 1 life extension project, covering the Aging Program, Environmental Qualification and related aspects.

CNEN has also monitored and participated in the PRE-SALTO and follow-up missions that took place at the Angra 1 plant. In general, it was verified that all the recommendations generated were already identified on the regulatory reports and addressed, with the respective corrective actions.

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ARTICLE 15 – RADIOLOGICAL PROTECTION

> Each Contracting Party shall take the appropriate steps to ensure that in all operational states the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed prescribed national dose limits.

15.1 - Overview of the Contracting Party's arrangements and regulatory requirements concerning radiation protection at nuclear installations, including applicable laws not mentioned under Article 7

Radiological protection requirements and dose limits are established in Brazil in the regulation for radiological protection CNEN–NN–3.01–Basic Radiation Protection Basic Directives [15], based on the Safety Series n. 115 – International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, jointly sponsored by FAO, IAEA, ILO, OECD/NEA, PAHO and WHO. These requirements establish that doses to the public and the workers be kept below established limits and as low as reasonably achievable (ALARA).

In 2010, CNEN started update in CNEN–NN–3.01–Basic Radiation Protection Basic Directives. This update will change some regulatory attributes to adapt GSR Part 3 - Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards.

15.2 – Regulatory expectations for the licence holder's processes to optimize radiation doses and to implement the 'as low as reasonably achievable' (ALARA) principle

Implementation of this regulation is performed by developing the basic plant design in accordance with the ALARA principle and through the establishment of a Radiological Protection Program at each installation. Plant design is assessed at the time of the licensing review and by evaluating the dose records during normal operation.

15.3 - Implementation of radiation protection programmes by the licence holders

The Radiological Protection Program of Angra 1 and Angra 2, included in the Final Safety Analysis Reports, sets forth the philosophy and basic policy for radiological protection during operation. The highest level policy is to maintain personnel radiation exposure below the limits established by CNEN and to keep exposures as low as reasonably achievable (ALARA), taking into account technical and economic considerations.

The present annual dose limit to workers is 20 mSv for Effective Dose (average of 5 consecutive years) and maximum of 50 mSv in any single year. For the extremities (hands and feet) or the skin, the equivalent dose limit is 500 mSv in per year. And for the crystalline lens, the annual equivalent dose limit is 20 mSv (average of 5 consecutive years) and maximum of 50 mSv in any year.

The actual personnel radiation doses at Angra Nuclear Power Plants continue to be much lower than the established limits. The dose distribution for workers at the Angra site demonstrates an adequate radiological protection program, with all averaged annual accumulated individual doses below 0,20 mSv and no one with radiation dose above 7,5 mSv in the 2019-2021 period. The dose distribution for the 2019-2021 period is summarized in the Table 7, shown below.

For the incoming years, efforts are in place to reduce the collective doses for Angra 1 and Angra 2, aiming to values below the industry average, by improving the ALARA planning of the activities, including source term reduction, additional shielding, and better use of the human performance tools.

A plant ALARA Commission for each Plant, composed of different groups (Operation, Maintenance, Chemistry, System Engineering and Radiological Protection), is in charge of implementing and monitoring the ALARA Program that describes procedures, methodologies, processes, tools and steps to be used in planning the work. The ALARA Program is continuously being revised and represents the best effort to minimize occupational doses.

The release of radioactive material to the environment is controlled by administrative procedures and kept below CNEN established limits. Additionally, the amount of radioactive waste and the radioactive effluents discharged to the environment also follow the ALARA principle.

Table 7 – Dose Distribution for Angra 1 and Angra 2 from 2019 to 2021

Year	2019 (TLD)		2020 (TLD)		2021 (TLD)	
Dose Range (mSv)	Number of Persons		Number of Persons		Number of Persons	
	A1	A2	A1	A2	A1	A2
D ≤ 0.2	1220	1985	1743	1395	1566	1900
0.2 < D ≤ 1.0	30	174	278	105	302	199
1.0 < D ≤ 2.5	1	54	92	31	100	81
2.5 < D ≤ 5.0	0	10	11	4	10	16
5.0 < D ≤ 7.5	0	0	0	0	3	0
7.5 < D ≤ 10.0	0	0	0	0	0	0
10.0 < D ≤ 15.0	0	0	0	0	0	0
15.0 < D ≤ 20.0	0	0	0	0	0	0
20.0 < D ≤ 50.0	0	0	0	0	0	0
50.0 < D	0	0	0	0	0	0
Total of Persons	1251	2223	2124	1535	1981	2196
Highest Dose (mSv)	1.02	3.55	4.48	3.28	6.00	4.37
Median Dose (mSv)	0	0	0	0	0	0
Average Dose (mSv)	0.02	0.09	0.17	0.07	0.20	0.13
Collective Dose (person.mSv)	19.41	206.36	351.25	110.74	388.84	289.21

A1: Angra 1 NPP / A2: Angra 2 NPP TLD: Thermoluminescent Dosimetry

The release of radioactive material to the environment is controlled by administrative procedures and kept below CNEN established limits. Additionally, the amount of radioactive waste and the radioactive effluents discharged to the environment also follow the ALARA principle.

The discharge limits are derived from the dose values to public individuals. The procedures for the release of plants ensure that the activity released by effluent are below these dose limits (0.25mSv/year). Similarly, values of set point detectors that monitor the effluents are derived from these discharge limits.

The reference levels for effluent´s discharge are in accordance with the reference level for dose constraint established in the Offsite Dose Calculation Manual (ODCM), approved by CNEN. In this manual, the dose for the hypothetical critical individual is calculated.

According to the CNEN's regulation CNEN-NN–1.14[8], an Effluents Releasing and Wastes Report is issued for each unit every semester, documenting the liquid, gaseous and aerosol effluents: batch number, radionuclides present and their concentration, waste quantity and type sent to radioactive waste facilities and the meteorological data in the period. In this report, the effective dose for the critical individual is also presented. In the period of 2019-2021, the highest dose reached was $1{,}53 \times 10^{-2}$ mSv in 2020, which is much lower than the 1 mSv/year value and the dose constraint value of 0,30 mSv/year, established in regulation CNEN-NN-3.01 [15].

The IBAMA does not interfere in this subject. It only receives the manifestation of CNEN about the projects' Radiological Protection in its environment licensing process.

A Radiological Environmental Monitoring Program, based on CNEN requirements, is conducted by ELETRONUCLEAR to evaluate possible impacts caused by plant operation. This program defines the frequency, places, types of samples (sea, river, underground and rainwater, fish, beach sand, marine and river sediments, algae, milk, grass, airborne, banana and soil) and types of analyses (gamma spectrometry, beta counting and tritium) for the survey of exposure rates. The evaluation of exposure rates is also made by direct measurement using thermoluminescent dosimeters distributed in special sectors around the Angra site, and at points located in the nearest villages and cities. The results of the monitoring program are compared with the pre-operational measurements taken, in order to evaluate any possible environmental impact. Annual reports are presented to CNEN. To date essentially no impact has been detected. Typical results are presented in Table 8, for the period 2019-2021 and in Fig. 20 for the life of the site.

Table 8 – Environmental Monitoring Program Results from 2019 to 2021

	YEAR		
	2019	2020	2021
	Measured values in mSv/30 days		
I – Impact Area	0,075	0,082	0,083
C – Control Area	0,075	0,078	0,078

Impact Area: 37 measuring points within 10 km radius from the plant.
Control Area: 4 measuring points beyond 10km radius from the plant.

The radius 10 Km was defined by ELETRONUCLEAR, in agreement with CNEN, using the same concept used in the establishment of the emergency planning zones EPZ, where it was identified by calculations assuming restrictive meteorological conditions that most of the contamination following an emergency in the Angra site plants, with large external releases, would remain within the first 10 Km of the plants.

These criteria adopted by ELETRONUCLEAR are in agreement with the IAEA guidance: "In order to be effective the protective actions need to be implemented first for those located within 3 to 5 km of the nuclear power plants, followed by those located more than 5 kilometers far"

However, monitoring of the impact of the operation of the plants on the environment surrounding the site performed by the Environmental Monitoring Laboratory of Eletronuclear encompasses lab analyses and radiation exposure rates measurements (TLD) within (impact area) and also beyond (control) 10 Km radius of the site epicenter.

As it can be seen from the above Table 6, there is essentially no variation of the measured values in the survey periods. The average values for the Impact and Control areas measurements are statistically equivalent, indicating the absence of radiological impact from the power plants.

This is confirmed by the graph shown in Figure 20, which shows a compilation of Impact and Control measurements from the preoperational phase of the first NPP to be installed on site up to the end of 2021, with two Plants in operation. The lack of data for 1985 in the Fig.20 was due to the destruction of the remote Environmental Monitoring Laboratory due to a landslide. The apparent variations in 1998 and 2001 are due to changes in monitoring places or changes in measuring instrumentation.

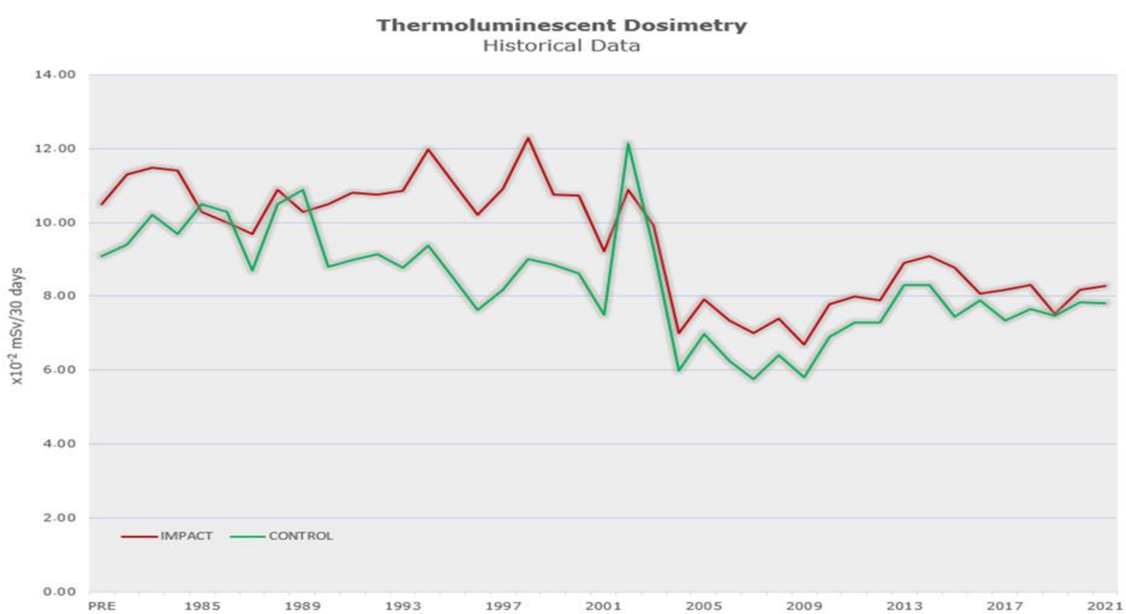

Figure 20 – Site lifetime environmental impact

15.4 - Regulatory review and control Activities

CNEN carries out annual radiation protection inspections on-site according to the periodic inspection programme, e.g. covering the resources, expertise and operation of the radiation protection organisation, dosimetry, radiation measurements in the plant, radioactivity measurements of effluents, and monitoring of radiation in the environment. CNEN carries out on-site inspections during annual maintenance outages to assess the aspects of occupational radiological protection and the application of the ALARA and also evaluate the final refuelling reports submitted by the licensees in accordance with the requirements of CNEN-NE-1.14 [8]

In addition, the Institute of Radiation Protection and Dosimetry (IRD) of CNEN conducts independent radiological monitoring program, which is further analyzed by the regulatory staff of CNEN and constrasted with ETN results.

In the period of January 2019 to December 2021, the Radiological Protection area of CGRC/DRS/CNEN performed 10 inspections and audits.

In conclusion, Brasilian regulations and practices are in compliance with Article 15.

ARTICLE 16 - EMERGENCY PREPAREDNESS

1. Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.

2. Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of the nuclear installation arc provided with appropriate information for emergency planning and response.

3. Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.

Article 16 (1) Emergency plans and programs

The planning basis for on- and off-site emergency preparedness in case of an accident with radiological consequences in the Angra Nuclear Power Station is based on the Emergency Planning Zone concept.

The Emergency Planning Zone (EPZ) encompasses the area within a circle with radius of 15 km centered at the Angra1 nuclear power plant. This EPZ is further subdivided in 4 smaller zones with borders at approximately 3, 5, 10 and 15 km from the power plants. The epicenter in Angra 1, the first plant to be built in the site, was established when the original emergency plan for the site was developed before start of Angra 1 operation, in the early 80´s. This plan was verified later before start of operation of the second plant Angra 2 (located about 500 m far from Angra 1), in early 2001, with the conclusion that the original plan remained adequate and did not need modifications following the inclusion of the second plant.

CNEN Resolution 9/69 presents the criteria for the establishment of the Exclusion Area (Area of property of licensee) and Low Population Zone requirements. The determination of the numerical values for the exclusion area and the low population area must meet the following requirements:

1 – Exclusion Area - the total radiation dose to the whole body cannot exceed 25 rem (0.25 Sv) and the total thyroid dose due to inhalation of iodine-131 cannot exceed 300.rem (3.00 Sv) for an individual located at a point on the outer boundary line. The time irradiation is two hours, counted from the beginning of the maximum postulated accident.

2 –Low Population Zone - the same doses limits established in the previous paragraph, cannot be exceeded for an individual located on a point of their boundary line, during the whole period of passage of the radioactive cloud resulting from the release of products fission due to the maximum postulated accident.

16(1).1 - On Site Emergency Preparedness

The On-site Emergency Plan covers the area of property of ELETRONUCLEAR, and comprises the first zone (in the past called EPZ-1, 0.5Km to about 1.5 km from the power plants and currently called EPA – Eletronuclear Property Area). For these areas, the planning as well as all actions and protection countermeasures for control and mitigation of the consequences of a nuclear accident are under ELETRONUCLEAR responsibility.

Specific Emergency Groups (Angra 1 NPP and Angra 2 NPP, Infrastructure Services, Head Office and Medical) under the Operation Coordination Superintendency are responsible for the implementation of the actions of the On-site Emergency Plan. Emergency Centers for coordination of the Emergency Plan activities are equipped with redundant communication systems and emergency equipment and supplies are established in different locations inside this area.

The former meteorological data acquisition and processing system was composed of seven (7) meteorological towers is in place. Measurements of meteorological variables are installed and distributed at three levels in a 100 meter height tower (tower A). Wind speed and direction, temperature (DT) and humidity are measured at 10, 60 and 100 meters in this tower. Additionally, three 15 meters satellite towers (towers B, C and D), installed in the vicinity of the site, measure the wind data. Precipitation is also measured near tower A. All these data are send to a computerized system in the Technical Support Center / Control Room of Units 1 and 2, through which the follow up and calculation of the spreading of the radioactive cloud is performed.

The former four meteorological towers have been modified with relocation of one of them and installation of three new towers. In addition, the data transfer is made to CNEN in packages every 15 minutes data transfer to CNEN for emergency management is underway. This new data acquisition system is under implementation but not yet operational.

The Decision Support System Argos (Accident Reporting and Guidance Operational System), which have the capability of making prognosis of up to 72h after event, for atmospheric releases, by means of the Numerical Weather Prediction, produced in Brazil by CPTEC/INPE, has been implemented and is fully operational at CNEN headquarters. Argos was originally developed by the Danish government, but now it is managed by an International Consortium that encompasses about 14 countries.

The On-site Emergency Plan involves several levels of activation, from Unusual Event, Alert, Area Emergency up to General Emergency.

The initial notification for activation of the On-site Emergency Plan is done by the Shift Supervisor from the Control Room, who preliminarily classifies the event and notifies the Plant Manager, as Plant Emergency Group Coordinator, which alerts the coordinators of the other Emergency Groups, the Site Superintendent and the Authorities (CNEN resident inspector, Civil Defense Department of the Rio de Janeiro State, Civil Defense Department of Angra dos Reis City and Eletronuclear Headquarters). The plant personnel and the members of the public inside this emergency zone are warned by means of the internal communication system, sirens and loudspeakers.

Twenty-four-hour / 7-day-a-week on-call personnel, under the responsibility of the Site Superintendent, ensure the prompt actuation of the Emergency Groups. Training and exercises (5 per plant) are performed yearly for personnel on-call. CNEN has also a Twenty-four-hour / 7-day-a-week on-call personnel, to deal with the emergencie situation, on the site and on the general office. Approximately 10 Emergency training and exercises (5 for each NPP) for overall Plant personnel and CNEN personnel are performed yearly.

The utility made a full revision of the methodology of classification of emergency situations using the NEI-99-01, “Methodology for Development of Emergency Action Levels”, Rev 5, 2008. The Regulatory Body also made a full revision of its own emergency procedures after approval of the emergency procedure of the utility.

Emergency training and exercises for overall Plant personnel are performed yearly. Information to the public on how to behave in a situation of nuclear emergency is provided by ELETRONUCLEAR through periodic campaigns, distribution of printed information, the local press and permanent information available in the Site Information Center.

Use of SAMG, developed for both Plants, has been integrated to the emergency Planning procedures.

In 2020, ELETRONUCELAR implemented the pre-distribution of potassium iodide pellets in the Vila Residencial de Praia Brava, a place next to CNAAA, in which emergency actions are in charge of the operator.

In 2021 a new nuclear facility was included in the PEL, the Spent Fuel Dry Storage Unit – UAS, and it was established that emergencies at this facility will be handled by Unit 2. The maximum emergency classification level for the UAS was set at Alert

16(1).2 - Off Site Emergency Preparedness

Brazil has established an extensive structure for emergency preparedness under the so-called Brazilian Nuclear Program Protection System (SIPRON), in according to Federal Law 12.731 from November 21st, 2012.

The SIPRON is now organized as follows:

a) A central body – that is the Institutional Security Office of the Presidency of the Federative Republic of Brazil.

b) Three nuclear emergency response centers, and

c) Five collegiate bodies.

Both the nuclear response centers and the collegiate bodies includes organizations at the federal, state and municipal levels involved with nuclear emergency preparedness and response, as well as those involved with law enforcement agencies and civil defense.

Within SIPRON, the Central Body issued a set of General Norms [16], consolidating all requirements of related national laws and regulations. These norms establish the responsibilities of each of the involved organizations and the procedures for the emergency management centers, communications, knowledge protection and information to the public (SIPRON General Norms are listed in item II.5 of Annex II).

The approach to emergency preparedness and response is based on the application of local resources in the response action to an emergency, applying mainly the resources available at the Municipality (local response level). The State and Federal Governments complement the local resources as necessary. Thus, SIPRON works in collaboration with the Municipal

Government, the State Government and the Federal Government, as necessary to attend nuclear emergencies.

Yearly exercises of the External Emergency Plan are performed, with the purpose of testing its effectiveness with full scale exercises in odd years and partial scale exercise in even years. The Nuclear Emergency Response Preparadness Committee - COPREN-AR performs the planning and evaluation of these exercises. Public information about how to act in a situation of nuclear emergency are provided by Nucleus of Public Communication about Nuclear Emergency – (NUCPEN/AR, acronym in Protuguese), through periodic campaigns, distribution of printed information, local Information programs and permanent information available in the Nuclear Observatory (Former Information Center). The COPREN/AR also participates in the review of the External Emergency Plan.

The exercise has been upgraded along the years as showed in the examples below. The conclusion is that those new actions do validate the plan.

Some of the improvements on the last general emergency exercises were:

- Improvement of previous and post public communication, involving more than 5,000 people in workshop and several other interactions. Federal government communication organization participated for the first time in the exercise.
- Simulated accident extended from 1 to 2 days, including overnight activities.
- A 3rd day included in the exercise to practice and improve public communication.
- Inclusion of practice of public evacuation by sea and by foot (simulating road disruption) which involved more than 500 people, a number considerably higher than the previous exercises.
- Improvement of communication with the regional emergency center by providing video conference between regional, state and federal emergency centers.
- Installation of 3 campaign hospitals in different regions around the plant (in other exercises only one campaign hospital was installed), with the medical staff actually attending more than 1,500 people of the region.
- Use of drones to evaluate radiological conditions in the NPP region.
- Creation of a specific committee for discussion of security issues and planning of exercise exercises – COPRESF.
- Increasing participation of the Ministry of Defense in emergency planning and support actions.
- Development of an information system to record actions taken and related information during the exercise of the External Emergency Plan, including the possibility of training simulation and results evaluation (SIREN).

- Development and application of procedures for storage, control and distribution of iodine tablets.
- Improvements on the Public Communication Group.
- Development of ARGOS system.
- Exercise with interface between Local Emergency Plan and Security Plan.
- Gathering of subsidies for the elaboration of protocols between the public security agencies and the operator's internal security force.
- In-person participation after the COVID pandemic period.
- Use of USIE by IAEA Contact Points, and
- Exploration of the COVID pandemic in the preparation of the exercise scenario.

The interface between safety and security authorities were addressed in the exercise conduction.

The COPREN-AR Committee holds about 7 annual meetings, discussing improvements. Discussions were held on the management of potassium iodide pellets and associated protocols.

The National Plan for Nuclear Emergency Situations (PNASEN) was developed and concluded, with guidelines and recommendations for the members of COPREN-AR and CCCEN. IAEA references were used in the development of this Plan.

A working group was created to develop a Manual for Social Communication on Nuclear Emergency Situations (PCOSEN), using also IAEA references. A plan to publicize activities with the Emergency Plan for communities in the municipality of Angra dos Reis, where the Brazilian nuclear plants are located, is also being restructured.

A working group is under development, under the coordination of CNEN, within the Committee for Articulation in the Areas of Security and Logistics of SIPRON – CASLON, with the objective of establishing a project base threat (DBT) or a threat estimate for the nuclear facilities of the Brazilian nuclear program. Within this process, the National Report on Threats to Nuclear Physical Security (RENASF) was finalized, a document that will serve as input to identify significant threats.

A working group was created to discuss aspects related to cyber threats with the aim of developing a specific standard in this area.

16(1).3 - Overview and implementation of main elements of national plan (and regional plan, if applicable) for emergency preparedness, including the chain of command and roles and responsibilities of the licence holder, the regulatory body, and other main actors, including State organizations.

In December 2021, the Brazilian Nuclear Program Protection Coordination Commission approved the National Plan for Nuclear Emergency Situations (PNASEN).

The PNASEN presents guidelines aimed to preparation, response, recovery, remediation, and closure actions, to be adopted within the scope of SIPRON, in the face of a nuclear emergency situation, in order to protect the environment, the health of the public, the nuclear facility workers and the responders.

The responsibility for the elaboration and coordination of the External Emergency Plan (PEE) lies with the Civil Defense Department of the Rio de Janeiro State.

There is a multidisciplinary committee, the Nuclear Emergency Response Planning Committee, COPREN/AR, whose function is, among others, to propose improvements to be tested and, if approved, incorporated into the External Emergency Plan, in addition to planning, developing scenarios, coordinate and evaluate emergency exercises. The COPREN/AR organizations also actively participate in the revision of External Emergency Plan.

The Coordination and decisions related to off-site actions in an emergency are taken by the Nuclear Emergency Coordination and Control Center (CCCEN, acronym in Protuguese) located in the city of Angra dos Reis. CNEN and the Utility actively participate in this Center. When needed CNEN perform specific recommendations related to radiological protection of the people and the environment. This Center is activated on an ALERT situation.

The State Center for Nuclear Emergency Management (CESTGEN, acronym in Protuguese) located in Rio de Janeiro city and the National Center for Nuclear Emergency Management (CENAGEN, acronym in Portuguese) locatd in Brasilia city operate giving support to CCCEN when needed. A Nuclear Emergency Information Center (CIEN) is established in the city of Angra dos Reis to support CCCEN in the public communication activities.

This centers' activities during an emergency are established in SIPRON General Norms[17], [18] (See also II.5 of Annex II) and is stated at the External Emergency Plan of the State of Rio de Janeiro, approved by the State of Rio de Janeiro Decree 44.384, of September 11th, 2013.

There are yet a navy hospital specialized for nuclear accidents in Rio de Janeiro city and a small hospital to deal with workers near the site.

Emergency Response Plans for CNEN and other involved agencies have been prepared, and detailed procedures have been developed and are periodically revised. The CNEN's Plan for Emergency Situation in Nuclear Power Reactors was updated in 2015.

This CNEN's Plan establishes a technical group to evaluate an emergency (CORAN) and a high-level group (CORE) to make the recommendations for the governmental agencies, both in its headquarters in Rio de Janeiro city.

CNEN has representatives in the following emergency centers CCCEN, CESTGEN, CNAGEN, mentioned above, and NPP Technical Support Center.

IRD is a CNEN's Institute and is part of the emergency notification system coordinated by DRS. It is responsible for the implementation of field actions in response to an emergency situation. The field data collected, after preliminary analysis by IRD specialists, is sent do CNEN headquarters (CORAN), compared with the ARGOS prognosis and used to drive CNEN's recommendations (CORE) to the Emergency Centers.

The Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA, acronym in Portuguese), through the Directorship of Environmental Protection – (DIPRO, acronym in Portuguese), supports CCCEN with technical resources and equipments in the event of environmental issues during nuclear accidents at the Angra site. IBAMA was accepted as a member of CCCEN and COPREN in 2013. In 2015, DIPRO elaborated its first review of the Complementary Emergency Plan (PEC).

The Federal Police and Civil Police of the State of Rio de Janeiro became CCCEC members in 2020.

16(1).4 - Implementation of emergency preparedness measures by the licence holders.

16(1).4.1 - Classification of emergencies

The classification of emergency situation is done using the emergency procedure of the utility – Local Emergency Plan (PEL). This procedure uses as reference the document NEI-99-01, "Methodology for Development of Emergency Action Levels", Revision 6, November 2012.

The emergency classes are:

- Non-Usual Event.
- Alert.
- Area Emergency, and
- General Emergency.

16(1).4.2 - Main elements of the on-site and, where applicable, off-site emergency plans for nuclear installations, including, availability of adequate resources and authority to effectively manage and mitigate the consequences of an accident.

The utility has an emergency group besides the control room for each utility, and other groups for infrastructure outside the NPP.

The main elements are described in Article 16(1).1 - On Site Emergency Preparedness

16(1).4.3 - Facilities provided by the licence holder for emergency preparedness (if appropriate, give reference to descriptions under Article 18 and Article 19 (4) of the Convention, respectively).

In order to comply with the Angra 2 TAC requirements related to emergency planning ELETRONUCLEAR awarded a contract to the Federal University of Rio de Janeiro to develop a comprehensive study on evacuation and sheltering possibilities. This study addressed, through computer simulation, movement of people and vehicles in different evacuation scenarios. In addition, availability of sufficient transportation, training of drivers and suitability of sheltering installations were also evaluated. The resulting recommendations were incorporated into a long-term action plan, already implemented. For this purpose, formal agreements have been signed to provide the Angra Municipality and Rio de Janeiro State civil defenses with better infrastructure for public shelters, health care and other measures related to emergency preparedness. These included an agreement between ELETRONUCLEAR and the National Transports Infrastructure Department (DNIT) to improve the BR-101 federal highway passing through the Angra site, at a cost of about 7 million US dollars provided by ELETRONUCLEAR. The work, already finished, comprised restoration of 60 km of asphalt paving, of the road drainage and emergency lanes at the roadsides, slope stabilization at the road hill side, building of crossings, underpasses and pedestrian passageways as well as elimination of three road bypasses.

In the same area of emergency preparedness, to provide an extra mechanism to monitor the environment, CNEN has installed an On-Line Radiation Monitoring System in the emergency planning zone (EPZ). The system is composed of thirteen Geiger Müller detectors disposed strategically around the Angra site. All data are locally collected and sent to the Institute of Radiation Protection and Dosimetry (IRD) by modem connection.

16(1).5 - Training and exercises, evaluation activities and main results of performed exercises including lessons learned.

COPREN/AR established that a full-scale exercise should be carried out biannually. On the other hand, one partial exercise should be carried out between two full-scale exercises. Full-scale exercises were performed in 2007, 2009, 2011, 2013, 2015 and 2019, some of then with the presence of international observers from fifteen countries. Partial exercises ware carried out in 2016, 2017, 2018 and 2020 and another one is scheduled for October 2022. Due to Covid the exercises carried out in 2020 and 2020 were in hybrid mode, as some institutions participated in virtual mode and others in face-to-face mode.

There are three types of exercises performed in Angra dos Reis city and in all of them the Regulatory Body participates.

The first one is carried out by the utility on the site. There are five exercises for each unit per year. During this exercise is verified that all groups that deal with an emergency are available with appropriate infrastructure and resources. In these exercises, some improvements implemented based on the lessons learned in the Fukushima accident are also tested, such as the use of mobile equipment for energizing buses and equipment for injecting water to drain the core. Severe accident scenarios are also developed, and the use of severe accident procedures is exercised.

The second type is a communication exercise of the SIPRON. There is at least one exercise of this type each 2 months.

The third exercise is an annual one involving all organizations that have actions off-site, including the Regulatory Body and the Utility. Each organization has its own emergency plan, and on this exercise, the actions are tested. This exercise consists of a scenario beginning with a Non-Usual Event and has an evolution until a general emergency with evacuation of the population of the neighborhood of the site.

In odd years the exercise includes the displacement of all organizations involved in response activities and population. In even years, the same type of exercise is performed but without personnel displacement.

On the annual exercises there are meetings before and after the exercise. In the meeting before, the recommendations and corrective actions of the past exercise are revisited, and the implementation status reviewed. After the exercise a meeting is done to obtain an initial evaluation and a detailed report is issued 3 months later.

Brazil, as IAEA contact point, has participated in most recent ConvEx exercises. In 2017, Brazil sent an observer to the ConvEx-3 exercise in Hungary and actively participated in the last ConvEx-3, in the United Arab Emirates, keeping the National Nuclear Emergency Management Center and the Institute of Radioportation and Dosimetry staffed during the entire period of the exercise.

The last ConvEx-3 exercise was an excellent opportunity to test the Brazilian structure for responding to an international nuclear emergency situation. The use of social media Simulator was a milestone for learning about issues related to public communication.

Brazil also participates in ConvEx-1b, on 14 April 2021, ConvEx-2a exercise, on 27 May 2021, ConvEx-2b exercise, carried out in the period of 9th to 11th March 2021 and 7-9 March 2022.

16(1).6 - Regulatory review and control activities.

The Regulatory Resident Inspection follows all real demand or exercises of the emergency plan. On each demand, the inspectors perform also an evaluation of the shift and the infrastructure needed to deal with the emergency.

Additionally an audit is performed each 6 months to verify the infrastructure and resources needed, the records of the exercises and when applicable, the implementation of corrective actions.

There are two different aspects linked to the calculation bases from the preparedness point of view. One is methodology (model), other is input data. In a complex terrain, like Angra's, quality and quantity of input data make a noticeable difference. CNEN has been making a significant effort for improving both aspects. The model inside Argos (Rimpuff) is no different from this point of view than models used by several countries. The input data are not only a question of need, but on purpose and availability. Right methodology and good input data target the other end of the process of impact assessment, the "visible" part of the response itself, two different challenges, plume trajectory and content. To know what is in the plume (source term) without knowing where it is (trajectory) would make the response quite more difficult and complex in terms of protection actions. CNEN has been making an extensive work to address both challenges, requiring the NPPs Operator to have 7 (seven) meteorological towers in operation onsite, increasing NWP to 1 km resolution, developing statistically the met towers observations inside the NWP, applying nudging techniques to initialize the Wind Field using surface observations on real time, having INPE/CPTEC experts working together with CNEN's experts. This has been done with cooperation of experts from all over the world. Part of this was achieved during the recent project with European Commission cooperation. The appropriate source term to be used for accidents is in intense debate, all around the world, because of the intrinsic difficulty in guessing which part of the core inventory will be available to be released in a real case. History shows that no country was able to guess precisely the source term for real severe accidents. We have been taking precautions and a conservative approach, i.e. to pre-prepare tables of nuclides most likely to be released depending on kind of accident in course, which will depend on initial information from the plant. This has necessarily to be compared to monitoring stations aftermath. Other improvement we have been seeking is to consider the actual inventory of our NPPs instead a theoretical one. And last but not least, we permanently pay attention to the debate in the international scientific community.

Article 16 (2) Information to the public and neighboring states

16(2).1 - Overview of the Contracting Party's arrangements for informing the public in the vicinity of the nuclear installations about emergency planning and emergency situations;

Regarding information to the public, SIPRON norm NG-05 [18] establishes the requirements for public information campaigns about emergency plans. The first public information campaign was conducted by FURNAS in 1982 before the first criticality of Angra 1. Several other campaigns have been conducted on a regular basis. The campaigns combine information on both on-site and off-site emergency plans, including the population living in the 15-km area around the plant. These campaigns include training courses for community leaders and public-school teachers, guided tours for students from public schools to the nuclear power plant, educational lectures in community associations and the distribution of informative material on a house-to-house basis, to local newspaper, radio, TV broadcast, buses and bus stations, schools, community association, churches, and administrative offices. These campaigns are conducted by a joint working group composed by personnel from the federal, state and municipal civil defence, state fire brigade, ELETRONUCLEAR volunteers, and CNEN and ELETRONUCLEAR technical and public information personnel.

In addition, visitors to the Site Information Center (over 20,000 in 2021), receive general information concerning, among other, nuclear energy generation, the Angra site, the operation of the plants, as well as the site emergency plan.

In June, 2018, the information center was closed in order to undergo extensive modernization. After an eight-month reform, the space reopened with a new name – Nuclear Observatory – and equipped with the latest technology, including a video wall and interactive screens. The reform also guaranteed greater accessibility. Even with the center closed, the company still received programmed visits. One of the intended initiatives is to restart the visit of students from the public educational system of the towns located around the Angra Nuclear Power Station. The goal is to double the number of annual visitors, going from 20,000 to 40,000.

In 2021, COPREN/AR deliberated to create a Working Group with the purpose of preparing a social communication manual, aimed to continuous clarification of the population surrounding the Almirante Álvaro Alberto Nuclear Power Plant on preparation and response to the nuclear emergency. The manual should be approved in 2022.

Brazil considers one of the most important parts of the response to a nuclear emergency situation is an effective, reliable, sufficient, transparent, clear and simple public communication.

Currently, the siren system is tested at 10:00 AM on 10th of each month. A silent test of the sirens is also done daily. The information about these tests is included in the calendar that is distributed every year to the whole population within the ZPE-5. These calendars also present the basic information on the emergency planning to the population. In addition, preceding every siren test or a general emergency exercise, specific flyers are distributed in relevant areas and handed along main routes to passing drivers and buses, and vehicles fitted with loudspeakers circulate through villages making announcements to ensure that all residents have been properly informed.

Furthermore, Eletronuclear has been strengthening the company's relations with the traditional communities situated around the Angra NPP, which consist of native Brazilian and quilombo villages. The quilombos are communities inhabited by the descendants of runaway enslaved Afro-Brazilian populations. These villages were established during the times when Brazil was still a Portuguese colony and when the country was a monarchy.

The company has given support to these communities during the coronavirus pandemic and is establishing projects to attend to their most urgent needs, as with sanitation, for example. Also, Eletronuclear has promoted visits to the Angra NPP and the company's Nuclear Observatory.

Figure 21 – Nuclear Observatory

16(2).2 - Arrangements to inform competent authorities in neighbouring States, as necessary.

It should be noted that, due to the particular geographical location of the Angra plants, no radiological impact is expected in any neighboring countries, even in the improbable event of a major release. Notwithstanding that fact, Brazil has signed both the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency, and a bilateral agreement with Argentina for notification and assistance in case of a nuclear accident.

16(3) - Fukushima Lessons Learned

Fukushima event insights have led to modifications in the Site Emergency planning, where the most important are:

- Planning of personnel and resources for simultaneous emergency conditions in both Plants.
- Implementation of procedures for use of additional mobile equipmente for control or mitigation of the event.
- Signing agreement of prompt notification of severe weather or other severe external event conditions with the Angra dos Reis Civil Defence monitoring center and development of a procedure for response to the different events.
- Incorporation of the SAMG team to the Technical Support Center emergency staff.
- Improvement of the realism of the exercises, as far as duration, actions of the different emergency teams and use of Plant simulators to provide the actual event development.
- Expanding of the evacuation routes, with the successfully tested evacuation by sea.
- Upgrading of the emergency centers.
- Use of mobile equipment in the internal exercises of the Local Emergency Plan

There is still considerable work to be done to upgrad the existing Emergency Centers, in special the ones external to the Plants to meet post Fukushima expectations. Further work is also needed to provide protection for Plant personnel and people living in the Site neighborhood, in case of early releases.

Brazil has made efforts to integrate Emergency, Preparedness and Response with Nuclear Security Response to improve the management and interface of these sensitive domains.

ARTICLE 17 – SITING

Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented:

(i) for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;
(ii) for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;
(iii) for re-evaluating as necessary all relevant factors referred to in sub-paragraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installation;
(iv) for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation.

Article 17 (1) Evaluation of site related factors

- ***Overview of the Contracting Party's arrangements and regulatory requirements relating to the siting and evaluation of sites of nuclear installations, including applicable national laws not mentioned under Article 7 of the Convention:***

The Brazilian siting regulation, CNEN 09/69[6] and CNEN-NE-1.04, Licensing of Nuclear Installations [5], require a site approval before the issuance of a construction authorization. The Angra site was approved for 3 nuclear power units. As established in these regulations, a site approval is issued after Regulator review and acceptance of, at least, the following information:

- General and safety characteristics of the proposed plant design.
- Population distribution, existing and planned roads, use of the area surrounding the site and distances to population centers.
- Physical characteristics of the site, including seismology, geology, hydrology and meteorology.
- Preliminary evaluation of potential effects on the environment resulting from plant construction and operation (normal and accident conditions);

- Preliminary site environmental pre-operational monitoring plan

Site related factors, in particular, those that affect nuclear safety, have been reviewed at specific times, that is, before issuance of the construction licenses for each one of the 3 nuclear power plants, during plant Periodic Safety Reviews or whenever new knowledge about external events that might affect the Angra site arose, indicating the need for such reviews.

The evaluation of all site related factors affecting the safety of the nuclear installations was initially performed for the design of the Angra 1 nuclear power plant in the 1970s. The American Weston Geophysical Corporation was involved in the geological and geophysical investigations of the region and site, together with Brazilian organizations. These investigations were reviewed during the 1980s for the design of Angra 2, the second plant to be built in this same site. The seismic catalogue and the geological faults were updated in 1998 by involving seismologists of the Institute of Astronomy and Geophysics of the University of São Paulo, considering the state of the art at that time. At that time, the installation of a seismometer was planned for the site, in order to study regional seismological aspects as micro-seismic events, analyze the propagation and attenuation of seismic waves and the crustal regional structure. This seismographic installation has been operating since the beginning of 2002.

As a preparation for the restart of Angra 3 construction, a Probabilistic Seismic Hazard Analysis (PSHA) was performed by specialists from Pontificia Universidade Católica – PUC, RJ (1999-2000), considering the previously mentioned seismic catalogue. The original horizontal Peak Ground Acceleration (PGA) of 0,1 g for Safe Shutdown Earthquake, which was deterministically adopted for the site, was confirmed by the PSHA.

In the context of the Angra 1 Periodic Safety Review (PSR), performed in 2004-2005, all external events assumed for the design of the plant structures have been reviewed. The seismic catalogue was updated considering seismic events up to December 2003. The seismic hazard analysis was updated in 2005.

The result of the PSR, as already reported in previous Brazilian National Reports, was that the original assumptions concerning seismic design response spectra, maximum floods and storms as well as off-site explosions were found to be still valid. A research on tornado events in the region (not considered in the original design basis) was also started at that time and presented a negligible probability of occurrence for the site.

A recent comprehensive review of site conditions was carried out, contemplating the newest version of the applicable regulations, in preparation for the restart of construction of Angra 3. Natural external events such as explosion, aircraft crash, meteorological and severe weather conditions, external flooding and earthquakes, as well as human made external events, were re-evaluated by experts from different research institutes in Brazil, considering the state of the art. The results of this review are presented in Article 17(3).

Furthermore, in the context of the Fukushima response Plan actions, it was again confirmed, as a first step of the evaluation, that the existing Angra Site Design Bases for external events were up to date in accordance to international practice, and that the protection measures adopted were adequate.

The second step of this evaluation consisted in determining the available margins of the existing design to accommodate extreme external events. The results are reported in Section D, specific for response actions derived from the Fukushima event.

The site related design criteria for the first two plants, Angra 1 and Angra 2, built in the Angra site are listed below:

Angra 1 was designed to resist the following external events:

- Two Earthquake levels are considered in the plant design: OBE (Operating Basis Earthquake) and SSE (Safe Shutdown Earthquake; this is also named as DBE – Design Basis Earthquake for this plant design).
- TNT explosion (20 tons) from a truck on the road close to the site, considered according to NRC RG 1.91 (1975).

Angra 2 was designed to resist the following external events:

- Two Earthquake levels are considered in the plant design: DBE (Design Basis Earthquake) and SSE (Safe Shutdown Earthquake).
- SSB load case, from the combined effects of a Safe Shutdown Earthquake (SSE) and a Burst Pressure Wave (BPW) is also considered for the main class 1 structures (structures that are required for plant shutdown and residual heat removal in case of SSE).
- TNT explosion (23 tons), considered according to NRC RG 1.91 (1978).

Both Units 1 and 2 were designed for the following external events:

- SSE level earthquake corresponding to 0,1g horizontal peak ground acceleration at the outcropping rock,
- External flooding: considering 10000 years return period flood and that the water will accumulate on the site to a maximum height of 45 cm;

- A conservatively adopted wind speed of 45 m/s and ASCE Standards used for design.

Due to the very low probability of occurrence the following external events were not considered in the design of Units 1 and 2 at Angra site:

- Tornadoes, waterspouts, and hurricanes.
- Tsunamis.
- Aircraft crash.

The corresponding Angra 3 Design Criteria for External events are presented in section 17(3).

The demographic distribution in areas that affect the emergency preparedness plan continues to be evaluated. An updating of the detailed population census in the vicinity (5-km radius) of the power plant was conducted in 1996. In addition of the 1996 data, collected by ELETRONUCLEAR, new data on population density in the vicinity of the site is available from the 2002 national census, and its update performed in 2007.

Article 17 (2) Impact of the installation on individuals, society and environment

The basic criterion concerning the impact of introducing a new industrial installation in a given site is that it should have minimum adverse effects on individuals, society and the environment.

For a nuclear power plant, the major impact is associated to the potential of radioactive releases, in normal operation or accidental conditions. Minimization of this risk is ensured by a design that adequately incorporates all levels of the “defense in depth” concept as demonstrated by deterministic safety analyses and complemented by probabilistic safety analyses.

The nuclear licensing of a new plant consists in the verification of compliance to the above criteria before issuing construction and operation licenses. These same criteria are monitored during plant operation and in particular, when performing a plant PSR, for authorization of continuation of plant operation.

Control and mitigation of Beyond Design Events are covered by symptom-oriented Emergency Operating Procedures and in case of Severe Accidents, by Severe Accident Management Guidelines.

A well-structured Emergency Plan is the last level of defense in depth for protection of the population.

The level of compliance of the Brazilian nuclear power plants to the above criteria is described in the text of the different Articles of this report.

The environmental licensing for authorization of construction and operation of a new project, contemplates, besides of radiation risk covered by the nuclear licensing, all other potential adverse effects arising from plant construction and operation activities on the population and environment in the area of influence of the plant are covered by the environmental licensing.

For example, the impacts from NPPs Angra-1, 2, 3, and the Radioactive Waste Management Centre are controlled by the environmental programs monitoring, such as: monitoring waste generation, quality of the drinking water; quality of the saline waters; quality of the wastewater; monitoring of the marine fauna and flora in the operational phase; monitoring of the plankton zones (phytoplankton, zooplankton, benthos and nekton). The environmental direct influence area has been established as the radio up to 15 km from the CNAAA (Admiral Álvaro Alberto Nuclear Power Station, in Angra dos Reis), which encompasses the municipalities of Paraty and Angra dos Reis with a total of 206,845 inhabitants (data from 2010 of the Brazilian Institute of Geography and Statistics - IBGE); and indirect influence area has been established as the radio up to 50 km from the CNAAA, which cover sixteen municipalities with a total estimated of 802,749 inhabitants (IBGE - 2010).

In December 2009, IBAMA issued the first amendment to the Installation License Nr.591/2009 including a new specific requirement related to the Paraty-Cunha Road implementation.

In March 2014, IBAMA issued the unified Operation License nr. 1217/2014 for the Almirante Álvaro Alberto Nuclear Power Site – CNAAA authorizing the operation of Angra 1 and Angra 2 NPPs, as well as the Waste Management Center – CGR and ancillary facilities for ten years.

At the issuance of the unified operating license to CNAAA in March 2014, the Installation License nr. 591/2009 was revised again generating the second amendment with 33 exclusive requirements for Angra 3 plant construction.

Article 17 (3) Re-evaluation of site related factors

A re-evaluation of site parameters as well as of the external events considered in the design of the existing Nuclear Power Plants, Angra 1 and Angra 2, performed in the context of the Angra 1 Periodic Safety Review (PSR) and ELETRONUCLEAR Fukushima Response Plan, have confirmed the validity of the original assumptions.

Similar results have been obtained from the subsequent PSRs, for Angra 2, completed in 2012 and the second Angra 1 PSR, completed in mid-2014, as well as in the first step of the evaluation performed in the scope of the ELETRONUCLEAR Fukushima Response Plan (see 17(1)).

As documented in the Angra 3 Preliminary Safety Analysis Report (PSAR) recent re-evaluations of the design criteria for external events, were performed for the new Angra 3 plant. This re-evaluation resulted in some external event design criteria differences when compared to the ones applied to Angra 1 and 2, basically due to new requirements in the present revision of the regulations applied for Angra 3.

These differences, as discussed below, do not have a substantial impact on the original site external events design criteria and are considered additional improvements agreed between CNEN and ELETRONUCLEAR to be applied for a new plant.

- All class 1 structures, systems and components shall be designed to resist a SSB load case, from the combined effects of a Safe Shutdown Earthquake (SSE) and a Burst Pressure Wave (BPW). The original horizontal Peak Ground Acceleration (PGA) of 0.1 g for SSE, which was deterministically adopted for the site, was confirmed by a Probabilistic Seismic Hazard Analysis (PSHA).
- All class 1 structures shall also be designed to resist tornado effects and an explosion from a TNT-loaded truck on the road in the vicinities. The tornado hazard analysis showed that a design for a medium EF3 (Enhanced Fujita scale) is a conservative assumption for the site.
- The maximum wind velocity was revised, taking into account the available data from CNAAA meteorological towers, Unit 3 location in the site and a 100-year-return period. Therefore, a maximum basic wind speed of 41.0 m/s was adopted and the Brazilian Standard for wind loads on civil structures shall be used to determine the characteristic wind speeds and the pressure coefficients. This revision does not represent a significant change of the site parameters adopted for Units 1 and 2, where a wind speed of 45 m/s was conservatively adopted, but other standards, such as ASCE, were used for design.

- Regarding water level (flood), precipitation and sea level were re-evaluated without significant consequences on plant design. The drainage system in the vicinity of Unit 3 is designed considering rainfalls with recurrence period of 10,000 years. Unit 3 ground-level is 1 (one) meter higher than Units 1 and 2. The access to safety buildings are placed 45 cm above ground level (+6.15 m), assuring that no flood will affect the plant operation. A detailed study completed in November of 2013, ELETRONUCLEAR Fukushima Response Plan. The design flooding level of the Angra 1 and Angra 2 Plants can withstand the heaviest rain in 70.000 years, with simultaneous blockage of all the site drainage channels (landslide) and concurrent with the maximum tide. The study indicated that there is no need of special measures against extreme flooding, except for some specific points where the flooding barriers are either damaged or have been removed. Work on these points have been or are underway
- The evaluation of existing margins of the Plants design for protection against external events, performed in the scope of Angra 1 and 2 evaluations of the ELETRONUCLEAR Fukushima Response Plan, indicate that its design is sturdy and that the Plants can withstand external event magnitudes substantially higher than the limits considered in the Design Bases.

In the “stress tests’ assessment report the specific Angra site external events have been assessed and a preliminary evaluation of the existing margins in case of beyond design occurrences was performed.

Later contracts with universities, and specialized technical organizations have produced detailed margin evaluations with the following results:

- External flooding: detailed study completed in November of 2013. The design flooding level of the Angra 1 and Angra 2 Plants can withstand the heaviest rain in 70.000 years, with simultaneous blockage of all the site drainage channels (landslide) and concurrent with the maximum tide. The study indicated that there is no need of special measures against extreme flooding, except for some specific points where the flooding barriers are either damaged or have been removed. Work on these points have been or are underway.
- Landslides: detailed study completed in November 2013. The Angra site is on the coast surrounded by nearby mountains and therefore subjected to possible landslides. Accordingly the surrounding slopes have been stabilized, provided with superficial and deep drainage channels and slope movement is continuously monitored. The study evaluated the existing protection measures, updated the geologic and geotechnical mapping around the site and performed the analysis

of an extreme case where one of the full slopes slides down on to the site.

The results of this extreme case is that some site facilities (e.g. the switchyard) might be affected but the Plants would not be reached. The study further recommended reinforcement of some barriers, implementation of additional slope monitoring instrumentation. These recommendations are being implemented.

- Earthquakes: Brazil is a low seismicity country. The design Safe Shutdown Earthquake horizontal peak ground acceleration (PGA) value for the site was established at 0.1g, at the outcropping rock. The assessment of the existing margins against earthquake have been done a) by walkdown evaluation by international expert with large experience in seismic analysis and b) performance of a seismic PSA.

The walkdown evaluations results indicated that the Angra 1 Plant should resist to earthquakes with PGA between 0.2 g and 0.3g, and for Angra 2, PGAs betwen 0.25g and 0.35g, substantially higher than the design SSE.

A full seismic PSA, performed for Angra 2, and completed in December of 2015, indicated that the Angra 2 Plant could resist to an earthquake with a PGA of up to 0.4g, confirming the previous walkdown estimation (see also Article 14, Angra 2 PSA results). The Angra 1 seismic PSA has not been started yet, but similar results are expected.

- Sea movements: the Angra site is located in a small bay (Itaorna bay) inside a large bay (Angra dos Reis bay) protected by a large amount of islands from open sea hazards.

Tsunamis are not included in the Plants external events design bases nor in the subsequent reevaluations of the site external events (see also Article 17(1) and 17(3)). No tsunamis have ever been reported to reach the Brazilian coast, and the distance from tectonic plaque borders, size of continental shelf and other possible causes would result in minor effects at the site, so no assessment of tsunami consequences was done.

Studies completed in October of 2014, have been performed to reevaluate the maximum wave heights to reach the Itaorna Bay considering extreme external events, in this case hurricanes. Hurricanes reaching the Brazilian coast are very rare; only one has been reported up to now reaching the coast in the southern part of Brazil. Calculations considering extreme climatic events, associated to the worst wind direction and highest intensity as well as maximum sea level have resulted in wave heights between 4,8 and 5,7 m, for a recurrence time of 10.000 years. These wave heights are higher than the design waves (4,4 m) considered for the dimensioning of the wave breaker that protect the Plants, endangering its stability and eventually exposing the Plants.

Verification of the behavior of the wave breaker to these additional loads is underway, and in case of need it will be reinforced.

- Tornados: tornados were not considered in the external event design bases for the Angra Plants, because of its very low probability of occurrence in the 10-7 per year range. Studies for evaluation of a tornado impact to the Plants structures was performed and a list of Structures, Systems and Components(SSC) potentially exposed to the effects of a tornado with indication of need for protection or not, was prepared. In a few cases additional protection is needed, but no jeopardizing of the plants safe shutdown was identified.

- ***Regulatory review and control activities***

In March 2012, CNEN agreed to consider the concept of tornadoes proposed for Angra 3 in the Eletronuclear technical report SE.T/3/BP/011006 Rev.1. The conclusions from the discussions with the CNEN for Angra 3 will serve as a basis for evaluating the improvement safety measures necessary for Angra 1 and Angra 2. Studies for evaluation of a tornado impact to the Plants structures was performed in ELETRONUCLEAR Fukushima Response Plan and a list of Structures, Systems and Components (SSC) potentially exposed to the effects of a tornado with indication of need for protection or not, was prepared. In a few cases additional protection is needed, but no jeopardizing of the plants safe shutdown was identified.

Article 17 (4) Consultation with other Contracting Parties likely to be affected by the installation

Due to the special geographical situation Angra site, no other Contracting Party is expected to be affected by the construction and operation of the nuclear power plant. Therefore, no consultation with neighboring countries is included in the licensing process.

Even so, Brazil has signed both the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency, as well as a bilateral agreement with Argentina for notification and assistance in case of a nuclear accident.

Since 2017, Eletronuclear represents Brazil in the Latin-America Independent Nuclear Oversight (Lat-iNOS) Project, a joint project carried out together with the nuclear operators of

Mexico and Argentina, focused on the continuous improvement of nuclear safety through review processes based on IAEA/WANO Guidelines. Since the creation of the project, there have already been 7 missions distributed among the participating countries, covering areas such as equipment reliability, leadership, operational experience, operations, and maintenance, among others.

ARTICLE 18 – DESIGN AND CONSTRUCTION

Each Contracting Party shall take the appropriate steps to ensure that:

(i) the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defense in depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur;

(ii) the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;

(iii) *the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the manmachine interface*

Article 18 (1) Implementation of defense in depth

The design of the Brazilian nuclear power plants is based on established nuclear technology in countries with more advanced programs. The licensing regulation CNEN-NE-1.04[5] formally requires the adoption of a "reference plant" which shall have a similar power rating, shall be under construction in the country of the main contractor, and shall go into operation with sufficient time to allow the use of the experience of pre-operational tests and initial operation.

Angra 1 was designed and constructed with American technology, which incorporates the concept of defense in depth, including the use of multiple barriers against the release of radioactive material. Safety principles such as passive safety or the failsafe function, automation, physical and functional separation, redundancy and diversity was also incorporated in the design.

Extensive use was made of American codes and guides such as ASME section III, ASME section XI, IEEE standards, ANSI standards and US NRC Regulatory Guides. Operating experiences from American plants, especially the fire at Browns Ferry and the accident at Three Mile Island, were incorporated through modification in the design, during the construction phase. Design review and assessment was performed through preparation of a PSAR and a FSAR, by FURNAS and its contractors, which were evaluated by CNEN during the licensing process.

Construction adopted a quality assurance program, which encompassed all activities related to safety conducted by FURNAS and its contractors and subcontractors. CNEN monitored the implementation of the quality assurance program through the regulatory inspection program and with the establishment of a resident inspector group during the construction phase.

In a similar manner, Angra 2 has been designed and constructed with German technology, within the framework of the comprehensive technology transfer agreement between Germany and Brazil. The German counterpart assumed technical responsibility for the jointly built plant during construction up to initial operation.

The plant is referenced to the Grafenrheinfeld nuclear power plant, recently shutdown definitively as a result of the German decision of abandon nuclear energy generation. The problem of long storage time of early manufactured components was dealt with by an appropriate and careful storage process, which involved adequate packaging, storage, monitored environmental conditions and a periodical inspection program. The electromechanical erection was performed by the Brazilian consortium UNAMON, which started its activities at the site in January 1996, with a strong technical support from ELETRONUCLEAR, Siemens and foreign specialized companies. A specific Quality Assurance Programme was established for the erection phase, including the main erector activities. Erection activities supervision and inspection were carried both by the main erector as well as by ELETRONUCLEAR. The electromechanical component pre-operational tests were performed in this phase, by the commissioning staff under the plant designer responsibility, as soon as allowed by the erection process.

For the Angra 3 design, the “defense in depth” concept was applied considering the concept evolution, where much more emphasis in the beyond design level is put nowadays as at the time of construction of the Angra 1 and 2 Plants, incorporating already internationally adopted beyond design measures (see Article 6, Angra 3), that in Angra 1 and 2, were or are being introduced through backfits.

The emphasis in the beyond design level, more specifically the 4^{th} and 5^{th} level of defense in depth that deals with accident management and confinement protection measures, that is prevention and mitigation of beyond design events including severe accidents. In spite of differences in detail, the following measures apply to the two plants in operation. The same measures will be implemented in Angra 3.

Prevention:

- PSA studies to identify and correct design and operation procedures weaknesses as well as risk management for maintenance activities (reduction of CDF).

- Symptom oriented Emergency Operating Procedures (EOP) with Critical Safety Function monitoring, including control of complex sequences in the beyond design range.
- Provision of additional means (portable Diesels, pumps, additional heat sink) and incorporation of these means into the EOPs, for the case of total loss of AC power and ultimate heat sink (post Fukushima measures still under implementation)

Mitigation:

- Severe accident Management Guidelines with incorporation of additional features (passive catalytic recombiners, filtered containment venting and containment sampling system). These measures are still being implemented.
- Incorporation of the use of SAMG in the Emergency Planning exercises.

The following recent improvements, all related to maintain the integrity of physical containment in case of beyond design events:

- Hydrogen Reducing System, which reduces the Hydrogen content in the containment continuously by means of PAR's (Passive Autocatalytic Recombiners) during normal operation, design basis accidents (DBA) as well as after beyond design basis accident (BDBA).
- Nuclear Sampling System for the Containment Sump and Atmosphere, which is designed for the purpose of obtaining high quality samples of the containment atmosphere even after a BDBA. In addition, also the containment sump can be sampled after BDBA.
- Containment Filtered Venting System, which vents the containment atmosphere through special filters to prevent loss of containment integrity in case of BDBA like core melt causing high pressure inside the containment.

Article 18 (2) Incorporation of proven technologies

After completion and initial operation of Angra 2 no other NPP design and construction work has been done in Brazil except design modifications for the Angra 1 and 2 plants and some work of continuation of adaptation and upgrading of the Angra 2 design documentation to Angra 3 conditions. This part of the Angra 3 design and engineering work is assigned to ELETRONUCLEAR design and engineering Superintendence (see Fig. 17), under the Technical Directorate.

The most significant modifications made in Angra 1 were the steam generators replacement in 2009 and the reactor pressure vessel head replacement in 2013. The original steam generators, of the Westinghouse D3 type, had the tube bundle made of Inconel 600 as well as the penetration welds of the RPV head, manufactured by Babcock & Wilcox. This alloy turned out to be very susceptible to primary water stress corrosion leading to an international program of substitution. Although the original head had more than 12 years effective full power that ranks it as high susceptibility, no indication was found during inspections. Together with the head all control rod drive mechanisms and thermal insulation have also been replaced. The new head was made by Mitsubishi Heavy Industry and the new welds were made with alloy 690 which is not susceptible to the primary water stress corrosion cracking. In the new steam generators, the tube material was also changed from Inconel 600 to the 690 alloy.

The new head was made by Mitsubishi Heavy Industry and the new welds were made with alloy 690 which is not susceptible to the primary water stress corrosion crack. The head replacement will ensure the safety and reliability of Angra 1 the long term, contributing to extending the life of the plant. The old head and the old CRDM were stored in the mausoleum with the steam generator replaced.

The new steam generators and RPV head, manufactured with updated proven technology, will ensure the safety and reliability of Angra 1 in the long term, and are an important contribution to the Angra 1 life extension programme.

For Angra 2 no major modifications as for Angra 1have been installed to date. The performed Plant modifications are related to upgrading and modernization of Plant systems, as for example, the full substitution of the conventional Reactor Control I&C (non safety) by digital I&C, to safety improvements, as the interconnection of the two sets of emergency Diesel generators, or also to beyond design measures backfitting, as upgrading of Primary and Secondary Bleed&Feed equipment or installation of passive catalytic recombiners.

Due to the long delay of Angra 3 construction, new design features, resulting from technology development, have been incorporated in the design, especially in the area of instrumentation and control, where full Digital I&C (DIC) will be installed for non safety as well as for safety I&C systems. However, only proven technology already used in other plants is being used as reference.

One major concern for Eletronuclear and possibly to other companies in countries that have German designed nuclear power plants, concerning proven technology for the coming years, results from the German decision to abandon nuclear power generation, with the last German Plant shutting down in 2022.

Article 18 (3) Design for reliable, stable and manageable operation

18 (3).1 Overview of the Contracting Party's arrangements and regulatory requirements for reliable, stable and easily manageable operation, with specific consideration of human factors and the human–machine interface (see also Article 12 of the Convention)

How specified in the Article 12 the regulatory body in Brazil considers human factors aspects following the USNRC approach. In case of Operanting Plant, the paragraph 21.2 of CNEN NE 1.26 – *Safety in the Operation of Nuclear Power Plants*, require that PSR should address, at minimum, several areas or safety factors, including human factors.

The proposed use of digital technology for the plant instrumentation will pose a challenge, not only to the licensee, but to CNEN as a reviewer as well.

CNEN has signed, in 2009/2010, an agreement with European Commission to provide technical cooperation to improve the capacity within CNEN to carry out review and assessment of the safety of digital I&C systems as part of the licensing process of Angra 3 NPP, in construction, and modernization of Angra 1 and Angra 2, in operation. Experiences and practices from European Reactors have been presented and discussed through workshops (4 workshops) and visit to nuclear power with upgraded DI&C (Paks NPP), licensing experiences, etc. Evaluations of concepts, criteria and general requirements of DI&C of Angra-3 described in the PSAR were carried out from 2007 to 2010, as part of License Construction issued by CNEN, see Article 8.

Guidance for assessment of quality and reliability of software and programmable electronics based on IEC standards was developed by GRS-ISTec, revision 1, July 2012. An internal guideline of CNEN, consolidating the licensing experience of I&C systems since 1981, based on the NUREG-800 approach, is under revision, balancing the experiences from US and European for digital I&C technology which is being used by new design (like EPR, AP1000), to be designed in the Angra-3 instrumentation. These experiences will be used in next phases of the safety evaluations of FSAR and commissioning activities, in compliance with of initial operation licensing requirements.

As discussed in Article 8, Digital I&C subject was incorporated in the second period (2015–2017) of the CNEN/EC Technical Cooperation Project. As a result of this activity the Brazilian Regulatory Body issue a provisional guide NT-CGRC-012/18 – *Guide for Licensing and Safety Assessment of Nuclear Reactor Instrumentation and Control Systems* (Guia de Licenciamento e Avaliação de Segurança de Sistemas de Instrumentação e Controle de Reatores Nucleares: In Portuguese).

CNEN has been also participating of international workshops for IAEA standard revisions and workshop with NRC of activities for Digital I&C.

18 (3).2 Implementation measures taken by the licence holder

The Brazilian Plants in operation or construction are of the PWR type, by far the most used concept for nuclear power generation, with designs proven through many years of operation of similar Plants.

The consideration of human factors and MMI for reliable, stable and manageable operation in the original design of the Brazilian Plants corresponded to the status of this technology in the countries suppliers of the technology (USA and Germany) at the time of the completion of the respective designs.

As mentioned in Article 12, human factor was not a major issue at the time of design of Angra 1, and several reevaluation and backfittiings were carried out in this area along the plant life. For Angra 2, more automation was already incorporated in the design, taken into account the state of the art of the technology. For Angra 3, it is expected that even more advances will be taken into account.

18(3).3 Regulatory review and control activities.

From the regulatory point of view, more attention will be taken with respect to these aspects, and the requirement for a Human Factor Engineering evaluation will be repeated for Angra 3.

ARTICLE 19 - OPERATION

Each Contracting Party shall take the appropriate steps to ensure that:

(i) *the initial authorization to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme demonstrating that the installation, as constructed, is consistent with design and safety requirements;*
(ii) *operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;*
(iii) *operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;*
(iv) *procedures are established for responding to anticipated operational occurrences and to accidents;*
(v) *necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;*
(vi) *incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body;*
(vii) *programmes to collect and analyse operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies;*
(viii) *the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.*

Article 19 (1) Initial authorization

The operation of a nuclear power plant in Brazil is subjected to two formal approval steps by CNEN within the regulatory process: Authorization for Initial Operation (AOI) and Authorization for Permanent Operation (AOP).

The Authorization for Initial Operation (AOI) is issued after the completion of the review and assessment of the Final Safety Analysis Report (FSAR) and taking into consideration the results of regulatory inspections carried out during the construction and pre-operational test period. Additionally, it requires the operator to have already an Authorization for Utilization of Nuclear Materials (AUMAN), and a Physical Protection Program in accordance with CNEN regulations, to have an emergency plan in accordance with SIPRON regulations and to have financial guarantees with respect to the civil liability legislation. In parallel, the corresponding environmental licence has to be obtained from IBAMA, in accordance with the national environmental legislation.

The Authorization for Permanent Operation (AOP), in addition to the AOI requirements, is based on the review of startup test results. Safety requirements during operation are established by regulation CNEN-NE-1.26 [9].

All the above-mentioned requirements have been successfully met for the Angra 1 and 2 Plants that have 37 and 21 years of operation, respectively. The Angra 1 AOI was issued in September, 1981 and the AOP in January 1985; for Angra 2, the AOI was issued in March 2000, and the AOP, much later in June 2011, because of non-technical reasons as explained in Article 6, item 6.2.

Operation is monitored by CNEN through an established system of periodical reports [8], notification of safety related events and through the regulatory inspection during operation. A group of CNEN resident inspectors is present at the site.

In the period 2019-2021, CNEN conducted 32 audits and inspections in Angra 1 NPP, including the following areas: Conduct of Operations, Chemistry, Radiation Protection, In-service Inspection, Physical Protection, and Implementation of the Local Emergency Plan, Event Analysis, and Monitoring of the Radioactive Effluents Release, Waste Treatment System, Fire Protection and Operators Training.

During the period 2016-2018, CNEN conducted 26 audits and inspections activities in Angra 2 NPP, concentrated in the following areas: Radiation Protection, Fire Protection, Quality Assurance, Event Analysis, Maintenance, Plant Modification and Monitoring of the Radioactive Effluents Release, Solid Waste Treatment System, Fuel Loading Cycles and Operators Training.

Additional 31 inspection covered areas of the organization common to both units, such as Meteorology Systems, Emergency Planning, Physical Protection, Waste Storage & Management and Training.

Article 19 (2) Operational limits and conditions

Limits and conditions for operation are proposed by the applicant in the FSAR, in the form of Technical Specifications. These technical Specifications are reviewed and approved by CNEN during the licensing process, and referenced in the Operation Licence document. No changes in these limits and conditions can be made by the licensee without previous approval by CNEN.

The project for adaptation of the original Angra 1 Specifications to the content and format of document NUREG 1431, Standard Technical Specifications for Westinghouse Plants, Rev. 1, was started several years ago following the practice of the American Plants. The new

Angra 1 Technical Specifications were elaborated, translated to Portuguese, and after a long review period, internally and by the Regulator, have been finally approved by CNEN in beginning of 2015 and implemented at the Plant in the end of 2015.

For Angra 2, the German licensing framework did not foresee Technical Specifications in the strict USNRC sense. The equivalent documentation, called "safety specifications" in the German procedure, is part of the Operating Manual, and is much more concise than the American ones. For the sake of uniformity, CNEN required that Technical Specifications following the Standard Format of NUREG 1431 be prepared also for Angra 2. This was again a huge adaptation job with extensive revision work. Being a new document, the Angra 2 Technical Specifications are being verified in practice and several revisions have been implemented to date as the result of feedback from operation. In the meantime the Specifications have been translated into Portuguese and this translation has been validated. The Portuguese version has been reviewed by CNEN and some modifications were required and implemented.

For Angra 2, the operability criteria of the systems, as required in the Limiting Conditions for Operation (LCOs), are defined in the Test Instructions. Each Test Instruction links the results of the test with the acceptance criteria of the associated LCO. An user-friendly software was developed and implemented in Angra 2 to support the Safety Function Determination Programme required in the Technical Specifications.

As an additional tool to support the Plants concerning acceptable Plant configurations, both Plants have available risk assessment tools, based on Plant specific living internal events PSA, either on-line (Risk monitor) for Angra 2 or through daily calculations, for Angra 1. Besides routine risk evaluation these tools allow assessment of complex situations and decision-making that would be complicated using only technical specification orientations.

Article 19 (3) Procedures for operation, maintenance, inspection and testing

Safety requirements during operation are established by regulation CNEN-NE-1.26 [9]. Additional CNEN regulations establish more detailed requirements for maintenance [19] and in-service inspection [20].

The implementation of these requirements at the plant is done through the preparation of an Operation Manual, which contains guidelines to develop, approve and control plant procedures according to the nuclear class and the Quality Assurance Program. It also contains the actual procedures for all activities to be conducted in the plant, related to operation, maintenance, inspection and testing.

An administrative procedure - Organisation of Operation Manual - provides the detailed requirements to develop, approve and control all plant procedures. In the case of surveillance procedures required by Technical Specifications or other regulations (ASME Code or KTA rules), another administrative procedure gives instructions in more details for the preparation of field procedures, implementation and control. Each Unit Operation Review Committee (CROU) approves all procedures of the respective unit. The Plant Operation Review Commission (CAON), which oversees both units, analyses and approves all nuclear safety class procedures and those that are related to the Quality Assurance Program.

All employees must follow written procedures, and each Department Manager (Operation, Maintenance, Technical Support, Chemistry, Health Physics, etc.), must assure that all tasks done under his/her responsibility are accomplished using the latest revision of the approved procedure. The Quality Assurance Department monitors and controls whether the plant organisation is using approved procedures during operation, maintenance, test and inspection.

The Operation Manual is divided into volumes according to specific areas of activity, such as: Administrative, Operation, Radiological Protection, Chemistry and Radio Chemistry, Reactor Performance, Nuclear Fuel, Instrumentation, Electrical and Mechanical Maintenance, Health Physics, Surveillance, Training, Physical Protection, Emergency Procedures, Fire Protection, Environmental Monitoring. Besides the Normal Operation Procedures, the Operation volume contains also the Abnormal and Emergency Operation Procedures for assisting in abnormal and accident occurrences, including procedures to be followed relative to the Emergency Plan. The procedures should be revised every 2 or 4 years, considering their classification as safety or quality documents.

In case of an accident evolution to core damage conditions, specific exit criteria have been incorporated in the Emergency procedures that call the guidelines of the Severe Accident Management Manual (SAM M), recently completed and tested for both Plants.

In cases where contracted companies (foreign or national) perform work in the plant, a temporary procedure is necessary. For a contracted company that develops its own procedures, a plant expert or an engineer related to the work to be performed, analyses the original procedure and sends it to the Quality Assurance to check if the acceptance criteria are achieved. A cover sheet with an approval form is attached to the procedure.

For other temporary procedures, the author writes the procedure, explains the reason for its temporary nature and establishes a validation period. Temporary procedures can be used only during the validity period stamped in the procedure.

The Work Control Group is responsible for planning all the maintenance, inspection and testing tasks in operation and outages. Inside the work package, procedures, plant modification documents, part lists and other references applicable to the task should be included. A task can be started only after discussion at the daily co-ordination meeting and the shift supervisor authorization.

Work control process stamps the “Work Permit” with a “Red Line” to identify tasks related to nuclear safety equipment. In this case, quality assurance and maintenance quality control personnel ensure that approved procedures and part lists with traceability are being used. In addition, for equipment that has a "Risk of Scram", an approved procedure must be used, and this procedure has a “Red Cover Sheet” to warn workers about risks and cautions to be taken.

During outages, a written and approved outage procedure controls the overall plant safety condition for inspection, testing and refueling operation.

Article 19 (4) Procedures for responding to operational occurrences and accidents

The Operation Manuals of Angra 1 and Angra 2 contain procedures to respond to anticipated operational occurrences and accidents. For abnormal conditions, procedures are used to return the plant to normal conditions as soon as practical or to bring the plant to a safe state, such as hot shutdown or cold shutdown. For accidents, Emergency Operating Procedures (EOPs) were written in accordance with latest reactor manufacturer guidelines and current international practices.

Although having different formats, both the EOPs for Angra 1 and Angra 2 are based on the same philosophy:

- If an event can be clearly identified, Event Oriented EOPs are used; e.g., for Angra 2, Event Oriented EOPs are provided for control of the following classes of accidents: LOCAs, steam generator tube rupture, secondary side breaks, overcooling transients, external impacts during plant operation with reduced inventory or at refueling.
- If the event cannot be clearly identified, Symptom or Safety Function oriented EOPs direct the operator into monitoring and restoration of the set of fundamental safety functions (Critical Safety Functions). If these safety functions are fulfilled the plant is in a safe state. These Safety Functions are Subcriticality, Core Cooling, Coolant Inventory, Containment Integrity, and Heat Sink.

The EOP structure, taking Angra 2 as example, consists of two levels of detail. The first level includes a diagnose chart, a trends-of-plant-parameters table, automatic actions flow diagram, a manual actions flow diagram. The second level includes an instrumentation list, detailed instructions for automatic and manual actions, explanatory remarks and diagrams and tables.

These EOPs cover accidents in the Design Basis and Beyond Design Basis up to but not including accidents with core melt (severe accidents). They assume the use of all available systems, even beyond their original design purposes and operating conditions.

These EOPs are being modified to call for specific procedures for installation and operation of mobile equipment as a means of power supply and steam generator cooling, in addition to the existing Plant systems. Preparation work for specific mobile equipment procedures is still underway.

Integrated Computerized Systems, added to Angra 1 and Angra 2 after initial design as a result of HFE evaluations (see Article 12), assist the operator in monitoring Critical Safety Functions (CSF) and other process variables. When a CSF (Subcriticality, Core Cooling, Coolant Inventory, Containment Integrity, and Heat Sink) is violated or there is a chance to reach the specified limits, there are approved procedures to be used to restore the CSF to normal condition. Color codes used in the Integrated Computerized System help the operators to act in an anticipated way, to avoid reaching the protection limits. These colors (green - Normal, yellow - Alert, orange - Urgent, red - Emergency) guide the operator to what procedure should be used. In case the Integrated Computerized System is not operable, there is a paper procedure that must be followed by the operator to confirm that no CSF is in the process of violation or has been already violated.

As indicated in 19(3) specific exit criteria have been incorporated in the Emergency procedures that call the guidelines of the Severe Accident Management Manual (SAM M).

Severe Accident Management Guidelines (SAMGs) have been developed for the Angra 1 plant in the 2008 – 2009 period through a contract with Westinghouse, using the Westinghouse Owner Group (WOG) concept. This concept was applied to essentially all Westinghouse PWR in the USA and abroad and was developed to address elements of USNRC Severe Accident Management Program (SECY-89-012).

The WOG SAMG provides structured guidance for: (1) Diagnosing plant conditions (2) Prioritizing response, (3) Evaluating alternatives and (4) Verifying implementation of actions, being a process for choosing appropriate actions, based on actual plant conditions.

No detailed knowledge of Severe Accident phenomena for the specific plant is required and the SAMG measures rely basically on existing equipment.

The resulting documentation consists of guidelines for the control room operators for the initial transition from the EOP to SAMG and guidelines, logic trees and computational aids to be used by the Technical Support Center staff that takes over operator orientation for management of severe accident conditions. The complete SAMG documentation also includes a set of background material with the bases for the guideline actions and of SAMG training material to be used for initial and periodic retraining.

A second contract was signed with Westinghouse to support ELTRONUCLEAR in the process of verification and validation of the Angra 1 SAMG, integration of these SAMG into the Emergency Planning (EP) documentation as well as training of the involved personnel. All the above tasks have been performed and the integration of the SAMG with the Emergency planning documentation was tested through performance of an EP exercise with activation of the Angra 1 Plant Emergency Centers Control Room and TSC. This work was completed in May 2016.

In 2020, under a contract with Westinghouse, the Angra 1 SAMG was updated based on the PWROG-16059-P PWROG Severe Accident Management Guidance for International Plants.

Some of important issues that were addressed in this update were:

- Post-Fukushima upgrades
- Other Operating Modes (Shutdown, refuelling)
- Spent Fuel Pool iniciated accidents
- Severe accident mitigation systems (Passive Hydrogen Recombiners)
- Integration of important improvements from the new consolidated PWROG SAMG (TSC support guides; improved guide fluidity; specific guides for I&C and BO)

To be coherent with the approach being adopted in the development of the SAMG for the Angra 2 plant as well as to follow IAEA and international practices, additional equipment to help manage a severe accident, such as passive H2 recombiners and filtered containment venting are being procured and purchased for installation in Angra 1. Accordingly, after clear definition of this additional equipment these SAMG will have to be revised to account for it.

Preparatory work for the development of a project to provide SAMG for the Angra 2 was pursued along 2009 - 2010, taking advantage of a recently signed Cooperation Protocol between Brazil and the European Commission, in which the EC provides funding for safety improvement projects. The project was initiated in March, 2011, and involved the development of Angra 2 specific SAMG, including transfer of know how. AREVA was the selected contractor.

So far an Angra 2 severe accident calculation model using the MELCOR code has been developed and validated, the calculations for a comprehensive set of plant damage states have been performed, and the results are being analyzed. Furthermore the evaluation of the Angra 2 existing mechanical, electrical and I&C equipment applicable for use in severe accident conditions has also been completed.

The next step consists in the development of simplified computational aids in form of curves or tables to allow quick identification of core or containment conditions in a severe scenario. Based on these results Angra 2 specific severe accident management strategies will be developed.

The following additional equipment specific for severe accident management is already being considered in the development of the Angra 2 SAMG: passive H2 recombiners, filtered containment venting and containment sampling system.

The main tasks performed jointly by ELETRONUCLEAR and the Contractor were: developing and validation of an Angra 2 specific severe accident calculation model using the MELCOR code, performance and evaluation of calculations for a comprehensive set of plant damage states, that provided the insights for development of Angra 2 specific accident management strategies; evaluation of the Angra 2 existing mechanical, electrical and I&C equipment with possible use in severe accident conditions and development of simplified computational aids in form of curves or tables to allow quick identification of core or containment conditions in a severe accident scenario.

From the inputs of the above tasks and taking as reference the AREVA Severe Accident Guidelines from German sister Plants, the Angra 2 specific Severe Accident Management Guidelines were developed and collected in the Angra 2 Severe Accident Management Manual.

For verification of these guidelines table top exercises have been performed. Two one-week training sessions have been provided by experts from the Contractor. The final exercise of use of the developed SAMGs integrated to an Emergency Plan exercise was successfully done in November 2015. In this exercise the Control Room and the TSC were activated with the actual personnel foreseen in the Emergency Plan Manual, and an exercise unknown to the participants was run, conducted by experts from the Contractor.

- *Regulatory review and control activities*

CNEN, based in international experience, prescribes a systematic examination of severe accident vulnerability using PSA. In this frame, CNEN issued the technical report NT-GEDRE-01/93 specifying the safety requirements. Moreover, the Operator Organization shall issue instructions and procedures that deal with the plant under severe accidents conditions according to the CNEN-NE-1.26 Standard (10/1997).

In 2010 CNEN initiated a project (BR/RA/01), supported by the European Commission (EC), and entitled: "Nuclear Safety Cooperation with the Regulatory Authorities of Brazil (CNEN)". Within this project, CNEN with support from the EC developed an internal capacity to carry out the assessments of matters related to severe accident management.

The main objective of this tasks has been reached and one draft standard with regulatory requirements for severe accident management was developed, as well as one draft guidelines to assessment of the severe accident management guidelines (SAMGs) submitted to CNEN by the ELETRONUCLEAR. This project has been started in June 2011 and was finalized in October 2013.

In 2015 CNEN initiated a second project EC Project BR3.01/12 (BR/RA/02), supported by the European Commission, and also entitled: Nuclear Safety Cooperation with the Regulatory Authorities of Brazil (CNEN). The main objective of Task 5 of this project is to support CNEN in the assessment of the Severe Accident Management Programs (SAMP) for Angra-2 and 3, possibly including the capacity to review and/or revise MELCOR nodalisations used in Angra-2.

Article 19 (5) Engineering and technical support

Engineering services and technical support are available for the operation of Angra 1 and Angra 2 within the ELETRONUCLEAR organization and supplemented by outside contractors. The technical support groups include all basic engineering disciplines: civil, electrical, mechanical, instrumentation and control, systems and components, safety analysis, stress analysis, reactor physics, and radiation protection. In this respect, the creation of ELETRONUCLEAR, combining FURNAS engineering and technical support groups with NUCLEN design capability, has significantly improved the support services available to both Angra 1 and Angra 2.

The engineering support staff is mostly involved with the design and implementation of plants modifications, derived from inputs provided by the Plants or by external operating experience.

The company has also made available experienced technical personnel to perform deterministic and probabilistic safety assessments to support Plants modifications, event analysis or Regulator requirements. Core reload calculations or mechanical and stress analysis for the Angra Plants are also performed in-house.

As referred in Article 18(2) the Company has an Engineering and Design Superintendence at Headquarters, dedicated to the conduction of the Angra 3 project design and engineering as well as special large engineering projects, e.g., the interim spent fuel storage installations. This Superintendence can also provide support to the Plants in several specialized technical disciplines.

The recent Incentive Retirement Program has reduced substantially the available engineering and technical support personnel, which will probably lead to the need of more use of specialized Contractors.

Another source of requirements for modifications is the regulatory body, which normally updates its regulations on the basis of new technological developments, experience feedback and new international practices.

Article 19 (6) Reporting of incidents significant to safety

Reporting requirements to CNEN during operations are established in regulation CNEN-NN-1.14 [8].

This standard establishes requirements for notification and classification of events and the format of the event reports. This standard is being revised considering technical information obtained from a technical cooperation with European Community - Spain, France, German and Hungary and material from USNRC and IAEA.

Different types of reports are identified, such as periodical reports and reports of abnormal events. Notifications of 1 or 4 hours are required for events that involve degradation of the plant safety conditions, or exposure to radiation of site personnel or the public to levels above the established limits. Required report events should be reported within 30 days. There are also requirements for special reports established in Technical Specifications.

Reports are classified in levels (1, 2, 3 and minor events), where reports classified as level 1 require reporting to the Regulator, level 2 are events considered of enough significance to be documented in detail and level 3 are operational deviations, documented in less detail than level 2 events, but nevertheless important for gathering of internal operational experience. Collected minor events, documented in a simplified way, are compiled in specific families and used to identify negative trends.

- *Statistics of reported incidents significant to safety for the past three years*

In addition, with the purpose of dissemination of operational experience that may be of value for other nuclear power plants, the ELETRONUCLEAR reports on the order of 5 significant events per plant/year to WANO and INPO.

Eletronuclear made the following required reports to CNEN due NN 1.14 regulations:

- Angra 1 reported two (3) events of safety significance in 2019, four (4) in 2020 and zero (0) in 2021.
- Angra 2 reported 1 event of safety significance in 2019, 1 in 2020 and 0 in 2021.

Other operational event reports as well as operational deviations that do not classify as reportable in accordance to regulation CNEN NN – 1.14[8], are available for CNEN audit and review.

- *Overview of the established reporting criteria and reporting procedures for incidents significant to safety and other events such as near misses and accidents*

The national standard CNEN-NN-1.14[8] establishes criteria for notification and for event report.

The Operational Experience of the utility considers five types of events:

- Events required by the standard NN 1.14 (type 1);
- Events not classified as required by standard but the utility considers important or with potential risk for the safety (type 2);
- Events of an operational deviation (type 3);
- Near misses or quasi-events (type 4);
- Special Reports required by technical specifications.

There are specific procedures to make the classification of the events and to establishes the investigation methodology (root cause analysis). There is also a procedure to deal with external operational experience.

- *Documentation and publication of reported events and incidents by both the licence holders and the regulatory body;*

All operational events classified as above are recorded in events reports. The regulatory body performs an evaluation of all events classified as required (type 1) by the standard with a generation of a technical document with corrective actions when applicable.

When applicable, other types of operational event reports can be evaluated. The assessment of regulatory body are recorded in specific regulatory reports.

On an annual basis the regulatory body performs an audit to evaluate the application of the methodology and to verify efficiency, effectiveness, trends and lessons learned.

- *Policy for use of the INES scale*

The International Nuclear Events Scale (INES) is used to classify the safety significance of the events in the event reports. Only INES events of level 0 have been reported to CNEN in the period from 2019 - 2021, related to Angra 1 and 2.

The classification of INES scale is required by CNEN-NN-1.14[6] regulation and performed by Eletronuclehar. CNEN perform the revision and when necessary, can require a revision and correction of the classification.

- *Regulatory review and control activities*

The regulatory resident inspection receives all operational event reports and perform screening selecting ones to perform specific assessment. All the required operational event reports are evaluated.

CNEN performs annual audits on the operational experience process in Angra 1 and Angra 2 NPPs.

Angra 1 received a WANO Peer Review follow-up Mission in 2016 in order to evaluate the recommendations and suggestions from the last mission in 2014.

A new WANO Peer Review Mission was performed in 2018 at both plants, Angra 1 and Angra 2.

Article 19 (7) Operational experience feedback

19(7).1 - Overview of the Contracting Party's arrangements and regulatory requirements on the licence holders to collect and analyse and share operating experience

The national standard CNEN-NE-1.26[9] establishes criteria for Analysis of Operation and Operational Experience. In according with this standard, the Operating Organization shall:

- conduct regular reviews concerning the operation of the plant to ensure that:
    - safety awareness prevails.
    - the measures established to increase safety are observed.
    - relevant documentation is kept up to date.
    - there is no evidence of overconfidence or complacency.
- The analyzes must be carried out by qualified persons, designated for this purpose, within the context of the PGQ and the results of these analyzes are duly documented together with the records of any corrective actions.
- search and evaluate information from operational experience at other plants that provide lessons for the operation of its own plant.

The evaluation of the operational experience of the plant, as well as that of other plants, must be carried out in a systematic way. Operational experience should be examined to detect any precursors of possible adverse safety trends. Safety-related events must be investigated using an appropriate methodology to determine their root cause, so that corrective actions can be taken, before adverse conditions arise, or to avoid their recurrence. The operating organization must maintain communication channels with designers, manufacturers and other organizations, aiming not only to provide feedback on operational experience, but also to obtain, if necessary, updated modifications and advice in the event of equipment failures or abnormal events.

The operational experience feedback process in Brazil comprises two complementary systems: one performed by ELETRONUCLEAR, processing both in-house and external information, and one performed by CNEN.

19(7).2 - Overview of programmes of licence holders for the feedback of information on operating experience from their own nuclear installation, from other domestic installations and from installations abroad.

At Eletronuclear the internal operational experience is collected and processed by specific groups inside the plants. Of the order of 25 to 70 reports of classes 1, 2 and 3, per Plant, per year, were produced in the review period. Statistically, about 2 to 3% were reports class 1, 25 to 30% reports class 2 and of the order of 70% of reports class 3.The main contents of these reports are the identification, classification and description of the event, the identification of the direct and root causes, the causal factors, the consequences to safety and the recommended corrective actions.

Of these reports, between 1-3 per year/plant were formally reported to CNEN (see statistics for 2016-2018 in Article 19(6) above) following the requirements of CNEN-NN-1.14 [6].

The internal safety committee at each plant (CROU) review these reports before release and the most significant ones, basically the ones that are reported to CNEN, have to be evaluated also by the CAON, the committee that evaluates the safety of operation. A subcommittee of the CAON has the task of analyzing all produced reports and feedback to the CAON any specific or general deficiencies of individual reports or in the reporting procedure and the main insights derived from the analyzed reports.

As indicated in Article 19(6), ELETRONUCLEAR is committed to report of the order of 5 significant events /year/plant to the World Association of Nuclear Operators – WANO as well as to the Institute of Nuclear Operators – INPO. When pertinent, these reports are also supplied to VGB, the German Association of Plant Operators.

Beginning in 2007, the plants have started to collect minor events and near misses. Every year about 1000 minor events per Plant are collected. The collected events are classified in families and trended.

In both plants Angra 1 and Angra 2, the Low Level Events (LLEs) are the base of the pyramid and are recorded and appropriately evaluated to prevent adverse trends of plant events. LLEs result in immediately Work Orders Request to solve the adverse condition, or are quantitatively evaluated and when reaching 30 LLE during the previously 6 months with same WANO Root Cause Code besides comparable description are presented at a Daily Management Meeting when is determined the depth of event analysis to be performed (Operating Event Report, Significant Event Report) that will lead to Corrective Actions. LLEs are also being used to support the Human Performance Indicators.

Insights from evaluation of these trends are used to establish corrective actions, as for example the implementation of an extensive human performance improvement program, referred to in Article 12, Human Factors.

External experience is handled by an Operational Experience Analysis group, belonging to the Plants Support Engineering. This group investigates relevant incidents occurred in the Angra Plants and in similar nuclear installations in order to make recommendations.

Following recommendations from an IAEA PROSPER mission in 2007, the task of collecting, analyzing and disseminating External Operating Experience (EOE) within Eletronuclear, formerly done by the Engineering Support area, has been reorganized, with the goal of promoting more participation of the Plants in the process, improving the effectiveness of the process.

EOE Committees were established at each unit with participants from the plants Support Engineering and Nuclear Safety divisions. These committees evaluate the collected EOE, the main sources being WANO and INPO Significant Event Reports, IAEA Incident Reporting System, VGB, EPRI, and reactor designer pertinent information. Furthermore, they issue and follow up recommendation’s implementation.

The External Operating Events (EOE), coming from WANO/INPO/VGB/IAEA, are analyzed and, if applicable to the station, an evaluation in plants processes is done and procedures can be improved. In all cases the experience is spread among the organization. The EOEs related to outages are informed to the employees before the following plant outage.

For both plants, if a corrective action demands a revision of documentation this is made so. In practical terms, when a document is revised due to OE, this document must have the letters OE on the left side of the page, and a mark to signalize the revision made, and by procedure it cannot be removed without the approval of the Plant Operational Review Committee (PORC).

In Angra 1, the Main 500 kV transformers were replaced, considering the Large Power Transformer Reliability WANO SOER. It was also used a lot of information which arose from Westinghouse Technical Bulletin and Nuclear Safety Advisory Letter to refer to other design modifications. Operational procedures are modified (when needed) upon OE recommendations such as the procedure to go from Hot Shut Down to Power (e.g. reactivity control - SOER).

In Angra 2, during the construction phase, several major improvements have been implemented based on the experience of the German plants, such as, replacement of the PZR valve station to allow discharge of water, use of the low pressure safety injection to provide back pressure to the high pressure safety injection, upgrading of the reactor limitation system, among others. Further modifications based on the same experience have been /are being implemented after beginning of plant operation, such as additional pressurizer valves for Primary Feed and Bleed, interconnection of emergency Diesels (large and small sets of emergency Diesels). Furthermore, several new or modified procedures have been implemented as result of international experience evaluation.

The ELetronuclear Response Plan to Fukushima also mentions goog examples of the Company initiatives originated by the external operating experience. The Eletronuclear Executive Directorate approved the Fukushima Response Plan and sent it to CNEN ate the beginning of December 2011. Preliminary Evaluation Report of the Fukushima accident formed the basis to the initiatives. The Plan, initially, included 3 evaluation fields, and encompassed 30 studies and 28 projects. These studies had been concluded and most of the projects as well. Nowadays, there is a report following the still ongoing activities, emitted each six months.

Main Activities:

The Stress Tests revaluated all the risks, such as seismic, hydrologic, flooding, winds, tornadoes, etc., accordingly to the methodology developed by WENRA – Western European Nuclear Regulators Association and taking to account the technical specifications of the Plants. These studies and analysis lead to a series of initiatives.

Main interventions in Angra 1 and Angra 2:

- Stablish alternatives to improve the means to do bleed & feed of primary and secondary circuits, in order to assure core cooling.
- Stablish alternative ways to assure spent fuel pool cooling
- Stablish alternative power supply to extend battery time and to guaranty power supply to the cooling chain equipment
- Stablish or improve PSA and SAMG
- Install catalytic H2 recombiners, a containment filtered venting system and a containment sampling system to beyond design conditions.

Main interventions in the site:

- Improvement in the water supply systems
- Alternative ways to assure diesel oil supply during extreme events conditions
- Stablish radiological control resources in case of extreme events conditions and radiological aspects in the severe accident management
- Acquire the mobile equipment needed to face extreme events conditions, assuring core cooling, spent fuel pool cooling and batteries power supply.

- Implant store area to the mobile equipment to be used as alternative in extreme events conditions
- Stablish alternative ways to evacuate the site in case of extreme environmental conditions
- Improve the Emergency Centers

Eletronuclear concluded the studies and analysis, and some initiatives gave birth to complementary actions.

Main activities still ongoing

Angra 1:

- PSA level 2 and other complements
- Alternative air supply to the primary relief valves (bleed & Feed)
- Improvement of the reactor cooling pumps seals
- Containment venting system and containment sampling system to severe accident conditions
- Action plan from Internal Flooding Analysis
- Improvement of the fire protection system following the recommendations of the Fire Hazard Analysis Report.

Angra 2:

- Install connections to allow the use of mobile diesel pumps during extreme conditions to supply inventory to assure reactor cooling via secondary circuit
- Commissioning of panels to connect the mobile diesel generators outside the safety buildings
- Alternative solution to spent fuel pool cooling during severe accident conditions
- Containment venting system and containment sampling system to severe accident conditions

Site:

- Erection of a seismic water reservoir and the seismic distribution system
- Stablish new radiological control points to severe accident conditions.
- Actions to improve slope stabilization and monitoring around the site
- Tornadoes evaluation and protective actions

To avoid the risk of insularity, due to the geographical location of the Brazilian plants, far away from the main nuclear centers, ELETRONUCLEAR has had from the beginning a policy of strong involvement with the nuclear industry. Technical exchange visits, technical review missions, observer or expert missions, from other nuclear power plants or organizations to Angra and from Angra personnel to other nuclear power plants, when conducted periodically, provide a valuable source of information on other plant experiences.

The invited Peer Review missions performed by WANO or the IAEA, as they aim to identify departure from industry best practices concerning safety and reliability in plant operation. ELETRONUCLEAR adhered to these review programs from their inception, and since 2004 has established policy of performing of a complete internal (self-assessment) and external evaluation at 3-year cycles, alternating IAEA OSART and WANO Peer Reviews.

A WANO Peer Review Team visited the Angra 1 and Angra 2 NPP from July 18 to August 03 2018. The purpose of the mission was to review operating practices in the areas of Management Organization and Administration; Operations; Maintenance; Technical support; Radiation Protection; Operating Experience; Chemistry and Accident Management. In addition, an exchange of technical experience and knowledge took place between the experts and their plant counterparts on how the common goal of excellence in operational safety could be further pursued.

Other missions occurred in the period covered by this report include some IAEA missions: one IGALL in October/2018, and two Pre-SALTO missions in Angra 1 NPP, the first one in November/2013 and another in May/2018. Besides, the first Lat-iNOS mission in Brazil in 2018 (an independent project of Brazil, Mexico and Argentina) in the area of Nuclear Safety Oversight. This project is based on IAEA/WANO guideline and was third mission in a sequence already well-succeded in Mexico and Argentina years before.

In 2019, Eletronuclear received some important international interchange and technical missions. In February, an IGALL workshop, IRS and Event Investigation IAEA Training Course; In April an IAEA Knowledge Management Seminar; In May, a IAEA Pre-SALTO Mission at Angra 1; in June a Leadership for Safety GS-R-2 Seminar; in August, an IAEA IGALL SC – Workshop; and a WANO MSM on Risk Management in Angra 2 NPP

Table 9 provides a list of such international review and technical support missions to Angra for the 2019 – 20218 review period.

Table 9 – International Technical and Review Missions to ELETRONUCLEAR power plants and head office between 2019 – 2021

No	Date	Organization	Location	Type of mission
1	October 15-17, 2019	WANO	Angra site	MSM on Leadership on the Field
2	October 7-11, 2019	WANO	Angra site	MSM on Risk Management
3	December, 2016	WANO	Angra site	Follow up Peer Review
4	February, 2017	WANO	Angra site and Corporate	Corporate Peer Review

No mission occured in 2020 due to the Covid-19 pandemic

Angra site: Plants and Operation Offices at CNAAA in Angra dos Reis
Corporate: Eletronuclear Head Office in Rio de Janeiro
WANO: Word Association of Nuclear Operators (PC – Paris Center, France)
MSM: Member Support Mission

Another important mechanism of transfer of experience is the participation in review or technical support missions to other nuclear power plants or organizations in the nuclear industry. ELETRONUCLEAR has had, since a long time, a strong participation in these type of missions.

Table 10 presents a list of the most relevant international technical missions with participation of Eletronuclear personnel to other organizations during the 2016 – 2018 period.

Table 10 – Technical Missions of ELETRONUCLEAR Personnel to other countries between 2019 – 2021

Country	Period	PRDE / RDE*
China	03/01/19 - 27/01/19	DO-080 / 1437.004
France	19/01/19 - 10/02/19	DO-081 / 1439.007
France	19/01/19 - 10/02/19	DO-082 / 1439.008
Japan	25/01/19 - 04/02/19	DO-090 / 1440.021
Germany	16/02/19 - 24/02/19	DO-003 / 1443.009
Spain	17/02/19 - 24/02/19	DO-004 / 1443.010

Country	Period	PRDE / RDE*
Mexico	04/03/19 - 15/03/19	DO-007 / 1446.005
Argentina	05/03/19 - 09/03/19	DO-010 / 1448.005
Argentina	24/03/19 - 30/03/19	DO-016 / 1451.006
USA	29/03/19 - 14/04/19	DO-021 / 1452.003
USA	08/04/19 - 19/04/19	DO-024 / 1453.007
Switzerland	14/04/19 - 20/04/19	DO-023 / 1453.004
France	01.06.19 - 31.05.20	DO-027 / 1456.004
France	26/0519 - 31/05/19	DO-032 / 1460.003
USA	03/06/19 - 29/06/19	DO-033 / 1461.001
USA	22/07/19 - 17/08/19	DO-043 / 1467.003
Germany	19/07/19 - 26/07/19	DO-039 / 1466.004
USA	08/07/19 - 03/08/19	DO-042 / 1467.004
Mexico	28/07/19 - 03/08/19	DO-043 / 1468.003
France / Spain	26/08/19 - 22/09/19	DO-047 / 1471.004
Belgium	21/09/19 - 29/09/19	DO-050 / 1473.007
England	12/09/19 - 22/09/19	DO-051 / 1473.008
Argentina	09/09/19 - 14/09/19	DO-055 / 1476.009
USA	07/10/19 - 03/11/19	DO-060 / 1477.006
France	28/09/19 - 05/10/19	DO-061 / 1477.007
Austria	22/09/19 - 28/09/19	DO-063 / 1478.013
England	18/10/19 - 25/10/19	DO-064 / 1479.006
France	06/10/19 - 19/10/19	DO-065 / 1479.007
Áustria	12/10/19 - 18/10/19	DO-068 / 1480.003
México	27/10/19 - 02/11/19	DO-074 / 1481.007
Áustria	28/09/19 - 05/10/19	DO-070 / 1481.004
USA	02/11/19 - 17/11/19	DO-078 / 1483.010
Switzerland	30/11/19 - 14/12/19	DO-085 / 1486.009
Argentina	26/11/19 - 04/12/19	DO-089 / 1487.007

Country	Period	PRDE / RDE*
USA	01/12/19 - 07/12/19	DO-093 / 1488.010
France	17/12/19 - 22/12/19	DO-096 / 1492.005
Japan	07.01.20 - 01.02.20	DO-097 / 1493.008
Spain	18.01.20 - 09.02.20	DO-098 / 1493.009
France	18.01.20 - 09.02.20	DO-099 / 1493.010
Germany	08.02.20 - 16/02/20	DO-002 / 1497.007
France	25/02/20 - 22/03/20	DO-005 / 1499.005
Austria	15.02.20 - 22.02.20	DO-009 / 1499.009
France	23.08.20 - 07.09.23	DP 1530.001
France / Belgium	27.02.21	DO-008 / 1560.002
France	29.10.21	DO-057 / 1599.001
Spain	15.10.21	DO-058 / 1599.004
Austria	30.10.21	DO-059 / 1600.009
Switzerland / Germany	14.11.21	DO-062 / 1601.003
Germany	13.11.21	DO-063 / 1603.009
Austria	28.11.21	DO-065 / 1604.004
Belgium	08.12.21	DO-068 / 1606.004
France	01.01.22	DO-067 / 1606.003

PRDE: *Preliminary Resolution of the Executive Board*

RDE: *Resolution (Aproval) of the Executive Board*

19(7).3 - Regulatory review and control activities for licence holder programmes and procedures

From the regulatory point of view, from 2019 to 2021, CGRC/DRS/CNEN audited the licensee internal and external operational experience assessment system to evaluate its adequacy.

All Significant Events Reported by the licensee goes through a preliminary evaluation by the resident inspectors to check for any inconsistencies and for the adequacy of the applicable recommendations. A final analysis of the event is carried out by the headquarters divisions.

There is a standard for classification of events. When a operational event is classified by this standard, a specific report is issued and the regulatory body perform a safety assessment of this report, recorded on a regulatory technical report. Follow-up regulatory inspections are performed to monitor the implementation of corrective actions. Also, this standard is beginning to be reviewed and updated, considering the references of IAEA and USNRC Guides.

19(7).4 - Programmes of the regulatory body for feedback of operational experience and the use of existing mechanisms to share important experience with international organizations and with other regulatory bodies.

CNEN is a member of the IAEA-IRS technical cooperation program exchanging experience with other participant countries. All reports required by CNEN NN 1.14 have been filed with the IRS. Some operational event reports were also filed, which although not required by NN 1.14, could be of interest in operational safety.

Also, CNEN has a bilateral technical cooperation agreement with German GRS to exchange experience in the areas of operational events, PSA and Ageing programs. In the period there was a meeting per year with GRS personnel.

19(7).5 – Impact of Coronavirus

On March 11, the World Health Organization (WHO) declared the global state of a pandemic caused by COVID-19, the disease caused by the novel coronavirus (SARS-Cov-2). On March 20, 2020, community transmission of the disease was declared throughout Brazil.

19(7).5.1 – Measures adopted by CNEN (Regulatory Body)

CNEN created a Crisis Cabinet composed by a Board of Directors of the Regulatory Body, who remained in a state of readiness, which allows the quick approval of new measures.

During pandemic period, CNEN had implemented the following procedures:

- The permanence of only one residente inspector inside each NPP in an alternate way.
- Some Inspections and audits were postponed.
- the employees belonging to the risk group as well as others that meet certain criteria (eg. Pregnant, breastfeeding, transplanted, more than 60 years old etc.), have been authorized to work at home.
- A WhatsApp communication channel has been established to disclose important and official information among employees in a quick manner.

In the beginning of pandemic, in March 2020, the Regulatory Body sent an Official Letter to Operanting Organizations asking about the adopted measures. In this Letter the CNEN Inform

> “National Nuclear Energy Commission (CNEN) established emergency measures in reaction to the Covid-19 pandemic. To avoid contagions and preserve the health of its servers and employees, activities will be carried out remotely, when possible, in all units of the Institution. Face-to-face work will only occur when it is essential for the maintenance of the institution's essential services, in accordance with what is determined by the federal government.
>
> CNEN seeks to maintain, in the face of the pandemic, the necessary care with its servers and employees, as well as ensuring society the adequate supply of products and services in the nuclear area and the maintenance of licensing and control activities, fundamental for the safety of the sector.
>
> CNEN has also rescheduled most of the trips and inspections, which would be carried out by inspectors stationed at Headquarters/Botafogo or at its other units, which support such activities. Operational monitoring will be maintained by the Resident Inspectors, while the Inspectors/Analysts will continue the review/assessment activities of the submitted technical documents and discussions, when necessary, should be carried out remotely.
>
> Finally, we inform you that CNEN maintains its capacity to initiate any response to the emergency, whether nuclear or radiological.

In this context, we emphasize that Eletronuclear (ETN) must submit, by March 31, 2020, a Contingency Plan or an Action Plan to face the COVID-19 pandemic, in order to maintain the nuclear and radiological safety of the CNAAA , containing at least:

- operational situation or interruption of activities.
- work regime changes.
- measures implemented to minimize the risk of the coronavirus spreading from outside to inside the facility.
- measures implemented to minimize the risk of the spread of coronavirus among facility personnel and the required (sufficient) number of personnel in critical positions at the facility (radiation protection supervisors, operators, etc.), as well as the availability of associated equipment and resources.
- conditions on maintenance and/or changes made with respect to the nuclear safety level of the facility, including:
  - Radiological Protection Service (Art. 09 of Resolution Nº 258, December 19, 2019, as well as Standard CNEN-NN-7.01).
  - Physical Protection (Art. 11 of Resolution Nº 258, December 19, 2019).
  - Fire Fighting Brigade (Art. 16 Resolution No 258, December 19, 2019) and
  - Situation of Nuclear Retort Operators and the installation's technical personnel (Article 10 of Resolution No 258, December 19, 2019).

We remind you that, as a result of the coronavirus, the Operating Organization must maintain the nuclear and radiological safety conditions, as well as other conditions contained in Resolution No 258, December 19, 2019, at whatever stage the installation is.

Due to the reduction in personnel, which has been determined by the Federal Government or caused by contamination by the virus, if it is not possible to maintain the level of safety required for the installation in question with on-site workers, it will be necessary to initiate a shutdown procedure, maintaining the safety level, both during and after the stop, in compliance with the regulations in force.

Finally, the ETN must present a weekly summary report of activities and occurrences."

19(7).5.2 – Measures adopted by Eletronuclear

The world was facing a new disease, of high transmissibility and the country was placed in social isolation as the main prevention measure. Eletronuclear promoted the teleworking regime to the company's employees, with the exception of the nuclear power plants operational area itself. The Eletronuclear Headquarters, in Rio de Janeiro, started to answer for remote work in its majority and the Central Nuclear Almirante Álvaro Alberto (CNAAA), in Angra dos Reis, continued with the essential workers for the operation of the plants, except for those who declared having some risk condition, in person and non-essential in telework.

The company created a business committee called the Crisis Committee, to assess and make managerial decisions in the face of the pandemic. In parallel, a technical health and safety working group (GT Saúde e Segurança) of the Eletrobras Companies was created, for technical discussion to support the necessary general decisions.

The Health and Safety WG, together with a medical consultant in the area of infectious diseases, developed a risk rating in order to classify employees in relation to the main comorbidities at greater risk for complications related to Covid-19; prepared prevention protocols and follow-up of suspected, confirmed and contacting cases and provided information to employees and prevention guidelines. Initially, the diagnostic method used was the periodic testing of employees in face-to-face work with a serological test.

During the pandemic period, Eletronuclear provided masks and alcohol for hand hygiene; performed more frequent cleaning of work environments and public transport; offered psychological support to all employees; in addition to other daily conducts, aimed at health and prevention of contamination by Covid-19 within the company. The occupational medicine team held specific meetings with various sectors of the company for guidance and clarification of doubts related to the new coronavirus.

The Covid-19 Service Center was created to assist, monitor and authorize/recommend leave from work for all employees considered to be suspected or cohabiting or confirmed to have the disease. For the operation, it was necessary to hire a doctor and two nursing technicians, with a workday of 12 hours a day, 7 days a week, including holidays, exclusively to perform such activities.

For the refueling outage of Angra 2 (2P16), in 2020, only the essential staff were hired to carry out extremely necessary activities, and the preventive measures adopted for the Eletronuclear employees were also implemented for these contractors. Booklets with guidelines on the prevention of Covid-19 were created and distributed.

After 2P16, the gradual return of CNAAA employees began, in waves, and later the initial phase of returning employees from the Headquarters. The first group to return to face-to-face work were employees classified as low risk for complications related to Covid-19.

The working hours of these workers were defined by each board, after agreement with their employees, prioritizing, especially in the case of Headquarters, avoiding peak hours in public transport, when entering and leaving the workplace and during lunch hours. In Angra dos Reis, not many journey adjustments were necessary, since in this location the company has its own transport for all employees.

Due to the favorable epidemiological conditions in the municipality of Angra dos Reis, after a period of 60 days from the return of the first wave, employees classified as medium risk were indicated for face-to-face work at the CNAAA.

The protocols were changed over time, in order to meet the needs of each moment. With the evolution of science, the testing protocols were modified, with that the systematic testing with serological test was suspended and the testing phase with antigen test began, a more effective test to determine the presence of the virus, in symptomatic cases or work contacts.

At the end of 2020 and beginning of 2021, there was a worsening of the national scenario related to the infection by SARS-Cov-2, which led the company to determine a 30% reduction in the workforce in face-to-face work at the Nuclear Power Plant and its dependencies in the municipality of Angra dos Reis and the return to remote work at Headquarters.

Still in the first months of 2021, Brazil started the vaccination campaign against Covid-19. Eletronuclear encouraged employees to get vaccinated and, once again, carried out educational activities aimed at promoting health and preventing diseases related to the new disease.

The refueling outage 1P26 at Angra 1 NPP, in 2021, was the first event that required the hiring of a greater number of people during the pandemic. Training was developed for the contractors to present the expectation of what the behavior should be within the company in the face of the new disease. With the beginning of activities, there was a need to reinforce the preventive measures defined by the company, to make the protocol and access control to the plants' dependencies more rigid.

After the experiences lived in 1P26, the company reinforced the protocol by implementing a mandatory random screening regime and the creation of an exclusive brigade to combat COVID-19 during 2P17 (the refueling outage of Angra 2, in 2021), in order to improve inspection and compliance with rules established by Eletronuclear.

After the period of the plants outages and with the advance of vaccination against COVID-19 showing a significant drop in cases of serious complications and deaths from the disease, there was then the decision to return to face-to-face work for employees who were still on telework.

At the beginning of 2022, with the relaxation of preventive measures in the municipalities, there was a significant increase in the number of confirmed cases among employees, even with the company maintaining the protocols on its premises. As in the whole country, this increase in cases did not generate important repercussions regarding the severity of the disease.

Article 19 (8) - Management of spent fuel and radioactive waste on the site

19(8).1 - Overview of the Contracting Party's arrangements and regulatory requirements for the on-site handling of spent fuel and radioactive waste.

Brazil has established and maintained the necessary legislative and regulatory framework to ensure the safety of its nuclear installations, including irradiated fuel and radioactive waste.

Since the current situation is the storage of spent fuel in pools, the general safety requirements for the management of spent fuel are contained in the safety requirementfor siting, design and operation of the nuclear reactors. Regulation CNEN-NE-1.04 [5] applies to the fuel stored in the nuclear power plant. Additional requirements are established in Regulation CNEN-NE-1.26 [10], for the operational phase, and Regulation CNEN-NE-1.14 [7] establishes the necessary reporting requirements

The Stanadard CNEN NE 1.26 - *Safety in the Operation of Nuclear Power Plants* presents, in the section 13, the requirements to be fulfilled by the operating organization of a nuclear power plant regarding the management of effluents and radioactive waste.

In subsection 13.4 it specifies that the operating organization must establish a radioactive waste management program which includes the treatment, initial storage, transport and interim disposal of such waste, and the requirements must be followed, where applicable, established in Standard CNEN NE 5.01 - *Transportation of Radioactive Materials* and in Standard CNEN NE 6.05 - *Management of Radioactive Waste in Radiative Installations*.

The Law 10308 of 20 November 2001 established the new legal framework for the storage and dispose of radioactive waste in Brazil. The Law confirms the Government responsibility for the final destination of radioactive wastes, through the action of CNEN. However, it also opens the possibility for the delegation of the construction, operation and administration of the radioactive waste final disposal facilities to third parties, nevertheless, the full legal responsibility of CNEN is retained.

The Law defines four types of storage facilities: initial, operated by the waste generator; intermediate; final (also called repository); and temporary, which may be established in case of accidents with contamination.

The Law establishes the rules for the site selection, construction, operation, licensing and control, financing, civil liabilities related to the storage and dispose of radioactive waste in Brazil. The Law also establishes the financial arrangements for the transfer of waste to CNEN and the compensation to the municipalities that accept in their territory the construction of radioactive waste storage and/or disposal facilities.

In compliance with Law 10308, CNEN issued on 30 April 2014 the safety regulationCNEN-NN-8.02 - Licensing of storage and disposal facilities for low- and intermediate-level radioactive waste. This regulation establishes general criteria and basic requirements of safety and radioprotection related to the licensing of radioactive waste storage and disposal facilities in Brazil for low- and intermediate-level waste. It is noteworthy that this safety guide is not applicable to waste classified as naturally occurring radioactive material (NORM). Furthermore, also on 30 April 2014, CNEN reviewed Its former guide related to radioactive waste management, from 1985, replacing it by a new guide with name of CNEN-NN-8.01 - Radioactive Waste Management for Low- and Intermediate-Level Waste.

19(8).2 - On-site storage of spent fuel - Measures taken for nuclear power plants.

The policy adopted with regard to spent fuel from nuclear power plants is to keep the fuel in safe storage until a technical, economic and political decision is reached about reprocessing and recycling the fuel or disposing of it as such. It should be highlighted that, by the federal Brazilian legislation, spent fuel is not considered radioactive waste. As stated by article 14 of the Brazilian Nuclear Policy (Decree No. 9600, of 5 December 2018), the spent nuclear fuel will be stored in an appropriate place, in order to preserve the future use of reusable material. Therefore, in the scope of this Convention, spent fuel will be not considered as such.

There is no spent fuel within the military or defense program in Brazil.

With respect to spent fuel storage, the Angra 1 spent fuel pool capacity has been expanded by the installation of compact racks to accommodate the spent fuel generated for the expected operational life of the unit. The Angra 1 spent fuel pool, located in the Angra 1 Fuel Building, has two regions: Region 1, composed of normal cells, with 252 fuel cells, and Region 2, composed of high density storage racks, with 1000 fuel cells.

In the case of Angra 2, the spent fuel pool, which is located inside the steel containment, has two types of racks:

a) Region 1: normal racks with capacity for 264 fuel assemblies, equivalent to one full core plus one reload of fuel of any burnup and with enrichment up to 4.3%;

b) Region 2: high-density storage racks with storage capacity for 820 spent fuel assemblies. The fuel assemblies to be stored in region 2 must have a given minimum burnup, which is a function of the original enrichment.

The inventory of spent fuel and the occupation of the respective Spent Fuel Pools at Angra site until December 2021 is presented in Table 11 below:

Table 11 – Spent Fuel Storage at Angra Units

Angra 1 NPP		Angra 2 NPP	
Spent Fuel Stored	Occupation (%)	Spent Fuel Stored	Occupation (%)
1106	88	685	63.2

Considering realistic assumptions the storage capacity of the Angra1 and Angra 2 Plants spent fuel pools will be exhausted by mid-2021. ELETRONUCLEAR has initially decided to adopt the construction of the Spent Fuel Complementary Dry Storage Unit of CNAAA – UAS. In July 25th 2017, HOLTEC International was contracted by ELETRONUCLEAR to construct a Complementary Dry Storage for 72 casks, to supply 15 storage devices (that assure more 5 years storage capacity of Angra 1 and Angra 2 spent fuel pools), to adjust Angra 1 and Angra 2 to enable the transfer of spent fuel assemblies, and to perform their transference from Angra 1 and Angra 2 pools to the UAS pad. The company strategy to provide additional spent fuel storage capacity is the acquisition of casks for dry storage, each 5 years.

On 27 July 2016 the the Brazilian Regulatory Body issued the Resolution 199 to license the Spent Fuel Complementary Dry Storage Unit of CNAAA – UAS. According to the Article 1 of

Resolution 199 the Brazilian Regulatory Body adopted, as standard model for preparing the Safety Analysis Report of the UAS, the American recommendation of Nuclear Regualatory Commission, titled Regulatory Guide 3.62 – *Standard Format and Content for Safety Analysis Report for Onsite Storage of Spent Fuel Storage Cask*. The Normative basis established for the Nuclear Licensing of UAS was: CNEN NE 1.04 – *Licensing of Nuclear Installations*, Regulatory Guide 3.62 – *Standard Format and Content for Safety Analysis Report for Onsite Storage of Spent Fuel Storage Cask*, NUREG-1567 – *Standard Review Plan for Fuel Dry Storage Facilities*, 10 CFR 72 – *Licensing Requirements for Independent Storage of Spent Fuel and High-Level Radioactive Waste*, CNEN NN 3.01 - *Basic Guidelines for Radiological Protection*, etc. However, the adoption of part of the American standards obeyed the criterion that the requirements of this did not prevail over the fulfillment of specific requirements of the CNEN, in the event that there was a conflict between them.

On April 23th, 2019, CNEN issued the Resolution No. 242, the first interim construction license, with conditioning clauses, limited to the construction of the flagstone for 72 storage drums of spent fuel of the UAS system and on September 3rd, 2019, the Environmental Installation License (LI Nº1310-2019) have been issued by environmental regulator body - IBAMA, valid until of September 3rd, 2025.

On September 05, 2019, CNEN issued the Resolution 249, the Construction License, with conditioning clauses, based on the Preliminary safety Analysis Report of UAS - Revision 3.

The dry storage solution adopted by Eletronuclar was based on Vertical Storage Modulos (Overpacks). The Overpacks functiom is ensuring the physical protection, radiation shielding, d structural protection for the Canister during the storage period and the heat exchange between the Canister and the environment. The Overpacks are mixed structure of concrete and steel, with wall thickness of about 700 mm and devices for air inlet and outlet. There are used to storage of Canisters in the vertical position, and it allows the monitoring of temperature and radiation and inspection of the Canisters.

Holtec International was the main contractor to the UAS project responsible for customisation of the HI-STORM FW system for the different technologies at Angra 1 & 2, modernisations of the plants for safe handling of the systems, civil design and construction of the UAS, and services for loading the dry storage devices with used fuel elements at the units and transferring them to the UAS.

Basically, the CNAAA UAS consists of the following Structure Systems and Components:

a. Concrete storage pad,

b. The HI-STORM FW casks,

c. HI-TRAC VW,

d. Variable Elevation Cask Staging Pedestal (VECASP),

e. Transfer Carriage,

f. Cask Handling Machine (CHM),

g. Ancillary Equipment Warehouse to store the HI-TRAC VW, ancillaries, and spare parts,

h. Security Building at the entrance to UAS to house security personnel staff and access controlfacilities, and

i. Safety Fence.

The facility was designed with physical security in mind such that visual ability to observe an intruder is unhindered, and additional security measures, such as video cameras was included. The storage pad is equipped with an efficient drainage system which is capable of providing adequate drainage for the physical condition of the UAS and surrounding environment. This design feature limits the risk of a mass fire from combustion of fuel or transmission fluid, which could be contained in the vehicles, by maintaining physical separation from the dry cask storage area. Chapter 15 provides the results of the fire evaluation. The casks are designed to maintain containment in the event of a design basis fire accident. Finally, a substantial area adjacent to the loaded UAS is cleared of any brush or foliage. This is done to remove materials from the vicinity of the dry cask storage area that may serve as a fire stimulant. This reduces the probability of fire in the área.

The centerpiece of the CNAAA UAS facility is the HI-STORM FW canister storage system certified in NRC docket # 72-1032. HI-STORM (acronym for Holtec International Storage Module) FW System is a spent nuclear fuel storage system designed to be in full compliance with the requirements of 10CFR72.

The HI-STORM FW (*Holtec International Storage Module Flood and Wind*) system designed by Holtec consist of a sealed mellitic multi-purpose canister (MPC) contained within a storage overpack (HI-STORM) constructed from a combination of steel and concrete. The HI-STORM FW System can safely store PWR fuel assemblies from CNAAA Units 1 and 2, in the MPC-37 or MPC-32ML, respectively. The MPC is identified by the maximum number of fuel assemblies it can contain in the fuel basket.

The HI-STORM FW overpack features an inlet and outlet duct configuration engineered to mitigate the sensitivity of wind direction on the thermal performance of the system that permit efficient, natural circulation of air to cool the MPC and the contained SNF. Thissystems was designed to limit the fuel cladding temperature rise under a most adverse flood event.

The HI-STORM FW overpack can be loaded with the MPC containing SNF using the HI-TRAC VW transfer cask and prepared for storage at the CNAAA facility. From the CNAAA facility the loaded overpack is then moved to the UAS and stored in a vertical configuration. The HI-TRAC VW transfer cask is required for shielding and protection of the SNF during loading and closure of the MPC and during movement of the loaded MPC from the cask loading area of a nuclear plant spent fuel pool to the storage overpack.

On January 9th, 2020, Eletronuclear in compliance with item 8 of the Standard CNEN-NE 1.04 - *Licensing of Nuclear Installations*, sent to CNEN the review 0 of the Final Safety Analysis Report (FSAR) of the UAS.

On February 26th, 2021, in compliance with item 8 of the Standard CNEN-NE 1.04 - *Licensing of Nuclear Installations*, and to response several CNEN's question, sent to CNEN the review 4 of the Final Safety Analysis Report (FSAR) of the UAS.

On March 9, 2021, CNEN Resolution No. 270 granted the Spent Fuel Dry Storage Facility (UAS) the Authorization for the Use of Nuclear Material.

On March 25th, 2021, CNEN issued the Resolution nº 275, Authorization to Inicial Operation to Spent Fuel Complementary Dry Storage Unit of CNAAA – UAS, with five conditioning clauses and valid for 02 (two) years.

In March 2021, the commissioning of the UAS was completed. In April, the first stage of the transfer of spent fuel elements from the spent fuel pool of Angra 2 to the UAS was carried out, covering 96 spent fuel elements. Between August and October, the second stage of this transfer took place, 192 spent fuel elements were taken to the UAS. Altogether, 288 spent fuel elements are stored in the UAS until December 2021. The Figures 22 to 26 show the steps sequence of transference process.

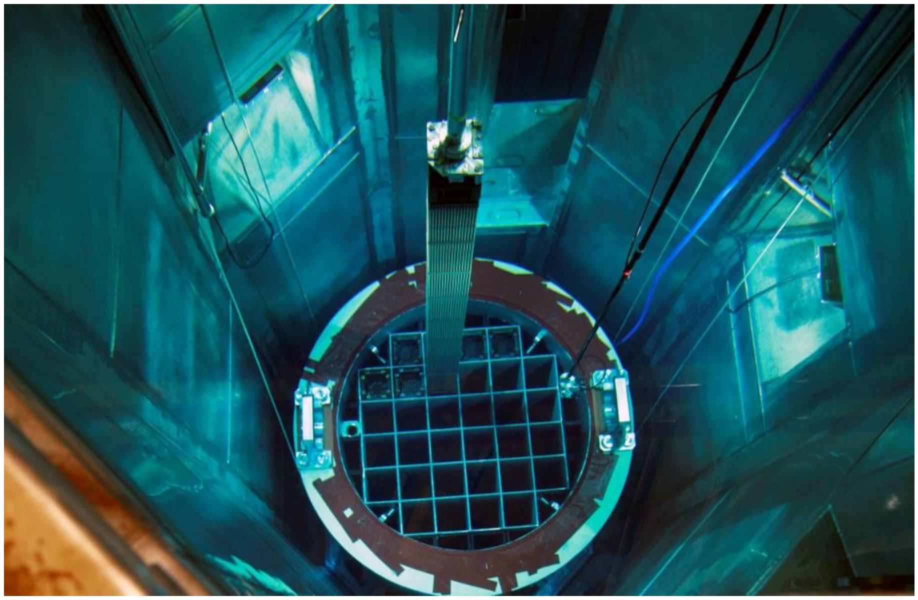

Figure 22 - Used fuel element from Angra 2 is inserted into a canister (Credit: ABDAN)

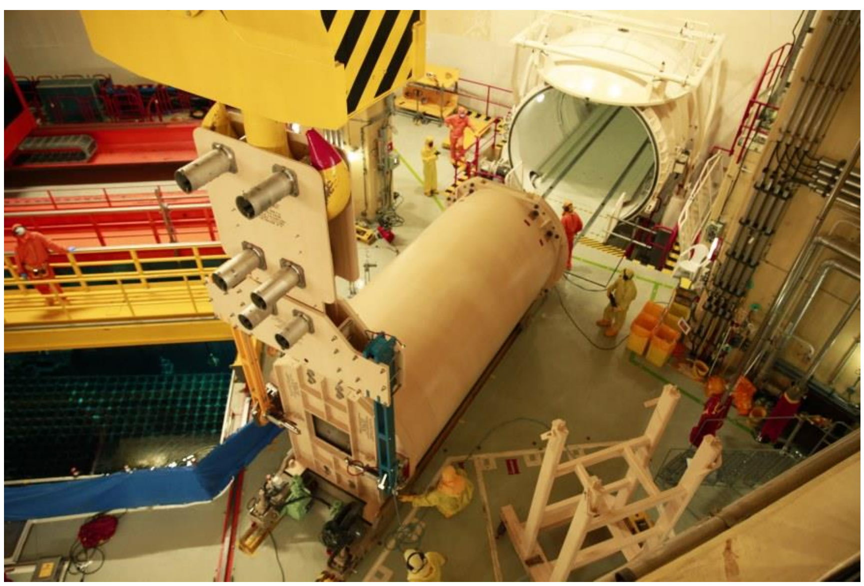

Figure 23 - Hi-Trac with canister is transported out of containment (Credit: ABDAN)

Figure 24 - Canister transfer from Hi-Trac to Hi-Storm (Credit: ABDAN)

Figure 25 - Hi-Storm transfer to UAS (Credit: ABDAN)

Figure 26 - Aerial photo of UAS during movement of the first Hi-Storm (Credit: ABDAN)

In the first half of 2022, the transfer of used fuels from Angra 1 was completed, totaling 6 HI-Storm containing 222 spent fuel elements. Now, a total of 15 HI-Storms are stored in the UAS.

19(8).3 - Regulatory review and control activities of On-site storage of spent fuel – Nuclear Power Plants

The Radioactive Waste Division (DIREJ), responsible for regulating and controlling all activities related to radioactive waste management in Brazil, comprises 18 people, being 7 with doctoral degree, 3 with master's degree, 3 with college degrees people and specialization and 5 administrative. The main activities of DIREJ are review and assessment of the submitted documentation and inspection of licensee's activities. Inspection and audits activities are conducted periodically and on a permanent basis in all storage facilities in Brazil. This division controls the transportation of radioactive materials and radioactive waste management in nuclear facilities, taking a close look at the facilities that manipulate, produce, use, transport or store radiation sources.

19(8).4 - Implementation of on-site treatment, conditioning and storage of radioactive waste – Nuclear Power Plants

Angra 1 nuclear power plant is equipped with systems for treatment and conditioning of liquid, gaseous and solid wastes. Concentrates from liquid waste treatment are solidified in concrete and conditioned in 1 m^3 liners. Compressible solid wastes may be conditioned in 200-liter drums and non compressible wastes in special boxes. Gaseous wastes are stored in holdup tanks and may be released from time to time. These tanks have the capacity for long-term storage, which eliminates the need for scheduled discharge. For the time being, medium and low-level wastes are being stored on site in an initial storage facility (Central Storage Facility).

A permanent long-term program for reduction of production of new waste and reduction of existing waste in Angra 1 is in place.

Angra 2 nuclear power plant is equipped with systems for treatment, conditioning, disposal and storage of liquid, gaseous and solid radioactive wastes. All Angra 2 waste treatment systems are highly automated to minimize human intervention and reduce operating personnel doses. Liquid wastes are collected in storage tanks for further monitoring and adequate treatment or discharge to the environment. The concentrate resulting from the liquid waste treatment is immobilized in bitumen by means of an extruder-evaporator and the dry concentrate is conditioned in 200-liter drums. Spent resins and filter elements are also immobilized in bitumen and conditioned in 200-liter drums. Compactable solid wastes are conditioned in 200-liter drums. Gaseous wastes are treated in the gaseous waste treatment system, where the radioactive gases are retained in delay beds containing active charcoal to let them decay well below allowable levels, before release into the environment throughout the 150 m high plant vent stack. No residues are produced in the gaseous waste treatment system, as all the system's consumables, mainly filter and delay bed fillings, are designed to last for the whole plant lifetime. The drums with waste are initially stored within the plant prior to being transported to the initial storage facility referred above.

According to the Brazilian legislation CNEN is responsible for the final disposal of all radioactive waste generated in the country.

Since no final radioactive wastes repository is available to date, the generated low and intermediate level wastes of Angra 1 are being stored in the already mentioned on-site Central Initial Storage Facility located at the Angra Power Plants site.

This facility is composed of three units, called Storage Facility 1, Storage Facility 2 and Storage Facility 3. Additionally, there is a Steam Generators Storage Facility for storage of the two original Angra 1 steam generators, replaced in 2009, of the original Angra 1 reactor vessel head, replaced in 2013, of one Angra 1 waste evaporator and one hundred sixty six metallic boxes containing non compressible waste produced during the replacement of the old steam generators. All the referred Storage Facilities are presently in operation.

As required by the Regulator, before final disposal, the isotope content and concentrations in the individual radwaste drums has to be known. For this purpose a special building, to be equipped with equipment for remote handling and scanning of the packeds, has been built and is ready for equipment installation.

In Angra 2, all the up to now produced waste drums are stored in a compartment of the Reactor Auxiliary Building, inside the Plant, specifically designed for this purpose. These drums will be transferred along the time to the Central Initial Storage Facility. The disposal system mentioned is the Initial Deposit Radioactive Solids Wastes - KPE, which is located inside the Reactor Auxiliary Building - UKA. This Radwaste Deposit has a capacity to store 1644 drums of medium and low activity.

The current inventory of waste stored at Angra site is presented in the Tables 12 and 13 below:

Table 12 - Waste Stored at Angra Site – Angra 1 NPP

Type of Waste	Nr. of Packages	Location
Concentrate	3158	Storage Facility 1/ Storage Facility 2 / Storage Facility3
Primary Resins	839	Storage Facility 1 / Storage Facility 2 / Storage Facility 3
Filters	553	Storage Facility 1 / Storage Facility 2 / Storage Facility 3
Non-Compressible	1030	Storage Facility 1 / Storage Facility 2 / Storage Facility 3 / Steam Generators Storage Facility
Compressible	929	Storage Facility 1 / Storage Facility 2 / Storage Facility 3
*Supercompacted Compressible Waste	128	Storage Facility 1
Secondary Resins	828	Storage Facility 1
TOTAL	7465	

*In 2006, ELETRONUCLEAR supercompacted 2027 compressible waste drums.

Table 13 - Waste Stored at Angra Site – Angra 2 NPP

Type of Waste	No. of Packages	Location
Filters	23	In Plant Storage (UKA building)
Concentrate	274	In Plant Storage (UKA building)
Primary Resins	140	In Plant Storage (UKA building)
Compressible	550	In Plant Storage (UKA building)
Non-Compressible	17	Storage Facility 3 / Steam Generators Storage Facility
TOTAL	1004	

19(8).5 - Activities to keep the amount of waste generated to the minimum practicable for the process concerned, in terms of both activity and volume.

Generated volume of solid radioactive waste material is kept to a minimum by preventing materials from becoming radioactive, by decontaminating and reusing radioactive materials, by monitoring for radioactivity and separating non-radioactive material prior to conditioning and storage, and by other volume reduction techniques. Procedures, personnel training and quality control checks are used to ensure that radioactive materials are properly packed, labeled and transported to the initial storage facility. Additionally, there are also procedures established for clearance of radioactive waste.

19(8).6 - Regulatory review and control activities on-site treatment, conditioning and storage of radioactive waste – Nuclear Power Plant.

The Radioactive Waste Division (DIREJ), responsible for regulating and controlling all activities related to radioactive waste management in Brazil, comprises 18 people, being 7 with doctoral degree, 3 with master's degree, 3 with college degrees people and specialization and 5 administrative. The main activities of DIREJ are review and assessment of the submitted documentation and inspection of licensee's activities. Inspection and audits activities are conducted periodically and on a permanent basis in all storage facilities in Brazil. This division controls the transportation of radioactive materials and radioactive waste management in nuclear facilities, taking a close look at the facilities that manipulate, produce, use, transport or store radiation sources.

19(8).7 - Conclusions on Article 19

All activities by CNEN and ELETRONUCLEAR related to Plants operation have always had the goal of ensuring Plant safety, reliability and search for continuous improvement.

Expectations for the operating Plants are good for near future. The replacement of Angra 1 steam generators, as well as the several upgrades made, presented in Article 6, resulted in substantial performance improvement for this Plant.

In the case of Angra 2 the plant effort to identify secondary side major equipment malfunction root causes and the countermeasures taken, were successful, as demonstrated by a Plant availability factor larger than 85% in the last 10 years, as shown in Table 2, of Article 6.

A considerable effort was spent in this review period, in enhancing the Plants response to beyond design events through the implementation of SAMGs, and all reported measures derived from lessons learned from the Fukushima accident (see Article 14 and ANNEX V).

The situation of storage capacity for the low and medium level Angra 1 waste up to conclusion of the final repository (planned for 2025), reported in previous National Reports, has been solved by means of several actions, including super-compaction of existing waste drums and construction of additional waste storage facilities.

The safety record for both plants has remained good with almost faultless safety system performance as demonstrated by the plants safety indicators and by the low number and low safety importance of the reported safety related events.

This has been also confirmed by the outcomes of the recent Angra 1 OSART follow up as well as the Angra 1 and 2 WANO peer review, both in 2014, and the subsequent Angra 1 and 2 WPR follow up in 2016, and in the Peer Review missions in both plants in 2018.

REFERENCES

[1] Convention on Nuclear Safety - Legal Series No. 16 - International Atomic Energy Agency - Vienna - 1994.

[2] Guidelines Regarding National Reports under the Convention on Nuclear Safety – INFCIRC/572. Rev6 (19 January 2018).

[3] REPÚBLICA FEDERATIVA DO BRASIL, 2020, National Report of Brazil for the 7th Review Meeting, Joint Convention on the Safety of pent Fuel Management and on the Safety of Radioactive Waste Management, October.

[4] COUNTRY NUCLEAR POWER PROFILE (IAEA) BRAZIL, 2021 (https://cnpp.iaea.org/countryprofiles/Brazil/Brazil.htm)

[5] Licensing of Nuclear Installations - CNEN-NE-1.04 - December 2002.

[6] Siting of Nuclear Power Plants - Resolution CNEN 09/69.

[7] Licensing of Nuclear Reactor Operator - CNEN-NN-1.01 – April 2014.

[8] Operational Reporting for Nuclear Power Plants - CNEN-NN-1.14 – January 2002.

[9] Operational Safety in Nuclear Power Plants - CNEN-NE-1.26 - October 1997.

[10] Safety Policy of CNEN – Directive n.295 of 23 December 1996.

[11] Quality Assurance Policy of CNEN – Directive n.296 of 23 December 1996.

[12] Health Requirements for Nuclear Reactor Operators - CNEN-NE-1.06 - 1980

[13] Certification of Qualification of Radiation Protection Supervisors - CNEN-NN-7.01 - October 1997.

[14] Quality Assurance for Safety in Nuclear Power Plants and Other installations - CNEN-NN-1.16 – April 2000.

[15] Basic Radiation Protection Directives - CNEN-NN-3.01 – March 2014.

[16] General Norm for Planning of Response to Emergency Situations – SIPRON – NG–02 - 1996

[17] Directive for the Preparation of Emergency Plans related to the Unit 1 of Almirante Alvaro Alberto Nuclear Power Plant – SIPRON Directiva Angra – 1997.

[18] General Norm for Establishing Public Information Campaigns about Emergency Situations – SIPRON - NG-05 – 1997.

[19] Maintenance of Nuclear Power Plants - CNEN-NE-1.21 - August 1991.

[20] In-service Inspection of Nuclear Power Plants - CNEN-NE-1.25 - September 1996.

[21] Law 10.308 of 2001.11.20 – Rules for the site selection, construction, operation, licensing and control, financing, civil liability and guaranties related to the storage of radioactive wastes.

Annex I

I.– EXISTING INSTALLATIONS

I.1. Angra 1

Thermal power	1876 MWth
Gross electric power	640 MWe
Net Electric power	609 MWe
Type of reactor	PWR
Number of loops	2
Number of turbines	1 (1High Pressure/2Low pressure)
Containment	Dry cylindrical steel shell and external concrete building.
Fuel assemblies	121

Main supplier	Westinghouse El. Co.
Architect Engineer	Gibbs & Hill / Promon Engenharia
Civil Contractor	Construtora Norberto Odebrecht
Mechanical Erection	Empresa Brasileira de Engenharia

Construction start date	March 1972
Core load	20 September 1981
First criticality	13 March 1982
Grid connection	1 April 1982
Commercial operation	1 January 1985

I.2. Angra 2

Thermal Power	3765 MWth
Gross electric power	1350 MWe
Net electric power	1280 MWe
Type of reactor	PWR
Number of loops	4
Number of turbines	1 (1High Pressure/3Low pressure)
Containment	Dry spherical steel shell and external concrete building.
Fuel assemblies	193

Main supplier	Siemens KWU
Architect Engineer	ELETRONUCLEAR/Siemens KWU
Civil Contractor	Construtora Norberto Odebrecht
Mechanical Erection	Unamon

Construction start date	1975
Core load	30 March 2000
First Criticality	14 July 2000
Grid connection	21 July 2000
Commercial operation	January 2001

I.3. Angra 3

Thermal Power	3765 MWth
Gross electric power	1405 MWe
Net electric power	1370 MWe
Type of reactor	PWR
Number of loops	4
Number of turbines	1 (1High Pressure/3Low pressure)
Containment	Dry spherical steel shell and external concrete building.
Fuel assemblies	193

Main supplier	Areva
Architect Engineer	ELETRONUCLEAR
Civil Contractor	TBD
Mechanical Erection	TBD

Construction start date	1978
Construction restart date	1st July, 2010
Core load	
First Criticality	
Grid connection	
Commercial operation	

ANNEX II

RELEVANT CONVENTIONS, LAWS AND REGULATIONS

II.1. Relevant International Conventions of which Brazil is a Party

Convention on Civil Liability for Nuclear Damage (Vienna Convention). Signature: 23/12/1993. Entry into force: 26/06/1993.

Convention on the Physical Protection of Nuclear Material. Signature: 15/05/1981. Entry into force: 8/02/1987.

Convention on Early Notification of a Nuclear Accident. Signature: 26/09/1986. Entry into force: 4/01/1991.

Convention on Assistance in Case of Nuclear Accident or Radiological Emergency. Signature: 26/09/1986. Entry into force: 4/01/1991.

Convention on Nuclear Safety. Signature: 20/09/1994. Entry into force: 24/04/1997.

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management – Signature 11.10.1997. Entry into force 16.04.2006.

Convention n. 115 of the International Labor Organization. Signature: 7/04/1964.

II.2. Relevant National Laws

Decree 40.110 dated 1956.10.10 - Creates the Brazilian National Commission for Nuclear Energy (CNEN).

Law 4118/62 dated 1962.07.27 - Establishes the Nuclear Energy National Policy and reorganizes CNEN.

Law 6189/74 dated 1974.12.16 - Creates Nuclebrás as a company responsible for nuclear fuel cycle facilities, equipment manufacturing, nuclear power plant construction, and research and development activities.

Law 6.453 dated 1977.10.17 - Defines the civil liability for nuclear damages and criminal responsibilities for actions related to nuclear activities

Law Nº 12.731 of 21/11/2012 that reorganize the Brazilian Nuclear Protection System (SIPRON).

Law 6938 of 1981.08.31 - Establishes the National Policy for the Environment PNMA), creates the National System for the Environment (SISNAMA) and the Council for the Environment (CONAMA).

Law 7781/89 dated 1989.06.27 - Reorganizes the nuclear sector.

Decree 99.274 dated 1990.06.06 - Regulates application of law 6938, establishing the environmental licensing process in 3 steps: pre-licence, installation licence and operation licence.

Decree 2210 dated 1997.04.22 - Regulates SIPRON, defines the Secretary for Strategic Affairs (SAE) as the central organization of SIPRON and creates the Coordination of the Protection of the Brazilian Nuclear Program (COPRON).

Law 9.605 dated 1998.02.12 – Defines environmental crimes and establishes a system of enforcement and punishment.

Decree 3719 dated1999.09.21 – Regulates the Law 9.605 and establishes the penalties for environmental crimes.

Law 9.765 dated 1998.12.17 – Establishes tax and fees for licensing, control and regulatory inspection of nuclear and radioactive materials and installations.

Decree 3833 dated 2001.06.05 – Establishes the new structure and staff of the Brazilian Institute for the Environment (IBAMA).

Law 10.308 dated 2001.11.20 – Establishes rules for the site selection, construction, operation, licensing and control, financing, civil liability and guaranties related to the storage of radioactive wastes.

Decree 1.019 dated 2005.11.14 – Promulgates the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

Federal Law 140 dated 2011.12.08 - Set standards to sections III, VI and VII of art. 23 of the Brazil's Constitution, associated with protection of outstanding natural landscapes, protection of the environment, control of pollution in any of its forms, and preservation of biodiversity. The law assigns roles to the multitude environmental agencies in the country at the Federal, Estate, and Municipal levels, as well as guidelines to pursue cooperation among these agencies.

II.3. CNEN Regulations

Res 09/69 - Normas para Escolha de Locais para Instalação de Reatores de Potência – ***(Siting of Nuclear Power Plants)*** June 1969

NN 1.01 - Licenciamento de operadores de reatores nucleares - Resol. CNEN 170/14 - ***(Licensing of nuclear reactor operators)*** April 2014.

NE 1.04 - Licenciamento de instalações nucleares - Resol. CNEN 15/02 - ***(Licensing of nuclear installations)*** December 2002.

NE 1.06 - Requisitos de saúde para operadores de reatores nucleares - Resol. CNEN 03/80 - ***(Health requirements for nuclear reactor operators)*** June 1980.

NN 1.14 - Relatórios de operação de usinas nucleoelétricas – Resol. CNEN 16/01 ***(Operation reports for nuclear power plants)*** January 2002.

NE 1.16 - Garantia de qualidade para a segurança de usinas nucleoelétricas e outras instalações - Resol. 17/00 - ***(Quality assurance for safety of nuclear power plants and other installations)*** April 2000.

NN 1.17 - Qualificação de pessoal e certificação para ensaios não destrutivos em itens de instalações nucleares – Resol. CNEN 118/11 - ***(Qualification and certification of personnel for non-destructive tests in nuclear power plants components)*** December 2011.

NE 1.18 - Conservação preventiva em usinas nucleoelétricas – Resol. CNEN 09/85 - ***(Housekeeping in nuclear power plants)*** September 1985.

NE 1.19 - Qualificação de programas de cálculos para análise de acidentes de perda de refrigerante em reatores a água pressurizada - Resol. CNEN 11/85 - ***(Qualification of calculation programs for the analysis of loss of coolant accidents in pressurized water reactors)*** November 1985.

NE 1.20 - Aceitação de sistemas de resfriamento de emergência do núcleo de reatores a água leve – Resol. CNEN 12/85 - ***(Acceptance criteria for emergency core cooling system for light water reactors)*** November 1985.

NE 1.21 - Manutenção de usinas nucleoelétricas - – Resol. CNEN 03/91 - ***(Maintenance of nuclear power plants)*** August 1991.

NE 1.22 - Programas de meteorologia de apoio de usinas nucleoelétricas – Ordinance CNEN DEx-1 04/89 - ***(Meteorological program in support of nuclear power plants)*** August 1989.

NE 1.25 - Inspeção em serviço de usinas nucleoelétricas – Resol. CNEN 13/96 - ***(In service inspection of nuclear power plants)*** September 1996*.*

NE 1.26 - Segurança na operação de usinas nucleoelétricas – Resol. CNEN 04/97 - ***(Operational Safety in nuclear power plants)*** October 1997*.*

NE 1.28 - Qualificação e atuação de órgãos de supervisão técnica independente em usinas nucleoelétricas e outras instalações - Resol. CNEN-CD Nº.15/99 de 16/09/1999 ***- (Qualification and actuation of independent technical supervisory agencies in nuclear power plants and other installations)*** September 1999*.*

NE 2.01 - Proteção Física de Unidades Operacionais da Área Nuclear – Resol. CNEN 253/19 - ***(Physical Protection of nuclear materials and Installations)*** November 2019*.*

NN 2.02 – Controle de Materiais Nucleares – Resol. CNEN 11/99 – ***(Control of Nuclear Materials)*** September 1999.

NE 2.03 - Proteção contra incêndio em usinas nucleoelétricas - Resol. CNEN 13/99 - ***(Fire protection in nuclear power plants)*** September 1999*.*

NN 3.01 - Diretrizes básicas de Proteção Radiológica - Resol. CNEN 164/14 - ***(Radiation protection directives)*** March 2014*.*

NE 3.02 - Serviços de proteção radiológica – Resol. 10/88 - ***(Radiation protection services)*** August 1988*.*

NE 5.01 – Regulamento para o Transporte Seguro de materiais radioativos - Resol. CNEN 271/21 - ***(Regulations for the Safe Transport of Radioactive Materials)*** March 2021*.*

NE 5.02 - Transporte, recebimento, armazenamento e manuseio de elementos combustíveis de usinas nucleoelétricas – Resol. CNEN 08/03 - ***(Transport, receiving, storage and handling of fuel elements in nuclear power plants)*** February 2003*.*

NE 5.03 - Transporte, recebimento, armazenagem e manuseio de ítens de usinas nucleoelétricas – Ordinance CNEN DEx1 02/89 ***(Transport, receiving, storage and handling of items in nuclear power plants)*** February 1989*.*

NE 7.01 - Certificação da qualificação de supervisores de radioproteção - Resol. CNEN 259/20 – ***(Certification of the qualification of radiation protection supervisors)*** March 2020*.*

NN 8.01 Gerência de Rejeitos Radioativos de Baixo e Médio Níveis de Radiação (Resolução 167/14) **(Low and Intermediate Radioactive Waste Management)** –April 2014.

NN 8.02 Licenciamento de Depósitos de Rejeitos Radioativos de Baixo e Médio Níveis de Radiação (Resolução 168/14)- **(Licensee of Low and Intermediate Level Radioactive Waste Deposits**) - April 2014.

NN 9.01 – Descomissionamento de Usinas Nucleoelétricas – Resol. CNEN 133/12 – ***(Decommissioning of Nuclear Power Plants)*** – November 2012.

NN 9.02 - Gestão dos Recursos Financeiros Destinados ao Descomissionamento de Usinas Nucleoelétricas – Resol. CNEN 204/16 – (***Management of Financial Resources For the Decommissioning of Nuclear Power Plants)*** Octubre 2016.

II.4. IBAMA Regulations

CONAMA – 01/86 - Estabelece requisitos para execução do Estudo de Impacto Ambiental (EIA) e do Relatótio de Impacto Ambiental (RIMA) - ***(Establishes requirements for conducting the environmental study (EIA) and the preparation of the report on environmental impact (RIMA)) -*** (23/01/1986).

CONAMA-28/86 - Determina a FURNAS a elaboração de EIA/RIMA para as usinas nucleares de Angra-2 e 3 - ***(Directs FURNAS to prepare an EIA/RIMA for the Angra-2 and 3 nuclear power plants) -*** (03/12/1986)

CONAMA-09/86 - Regulamenta a questão de audiências públicas - ***(Regulates the matters related to public hearings) -*** (03/12/1987).

CONAMA-06/86 – Institui e aprova modelos para publicação de pedidos de licenciamento - ***(Establishes and approves models for licensing application) -*** (24/01/1986).

CONAMA-06/87 – Dispõe sobre licenciamento ambiental de obras de grande porte e especialmente do setor de geração de energia elétrica - ***(Regulates environmental licensing of large enterprises, specially in the area of electric energy generation) -*** (16/09/1987).

CONAMA-237/97 – Dispõe sobre os procedimentos a serem adotados no licenciamento ambiental de empreendimentos diversos - ***(Establihses procedures for environmental licensing of several types of enterprises) –*** (19/12/1997).

IBAMA Normative Instruction n º 184/08– (***Establishes within this Agency, the procedures for federal environmental permits) –*** (17/07/2008).

IBAMA Normative Instruction n º 184/08– (***Establishes within this Agency, the procedures for federal environmental permits) –*** (17/07/2008).

IBAMA Normative Instruction n º 05/2012 **–** (***Eestablishes transitional procedure for environmental authorization for the transport of dangerous goods activity***) - (09/05/2012).

IBAMA Normative Instruction n º 01/2016 **–** (***Establishes the criteria for the licensing of radioactive facilities)*** - (01/02/2016).

II.5. SIPRON Regulations

NG-01 - Norma Geral para o funcionamento da Comissão de Coordenação da Proteção do Programa Nuclear Brasileiro (COPRON) - ***(General norm for the Coordination Commission for the Protection of the Brazilian Nuclear Program).*** Port. SAE 99 of 13.06.1996.

NG-02 - Norma Geral para planejamento de resposta a situações de emergência. **- *(General norm for planning of response to emergency situations).*** Resol. SAE/COPRON 01/96.

NG-03 - Norma Geral sobre a integridade física e situações de emergência nas instalações nucleares - ***(General norm for physical integrity and emergency situations in nuclear installations).*** Resol. SAE/COPRON 01/96.

NG-04 - Norma Geral para situações de emergência nas unidades de transporte - ***(General norm for emergency situations in the transport units).*** Resol. SAE/COPRON 01/96.

NG-05 - Norma Geral para estabelecimento de campanhas de esclarecimento prévio e de informações ao público para situações de emergência - ***(General norm for establishing public information campaigns about emergency situations).*** Port. SAE 150 of 11.12.1997.

NG-06 - Norma Geral para instalação e funcionamento dos centros de resposta a situações de emergência nuclear - ***(General norm for installation and functioning of response center for nuclear emergency situations).*** Port. SAE 27 of 27.03.1997.

NG-07 - Norma Geral para planejamento das comunicações do SIPRON ***(General norm for SIPRON communication planning).*** Port. SAE 37 of 22.04.1997.

NG-08 - Norma Geral sobre o planejamento e a execução da proteção ao conhecimento sigiloso no âmbito do SIPRON ***(General norm for the planning and execution of the protection of the classified knowledge within SIPRON).*** Port. SAE 145 of 07.12.1998.

NI-01 – Norma Interna que dispõe sobre a instalação e o funcionamento do Centro Nacional para o Gerenciamento de uma Emergência Nuclear (***Internal Norm on the installation and operation of the National Center for the Management of a Nuclear Emergency***). Port. SAE 001 of 05.21.1997.

Diretriz Angra-1 - Diretriz para elaboração dos planos de emergência relativos a unidade 1 da Central Nuclear Almirante Alvaro Alberto - ***(Directive for the preparation of emergency plans related to Unit 1 of Almirante Alvaro Alberto Nuclear Power Plant - Angra 1).*** GSIPR Nº 34 of 24 /08/ 2012.

Comitê de Planejamento de Resposta a Situações de Emergência Nuclear no Município de Angra dos Reis – COPREN/AR ***(Committee for Nuclear Emergency Response Planning in the city of Angra dos Reis)*** – Port. nº8 – GSIPR of 24/03/ 2011.

Comitê de Planejamento de Resposta a Situações de Emergência Nuclear no Município de Resende – COPREN/RES ***(Committee for Nuclear Emergency Response Planning in the city of Resende)*** – Port.nº 40 – CH/GSIPR, of 25/06/ 2012.

Comitê de Articulação nas Áreas de Segurança e Logística do Sistema de Proteção ao Programa Nuclear Brasileiro – CASLON ***(Coordination Commitee for the Safey and Suport Areas of the System for Protection of the Brazilian Nuclear Program) –*** Port. nº31 GSIPR, of 26 /03/ 2012.

Annex III

RESEARCH REACTORS

III.1 - The Research Reactor IPR-R1 TRIGA Mark I of Nuclear Technology Development Center (CDTN)

III.1.1 - General information:

Details on TRIGA research reactor technical characteristics and general operation experience at CDTN can be found in the IAEA Research Reactor Data Base (RRDB) https://nucleus.iaea.org/rrdb/#home.

Research Reactor Details of TRIGA - Mark I

- Country Brazil
- Facility Name IPR-R1
- Status OPERATIONAL
- Owner Nuclear Technology Development Center CDTN, Belo Horizonte
- **Operator** Nuclear Technology Development Center CDTN, Belo Horizonte
- **Administrator**: CAMPOLINA, Daniel de Almida Magalhães, head of TRIGA Reactor Unit Service (SEURT).
- Address Rua Professor Mario Werneck S\N,
- Telephone +553134399594, +553134399531
- Fax +5531306932253
- E-Mail campolina@cdtn.br
- Web Address www.cdtn.br
- Licensing Brazilian Nuclear Energy Commission
- Construction Date 1958/01/01
- Criticality Date 1960/11/06
- Safeguards IAEA/ABACC

Technical Data

- Reactor Type TRIGA Mark I
- Thermal Power, Steady (kW) 100
- Max Flux SS, Thermal (n/cm2-s) 4.2 E+12
- Max Flux SS, Fast (n/cm2-s) 1.4E+12
- Thermal Power, Pulsed (MW) 0.00
- Moderator H2O, ZrH
- Coolant light water
- Natural Convection Cooling yes
- Cool Velocity In Core 40.18 m/s
- Forced Cooling at N/A
- Reflector Graphite
- Reflector Number of Sides annular
- Control Rods Material B4C
- Control Rods number 3

Experimental Facilities

- Vertical Channels 1
- Vertical Max Flux (n/cm2-s) 1.0 E+6
- Vertical Use neutron
- radiography Extractor
- In-core Irradiation Channels 4+2+1
- In-Core Max Flux (n/cm2-s) 4.2E12
- Reflector Irradiation Channels 40-80 pos.

Fuel data

- Enrichment LEU ≤ 20% U-ZrH
- Origin of Fissile Material USA
- Dimensions of Rods (mm) 36.3 DIA, 720.6 L (SS)
  - 35.6 DIA, 722.4 L (Aluminum)

- Cladding Material SS or Aluminum
- Cladding Thickness (mm) 0.51 (SS) or 0.76 (Aluminum)
- Fuel Material UZrH
- Fuel Loading per Element (g U-235) 38
- Burnup on Discharge, max (%) 25
- Burnup Average (%) 5
- Last Spent Fuel Shipment, Year never
- Last Spent Fuel Shipment, Rods none
- Final destination none
- Last Receipt Year 1972
- Last Receipt Element 79
- Spent Fuel Storage Capacity 66
- Fuel Fabricator General Atomics, USA
- Fuel, present status, core 63
- Stored spent fuel 1
- Stored Fresh fuel 4
- Fuel storage capacity 66
- Fuel, total at site 68

Reactor Utilization

- Hours per Day 8
- Days per Week 1
- Weeks per Year 40
- MW Days per Year 1.5
- Materials/fuel test experiments NO
- Isotope Production NO
- Neutron Scattering NO
- Neutron Radiography YES
- Activation Analysis YES
- Number of samples
- irradiated/year 1000

Teaching:

- Number of students/year 2
- Training NPP operators: no
- Number of operators/year 0
- Since 2013, operates at 100kW

III.1.2 - Ad. Article 10: Priority to safety

The following elements of nuclear safety are implemented: inherently safe reactor design, technical specifications and limitations based on safety analysis, organization and staffing, training of personnel, quality assurance system, regular inspections and maintenance, inspections, promotion of safety culture, international inspections (safeguards).

The basic safety documents are Safety Analysis Report (originally provided by the reactor manufacturer, updated in 2013 and 2021), Emergency Procedures, Operating Procedures, Fire Protection Plan, Security Plan and Quality Assurance Plan.

Reactor safety is implemented and controlled by the internal Reactor Safety Committee consisting of members of the Institute and an external member. All actions, experiments, plans and documents related to reactor safety must be reviewed and approved by the Safety Committee.

In January 2018 the IPR-R1 Research Reactor received its first Operating License issued by the Brazilian Regulatory Body.

In the period from 2019 to 2021, no abnormal events recorded, no abnormal radioactive releases recorded, and no radiological accidents recorded.

III.1.3 - Ad. Article 11: Financial and human resources

Financial and human resources available:

- Annual Cost 25,000 US$
- Total Staff 7
- No. of Operators 3

Financial provisions for decommissioning are not provided.

III.1.4 - Ad. Article 12: Human factor

Reactor operators are trained in according to Training and Retraining Program established by Operating Organization and approved by CGRC. Human errors basically are prevented by:

- Organization and system of personal responsibilities,
- Quality assurance program,
- Verification and control.

Strong emphasis is put on personal qualification and responsibilities. The operation staff are carefully selected and trained. The CNEN/CGRC monitors the adequacy of the human resources of the licensee through the evaluation of its performance, especially through the analysis of the human factor influence on operational events. The training and retraining program is also evaluated by CNEN within the licensing procedure and through regulatory inspections.

In the specific case of reactor operators, see Article 19 of this Ninth Report, CNEN has established regulations related to their authorization[7] and their medical qualification[12].

The Reactors Operators Licensing Board has the purpose to verify compliance with the standard CNEN-NN-1:01, Licensing of nuclear reactor operators, and CNEN-NE-1.06, *Health requirements for nuclear reactors operators*, evaluate and audit the training program and re-training of reactor operators and verify the ability of operators through written tests, practical-oral test and performs the test in the research reactor itself. It is responsible for all technical activities to support the issue of an Operator Reactor License.

In the period 2019 – 2021, CNEN has issued a total of 4 licenses for Research Reactor IPR-R1 TRIGA Mark I,

- 2019 – none.
- 2020 – 4 renewals (2 RO and 2 SRO).
- 2021 – none.

III.1.5 - Ad. Article 13: Quality assurance

The Nuclear Technology Development Center (CDTN) has established its quality assurance programs for IPR-R1 TRIGA Mark I Research Reactor, in accordance with the mentioned requirements in Article 13 of this Ninth National Report and assessed by CGRC. Quality assurance is implemented as part of the Quality Assurance Program. The head of the reactor operation service is responsible for its implementation. The corresponding procedures were developed and are currently in place. The programs provide for the control of activities which influence the quality of items and services important to safety as: design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, commissioning, operation, maintenance, repair and training. The quality assurance programs are described in Chapter 12 of the Safety Analysis Report of IPR-R1 TRIGA Mark I Research Reactor.

Appropriate internal QA and QC documentation is applied. QA activities in reactor operation are subject to internal and external audits and inspections.

III.1.6 - Ad. 14: Assessment and verification of safety

The in-service inspection plan is implemented as part of the QA/QC program and a periodic safety verification are performed through internal inspections and audits. Safety related modification are reviewed by the internal Reactor Safety Committee. Major reconstruction and renewal was performed in 1995 related to control system of the IPR-R1. The IPR-R1 instrumentation upgrade also contemplates the International Atomic Energy Agency (IAEA) recommendations, for safe research reactors operation included in IAEA-TECDOC-1066 - *Specifications of Requirements for Upgrades Using Digital Instrumentation and Control Systems,* Safety Guide No. NS-G-1.3 - *Instrumentation and Control Systems Important to Safety in Nuclear Power Plants,* ANSI Guide ANSI/ANS 15.15-1978, “Criteria for the Reactor Safety Systems of Research Reactors” and the IAEA Safety Series 35-S1.

In sense of regulatory activities, the CGRC periodically audits in the following areas: radiation protection, conduction of operation, reactor operators retraining, fire protection, emergency preparedness.

In the period of January 2019 to December 2021, the CGRC/DRS/CNEN performed 2 inspections and audits.

III.1.7 - Ad. 15: Radiation protection

Radiation protection is implemented and performed by the Radiation Protection Service of Reactor, with technical support of Nuclear and Radiation Safety Division of CDTN. Internal, national and international regulations and recommendations are respected. The dose restriction limit for a reactor operation staff member is 20 mSv per year. The CGRC audits frequently the CDTN’s Radiation Protection Program.

In the period of January 2019 to December 2021, the Radiological Protection area of CGRC/DRS/CNEN performed 2 inspections and audits.

III.1.8 - Ad. 16: Emergency preparedness

Emergency plans for TRIGA reactor are specified in the Safety Analysis Report according to NUREG-1537 format.

Appropriate procedures are prepared in the form of special written documents for practical use in emergency situation. The procedures are subject to internal and external verification and approval. The procedures include: reactor status data, identification of emergency situation, description of the actions, alarming, reporting, informing and responsibilities for the following internal and external emergency events:

- Maximum Hypothetical Accident.
- Insertion of Excess Reactivity.
- Loss of Coolant.
- Loss od Coolant flow.
- Mishandling or Malfuction of fuel.
- Loss of Normal Electrical power.
- External Events.
- Mishandlin or Malfuction of Equipment.

The procedures are part of the operation documentation permanently available in the control room, in the office of the reactor center and in the physical protection office.

The reactor operation staff, the radiological protection staff and the physical protection staff are trained in using the procedures. Periodic retraining is provided.

Since when the Emergency Plan was implemented, the reactor has operated without incident record that has caused any material or physical damage.

The emergency classes are:

- Unusual Events.
- Alert
- Site Area Emergency
- General Emergency.

CNEN is a member of the IAEA-IRSRR technical cooperation program exchanging experience with other participant countries related events in research reactors.

III.2 - The Research Reactor IPEN/IEA-R1 Pool Reactor of Institute for Energy and Nuclear Research (IPEN)

III.2.1 - General information

Details on IEA-R1research reactor technical characteristics and general operation experience at IPEN can be found in the IAEA Research Reactor Data base http://www.iaea.org/worldatom/rrdb/.

Research Reactor Details of IEA-R1 - POOL

- Country Brazil
- Facility Name IEA-R1
- Status OPERATIONAL – since 2013 – operates at 4,5 MW
- Owner Institute for Energy and Nuclear Research (IPEN), São Paulo
- Operator Institute for Energy and Nuclear Research (IPEN), São Paulo
- Administrator: Walter Ricci Filho head of reactor operational group
- Address Av Lineu Prestes 2241, CID Universitária, São Paulo - SP
- Telephone +551131338820
- Fax +5511338815
- E-Mail wricci@ipen.br
- Web Address www.ipen.br
- Licensing Brazilian Nuclear Energy Commission
- Construction Date 1956/01/11
- Criticality Date 1957/09/16
- Safeguards IAEA/ABACC

Technical Data

- Reactor Type POOL
- Thermal Power, Steady (kW) 5000

- Max Flux SS, Thermal (n/cm2-s) 4.6 E+13
- Max Flux SS, Fast (n/cm2-s) 1.3E+14
- Thermal Power, Pulsed (MW) 0.00
- Moderator GRAPHITE, BE,
- Coolant light water
- Cool Velocity in Core 0,8 M /S
- Natural Convection Cooling yes≤200kw
- Forced Cooling ≥200kw
- Reflector graphite
- Reflector Number of Sides annular
- Control Rods Material IN,AG and CD
- Control Rods number 4

Experimental Facilities

- Horizontal Channels 12
- Horizontal Max Flux (n/cm2-s) 7.0 E+08
- Horizontal Use Neutron Scattering, nêutron radiography, NCT
- Vertical Channels 1
- Vertical Max Flux (n/cm2-s) 2.0 E+11
- Vertical Use pneumatic system

Irradiation Facilities

- In-core Irradiation Channels BE IRRAD.
- In-Core Max Flux 1.17E14 n/cm2-s
- Reflector Max Flux 1.17E14 n/cm2-s

Fuel data

- Enrichment Uranium LEU 19,9% (U3O8-AL and U3SI-AL)
- Origin of Fissile Material BRAZIL
- Equilibrium Core Size 72
- Dimensions of Rods (mm) 37.3 DIA, 723.9 L
- Cladding Material SS
- Cladding Thickness (mm) 0.51

- Fuel Material UZRH
- Last Spent Fuel Shipment Year 2007
- Last Spent Fuel Shipment Rods 219
- Final destination USA
- Spent Fuel Storage Capacity 600
- Fuel Fabricator GENERAL ATOMICS, USA
- Fuel, present status, core 56
- spent fuel storage 24 LEU
- fuel storage capacity 108
- total occupied 27

Reactor Utilization

- Hours per Day 24
- Days per Week 3
- Weeks per Year 42
- MW Days per Year 525
- Materials/fuel test experiments YES - 2
- Isotope Production YES - 20000 GBq/year
- Neutron Scattering - 600h
- Neutron Radiography YES - 600h
- Activation Analysis YES - 800h

Number of samples irradiated

- Activation analysis - 800
- Geochronology - 140

Teaching:

- Number of students/year 64
- Training Operators/Experiments 8

III.2.2 - Ad. Article 10: Priority to safety

The following elements of nuclear safety are implemented: inherently safe reactor design, technical specifications and limitations based on safety analysis, organization and staffing, training of personnel, quality assurance system, regular inspections and maintenance, inspections, promotion of safety culture, international inspections (safeguards).

The basic safety documents are: Safety Analysis Report (originally provided by the reactor manufacturer, updated following IAEA standard format in 2013), Emergency Procedures and Operating Procedures.

Reactor safety is implemented and controlled by the internal Reactor Safety Committee consisting of members of the Institute management. All actions, experiments, plans and documents related to reactor safety must be reviewed and approved by the Safety experience Committee.

In the period from 2019 to 2021, no abnormal events recorded, no abnormal radioactive releases recorded and no radiological accidents recorded.

III.2.3 - Ad. Article 11: Financial and human resources

Financial and human resources available:

- Annual Cost 60,000 US$
- Total Staff 17
- No. of Operators 17
- Safety improvements financed within the yearly budget (00,000 US$).
- Financial provisions for decommissioning are not provided.

III.2.4 - Ad. Article 12: Human factor

Reactor operators are trained in according to Training and Retraining Program established by Operating Organization and approved by CGRC. Human errors basically are prevented by:

- Organization and system of personal responsibilities,
- quality assurance program,
- Verification and control.

Strong emphasis is put on personal qualification and responsibilities. The operation staff are carefully selected and trained. The CNEN/CGRC monitors the adequacy of the human resources of the licensee through the evaluation of its performance, especially through the analysis of the human factor influence on operational events. The training and retraining program is also evaluated by CNEN within the licensing procedure and through regulatory inspections.

In the specific case of reactor operators, see Article 19 of this Seventh Report, CNEN has established regulations related to their authorization[7] and their medical qualification[12].

The Reactors Operators Licensing Board has the purpose to verify compliance with the standard CNEN-NN-1:01, Licensing of nuclear reactor operators, and CNEN-NE-1.06, *Health requirements for nuclear reactors operators*, evaluate and audit the training program and re-training of reactor operators and verify the ability of operators through written tests, practical-oral test and performs the test in the research reactor itself. It is responsible for all technical activities to support the issue of an Operator Reactor License.

In the period 2019 – 2021, CNEN has issued a total of Reactor Operator Licenses:

- 2019 – N/A.
- 2020 – 09 ROs and 04 SROs.
- 2021 - N/A.

III.2.5 - Ad. Article 13: Quality assurance

The Institute for Energy and Nuclear Research (IPEN) has established its quality assurance programs for the IEA-R1 Research Reactor, in accordance with the mentioned requirements in Article 13 of this Seventh National Report and assessed by CGRC. Quality assurance is implemented as part of the Quality Assurance Program. The head of the reactor operation department is responsible for its implementation. The corresponding procedures were developed and are currently in place. The programs provide for the control of activities which influence the quality of items and services important to safety as: design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, commissioning, operation, maintenance, repair and training. The quality assurance programs are described in Chapter 18 of the Safety Analysis Report of IEA-R1 Research Reactor.

Appropriate internal QA and QC documentation is applied. QA activities in reactor operation are subject to internal (QA manager team) and external (Brazilian Nuclear Energy Commission) audits and inspections.

III.2.6 - Ad. 14: Assessment and verification of safety

The reactor is regularly maintained. Major reconstruction and renewal was performed in 1995. The conversion of IEA-R1 Reactor from HEU to LEU has started in late 1988 with the introduction of the first Brazilian made fuel element of U3O8-Al dispersion type with 1.9 gU/cm3. The strategy was to substitute gradually the HEU fuel to LEU fuel. Having a heterogeneous core (HEU and LEU), the design decision was made to have identical geometry (plate thickness, width and pitch between plates) for both fuel assemblies, and to have the same quantity of 235U in the fuel plates (10 g /fuel plate; 180 g /fuel assembly) and this process was finished in 1997.

In 1995, the Instituto de Pesquisas Energeticas e Nucleares (IPEN/CNEN-SP) took the decision to modernize and upgrade the power of the IEA-R1 reactor from 2 to 5 MW. In the upgrading of the IEA-R1 Research Reactor, the core was completely converted from HEU to LEU. Its size was changed from 30 to 25 fuel elements in order to optimize the neutron flux. Also, the uranium content of the fuel plate was increased to 2.3 gU/cm3. Neutronic, thermalhydraulic and fuel performance analyses of the IEA-R1 core for 5 MW showed that all criteria are within the limits and margins established. To accomplish safety requirements, a set of actions was performed following the recommendations of the IAEA Safety Series 35 applied to research reactors. Such actions consisted in the modernization of old systems, design of new ones, safety evaluations and licensing and elaboration of experimental/operational routines to be submitted and approved by the Safety Review Committee after then the documentation was submitted to CGRC to regulatory approve.

The spent fuel was shipped from the location for permanent storing in the USA in 1998. The in-service inspection plan is implemented as part of the QA/QC program and a periodic safety verification are performed through internal inspections and audits. Safety related modification are reviewed by the internal Reactor Safety Committee.

Others implementations:

- New water treatment and purification system- 2004/2005;
- Replacement of reactor control and safety rods- 2004/2005;
- New primary heat exchanger-2006/2007;
- Installation of a new rabbit system for short irradiations in the reactor core-2007;
- Replacement of several radiation monitor and detectors-2006/2007;
- Pneumatic system to transfer reactor irradiated targets to processing area-2007;
- Replacement of heat exchange. Studies regarding ageing program were conducted according to IAEA procedures described in the TR 338 (2001) and Technical document

792 (1995). Replacement of All auxiliary instrumentation racks at the reactor control room. - 2007;

- Installing a voltage stabilizer for protection of the control console and auxiliary systems – 2008;
- Installing monitoring and recording images system. As provided for Physical Protection Plan and the Safety Analysis Report – 2008;
- Installation inside reactor core the first fuel element with fixed instrumentation for collecting thermal parameters inside and outside cladding, allowing continuous online surveillance during operation. This activity was carried out with cooperation of the Nuclear Engineering department and considerable effort from Nuclear Metallurgy staff – 2010;
- Upgrading of electronic racks settled at the Control Room, as well as the initial operation of a meteorological tower that provide the Emergency Planning staff with accurate real time data regarding atmospheric conditions – 2011;
- Exchange of the secondary circuit pumps (2). Carried out the Reactor pool floor adjustment to the standards of radiation protection (epoxy floor)/reform of the engine room (basement), Repair of the emergency stairs and signaling of fire, exchanging of the cooling tower due to loss of heat exchange efficiency to 5 MW and exchanges of guy wires and tensioning of the ventilation and exhaust system chimneys due to corrosion – 2012;
- Modernization of the main gate of the Research Reactor Center to better personal control, emergencies and physical protection – 2013;
- Structural and electrical modernization of the diesel generators building – 2013;
- Improvement to the electrical discharges ground for reactor building – 2014;
- Exchange the pipe primary cooling circuit – 2014.

In sense of regulatory activities, the CGRC periodically audits in the following areas: radiation protection, conduction of operation, reactor operators retraining, fire protection, emergency preparedness.

In the period of January 2019 to December 2021, the CGRC/DRS/CNEN performed 6 inspections and audits.

III.2.7 - Ad. 15: Radiation protection

Radiation protection is implemented and performed by the Radiation Protection Service of the IPEN. Internal, national and international regulations and recommendations are respected. The maximum dose for a reactor operation staff member is 20 mSv per year. The CGRC annually audits the IPEN's Radiation Protection Program implementation.

III.2.8 - Ad. 16: Emergency preparedness

Emergency plans for IEA-R1 reactor were developed based on Regulatory Guide 2.6 - *Emergency Planning for Research and Test Reactors*, *Revision 1, March 1983, USNRC, USA* and ANSI/ANS-15.16-1982 - *Emergency Planning for Research Reactors, American Nuclear Society, E.U.A*. Appropriate procedures were prepared in the form of special written documents for practical use in emergency situation, March 2013. The procedures are subject to internal and external verification and approval.

The procedures include: reactor status data, identification of emergency situation, description of the actions, alarming, reporting, informing and responsibilities.

The emergency classes are:

- Non Usual Event;
- Alert;
- Area Emergency.

The procedures are part of the operation documentation permanently available in the control room, in the office of the reactor center and in the physical protection office. The reactor operation staff, the radiological protection staff and the physical protection staff are trained in using the procedures. Periodic retraining is provided. Since when the Emergency Plan was implemented the reactor has operated without incident record that has caused any material or physical damage.

III.3 - The Research Reactor IPEN/MB-01 Pool Reactor of Institute for Energy and Nuclear Research (IPEN)

III.3.1 - General information

Details on IPEN/MB-01 research reactor technical characteristics and general operation experience at IPEN can be found in the IAEA Research Reactor Database http://www.iaea.org/worldatom/rrdb/.

Research Reactor Details of IPEN/MB-01

- Country Brazil
- Facility Name IPEN-MB-01
- Status OPERATIONAL
- Owner Institute for Energy and Nuclear Research (IPEN), São Paulo
- Operator Institute for Energy and Nuclear Research (IPEN), São Paulo
- Administrator Ultra Bitelli, ULYSSES, head of reactor operational group
- Address Av. Lineu Prestes 2242,
- Telephone +551131339423
- Fax +551131339423
- E-Mail ubitellij@ipen.br
- Web Address www.ipen.br
- Licensing Brazilian Nuclear Energy Commission
- Construction Date 1984/11/01
- Criticality Date 1988/11/09
- Safeguards IAEA/ABACC

Technical Data

- Reactor Type POOL
- Thermal Power, Steady (kW) 00.100
- Max Flux SS, Thermal (n/cm2-s) 1.0 E+9
- Max Flux SS, Steady (n/cm2-s) 6.0 E+9
- Thermal Power, Pulsed (MW) 0.00

- Moderator Deionized Water
- Natural Convection Cooling yes
- Reflector H2O
- Control Rods Material AG, IN, CD, BC
- Safety and Control Rods number 48 pins

Fuel data

Stainless stell fuel pins

- Fuels pellets 680 UO2
- Pins diameter 9.8 mm
- Pins length 1.194 mm
- Active length 546 mm filled LEU 4.35% UO2 Pellets

Reactor Utilization

- Hours per Day 3
- Days per Week 4
- Weeks per Year 44
- MW Days per Year 0
- Materials/fuel test experiments yes, 150
- Isotope Production NO
- Neutron Scattering NO
- Neutron Radiography NO
- Activation Analysis NO
- Number of samples irradiated/year 00

Teaching:

- Number of students/year 22
- Training NPP operators: NO
- Number of operators/year 7

III.3.2 - Ad. Article 10: Priority to safety

The IPEN/MB-01 research reactor (critical assembly) was designed based on BNL-5083l-I - *Design Guide for Category I Reactors - Critical Facilities, BRYNDA, W.J; & POWELL, R.W*. Brookhaven National Laboratory, 1978, and has followed the recommendation of Safety Series nº 35 da Agência Internacional de Energia Atômica – IAEA.

The following elements of nuclear safety are implemented: inherently safe reactor design, technical specifications and limitations based on safety analysis, organization and staffing, training of personnel, quality assurance system, regular inspections and maintenance, inspections, promotion of safety culture, international inspections (safeguards).

The basic safety documents are: Safety Analysis Report, updated following IAEA standard format in 1991), Emergency Procedures and Operating Procedures. Reactor safety is implemented and controlled by the internal Reactor Safety Committee consisting of members of the Institute management. All actions, experiments, plans and documents related to reactor safety must be reviewed and approved by the Safety Committee.

In the period from 2019 to 2021, no abnormal events recorded, no abnormal radioactive releases recorded, and no radiological accidents recorded.

III.3.3 - Ad. Article 11: Financial and human resources

Financial and human resources available:

- Annual Cost 00,000 US$
- Total Staff 12
- No. of Operators 7

III.3.4 - Ad. Article 12: Human factor

Reactor operators are trained in according to Trainning and Retraining Program established by Operating Organization and approved by CGRC. Human errors basically are prevented by:

- Organization and system of personal responsibilities,
- quality assurance program,
- Verification and control.

Strong emphasis is put on personal qualification and responsibilities. The operation staff are carefully selected and trained. The CNEN/CGRC monitors the adequacy of the human resources of the licensee through the evaluation of its performance, especially through the analysis of the human factor influence on operational events. The training and retraining program is also evaluated by CNEN within the licensing procedure and through regulatory inspections.

In the specific case of reactor operators, see Article 19 of this Seventh Report, CNEN has established regulations related to their authorization[7] and their medical qualification[12].

The Reactors Operators Licensing Board has the purpose to verify compliance with the standard CNEN-NN-1:01, Licensing of nuclear reactor operators, and CNEN-NE-1.06, *Health requirements for nuclear reactors operators*, evaluate and audit the training program and re-training of reactor operators and verify the ability of operators through written tests, practical-oral test and performs the test in the research reactor itself. It is responsible for all technical activities to support the issue of an Operator Reactor License.

In the period 2019 – 2021, CNEN has issued a total of 21 licenses for Reactor Operator:

- 2019 – N/A.
- 2020 – 04 ROs and 04 SROs.
- 2018 – N/A.

III.3.5 - Ad. Article 13: Quality assurance

The Institute for Energy and Nuclear Research (IPEN) has established its quality assurance programs for IPEN/MB-01 research reactor, in accordance with the mentioned requirements in Article 13 of this Seventh National Report and assessed by CGRC. Quality assurance is implemented as part of the Quality Assurance Program. The head of the reactor operation department is responsible for its implementation. The corresponding procedures were developed and are currently in place. The programs provide for the control of activities which influence the quality of items and services important to safety as: design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, commissioning, operation, maintenance, repair and training. The quality assurance programs are described in Chapter 17 of the Safety Analysis Report of IPEN/MB-01 research reactor.

Appropriate internal QA and QC documentation is applied. QA activities in reactor operation are subject to internal (QA manager team) and external (Brazilian Nuclear Energy Commission) audits and inspections.

III.3.6 - Ad. 14: Assessment and verification of safety

The reactor is regularly maintained. The in-service inspection plan is implemented as part of the QA/QC program.

In sense of regulatory activities the CGRC periodically audits in the following areas: radiation protection, conduction of operation, reactor operators retraining, fire protection, emergency preparedness.

In the period of January 2019 to December 2021, the CGRC/DRS/CNEN performed 8 inspections and audits.

III.3.7 - Ad. 15: Radiation protection

Radiation protection is implemented and performed by the Radiation protection service of IPEN/MB-01. Internal, national and international regulations and recommendations are respected. The maximum dose for a reactor operation staff member is 20 mSv per year.

III.3.8 - Ad. 16: Emergency preparedness

Emergency plans for IEA-R1 reactor are specified in the Safety Analysis Report according to an appropriate IAEA format.

Appropriate procedures are prepared in the form of special written documents for practical use in emergency situation, Nov 2013. The procedures are subject to internal and external verification and approval.

The procedures include reactor status data, identification of emergency situation, description of the actions, alarming, reporting, informing and responsibilities for the following internal and external emergency events:

- radiological reactor accidents:
- Fall of objects or tools in the tank Moderator outside the reactor core,
- Violation of the limits of Technical specifications for radioactive effluents,
- Electric Power loss of the external network and internal loss of electrical power,
- loss of reactor shielding (primary water),

- release of radioactivity in the controlled area,
- release of radioactivity outside controlled area,
- ATWS Accident Transients without SCRAM,
- non-radiological accidents:
- fire in the reactor building,
- Precipitation intense rainfall,
- Storms and strong winds.
- earthquake,
- sabotage and not-authorized access.

The procedures are part of the operation documentation permanently available in the control room, in the office of the reactor center and in the physical protection office. The reactor operation staff, the radiological protection staff and the physical protection staff are trained in using the procedures. Periodic retraining is provided. Since when the Emergency Plan was implemented the reactor has operated without incident record that has caused any material or physical damage.

III.4 - The Research Reactor IEN-R1 ARGONAUTA of Institute of Nuclear Engineering (IEN)

III.4.1 - General information

Details on IEN-R1 ARGONAUTA research reactor technical characteristics and general operation experience at IEN can be found in the IAEA Research Reactor Database http://www.iaea.org/worldatom/rrdb/.

Research Reactor Details of ARGONAUTA:

- Country Brazil
- Facility Name IEN
- Status OPERATIONAL
- Owner: Institute of Nuclear Engineering - IEN, Rio de Janeiro
- Operator: Institute of Nuclear Engineering - IEN, Rio de Janeiro

- Administrator: RENKE, Carlos Alberto Curi, head of reactor operational group
- Address Rua Helio de Almeida 75, Ilha do Fundão, C.P.
- Telephone +552121733909
- Fax +5531306932253
- E-Mail renke@ien.gov.br
- Web Address www.ienmgov.br
- Licensing Brazilian Nuclear Energy Commission
- Construction Date 1963/07/07
- Criticality Date 1965/02/20
- Safeguards IAEA/ABACC

Technical Data:

- Reactor Type ARGONAUTA
- Thermal Power, Steady (kW) 0.200
- Max Flux SS, Thermal (n/cm2-s) 4.4 E+09
- Max Flux SS, Fast (n/cm2-s) 8.9E+09
- Thermal Power, Pulsed (MW) 0.001
- Moderator H2O
- Coolant light water
- Natural Convection Cooling yes
- Cool Velocity in Core 0.0113 M/S
- Reflector graphite 6
- Reflector Number of Sides annular
- Control Rods Material CD
- Control Rods number 3

Experimental Facilities:

- Horizontal Channels 15
- Horizontal Max Flux (n/cm2-s) 2.5 E+05
- Horizontal Use Irradiations, Spectrometry, Neutron radiography and neutron tomography
- Vertical Channels 5
- Vertical Use Exponential measurements
- In-core Max Flux (n/cm2-s) 4.4 E+09
- Reflector Irradiation Facilities 1

Fuel data:

- Enrichment Min — % 19.90 U3O8-AL
- Enrichment Max — % 19.90 U3O8-AL
- Origin of Fissile Material — USA
- Dimensions of Rods (mm) — 37.3 DIA, 723.9 L
- Cladding Material — Aluminum
- Cladding Thickness (mm) — 0.51
- Fuel Material — UZRH
- Fuel Loading per Element (g U-235) — 56
- Burnup on Discharge, max (%) — 25
- Burnup Average (%) — 5
- Fuel Fabricator — GENERAL ATOMICS, USA
- Fuel, present status, core — 56
- spent fuel storage — 8 LEU
- fresh fuel storage — 38
- total at location — 94

Reactor Utilization:

- Hours per Day — 8
- Days per Week — 5
- Weeks per Year — 43
- MW Days per Year — 0
- Materials/fuel test experiments — NO
- Isotope Production — YES
- Neutron Scattering — YES
- Neutron Radiography — YES
- Activation Analysis — YES
- Number of samples irradiated/year
- Teaching: — YES
- Number of students/year
- Training NPP operators: — NO
- Number of operators/year — 10

III.4.2 - Ad. Article 10: Priority to safety

The following elements of nuclear safety are implemented: Inherently safe reactor design, technical specifications and limitations based on safety analysis, organization and staffing, training of personnel, quality assurance system, regular inspections and maintenance, inspections, promotion of safety culture, international inspections (safeguards).

The basic safety documents are: Safety Analysis Report (originally provided by the reactor manufacturer, updated following IAEA standard format in 1991), Emergency Procedures and Operating Procedures. Reactor safety is implemented and controlled by the internal Reactor Safety Committee consisting of members of the Institute management. All actions, experiments, plans and documents related to reactor safety must be reviewed and approved by the Safety Committee.

In the period from 2019 to 2021, no abnormal events recorded, no abnormal radioactive releases recorded and no radiological accidents recorded.

III.4.3 - Ad. Article 11: Financial and human resources

Financial and human resources available:

- Annual Cost US$50,000
- Total Staff 12
- No. of Operators 3

III.4.4 - Ad. Article 12: Human factor

Reactor operators are trained in according to Training and Retraining Program established by Operating Organization and approved by CGRC. Human errors basically are prevented by:

- Organization and system of personal responsibilities,
- quality assurance program,
- Verification and control.

Strong emphasis is put on personal qualification and responsibilities. The operation staff are carefully selected and trained. The CNEN/CGRC monitors the adequacy of the human resources of the licensee through the evaluation of its performance, especially through the analysis of the human factor influence on operational events. The training and retraining program is also evaluated by CNEN within the licensing procedure and through regulatory inspections.

In the specific case of reactor operators, see Article 19 of this Seventh Report, CNEN has established regulations related to their authorization[7] and their medical qualification[12].

The Reactors Operators Licensing Board has the purpose to verify compliance with the standard CNEN-NN-1:01, Licensing of nuclear reactor operators, and CNEN-NE-1.06, *Health requirements for nuclear reactors operators*, evaluate and audit the training program and re-training of reactor operators and verify the ability of operators through written tests, practical-oral test and performs the test in the research reactor itself. It is responsible for all technical activities to support the issue of an Operator Reactor License.

In the period 2019 – 2021, CNEN has issued a total of licenses for Reactor Operator:

- 2019 – N/A.
- 2020 – 03 ROs and 01 SRO.
- 2018 – N/A.

III.4.5 - Ad. Article 13: Quality assurance

The Institute of Nuclear Engineering (IEN) has established its quality assurance programs for IEN-R1 ARGONAUTA research reactor, in accordance with the mentioned requirements in Article 13 of this Seventh National Report and assessed by CGRC. Quality assurance is implemented as part of the Quality Assurance Program. The head of the reactor operation department is responsible for its implementation. The corresponding procedures were developed and are currently in place. The programs provide for the control of activities which influence the quality of items and services important to safety as: design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, commissioning, operation, maintenance, repair and training. The quality assurance programs are described in Chapter 17 of the Safety Analysis Report of IEN-R1 research reactor.

Appropriate internal QA and QC documentation is applied. QA activities in reactor operation are subject to internal (QA manager team) and external (Brazilian Nuclear Energy Commission) audits and inspections.

III.4.5 - Ad. 14: Assessment and verification of safety

The reactor is regularly maintained. Major reconstruction and renewal was performed in 1991. The in-service inspection plan is implemented as part of the QA/QC program.

Periodic safety evaluations are performed. In sense of regulatory activities the CGRC periodically audits in the following areas: radiation protection, conduction of operation, reactor operators retraining, fire protection, emergency preparedness.

In the period of January 2019 to December 2021, the CGRC/DRS/CNEN performed 2 inspections and audits.

III.4.6 - Ad. 15: Radiation protection

Radiation protection is implemented and performed by the Radiation protection service of the IEN. Internal, national and international regulations and recommendations are respected. The maximum dose for a reactor operation staff member is 20 mSv per year.

III.4.7 - Ad. 16: Emergency preparedness

Emergency plans for ARGONAUTA reactor are specified in the Safety Analysis Report according to an appropriate IAEA format. Appropriate procedures are prepared in the form of special written documents for practical use in emergency situation, April 2013. The procedures are subject to internal and external verification and approval.

The procedures include: reactor status data, identification of emergency situation, description of the actions, alarming, reporting, informing and responsibilities for the following internal and external emergency events:

- radiological reactor accidents;
- loss of reactor shielding (primary water);
- release of radioactivity in the controlled area;
- release of radioactivity outside controlled area;
- non-radiological accidents;
- fire in the reactor building;
- precipitation intense rainfall;
- storms and strong winds
- earthquake,
- sabotage and not-authorized access.

The procedures are part of the operation documentation permanently available in the control room, in the office of the reactor center and in the physical protection office.

The reactor operation staff, the radiological protection staff and the physical protection staff are trained in using the procedures. Periodic retraining is provided.

Since when the Emergency Plan was implemented the reactor has operated without incident record that has caused any material or physical damage.

III.5 - Research Reactor – RMB - Brazilian Multipurpose Reactor of Research and Development Directory – DPD/CNEN

III.5.1 - General information

RMB main function are radioisotope production for medical, industrial and research applications, fuel and materials irradiation testing, neutron beam laboratory, education and training.

The RMB project managed by the Research and Development Directorate of the Brazilian Nuclear Energy Commission (DPD-CNEN):

- Project Cost estimation of US$ 500 million.
- Open pool multipurpose research reactor with a primary cooling system through the core.
- The reactor core will be compact, using MTR fuel assembly type, with planar plates, U_3Si_2–Al dispersion fuel with 4,8 g U / c m^3 density and 19,9 % U^{235} enrichment.
- The reactor core will be cooled and moderated by light water, using light water, beryllium and heavy water as reflectors.
- Neutron flux (thermal and fast) higher than $2x10^{14}$ n / cm^2.s.

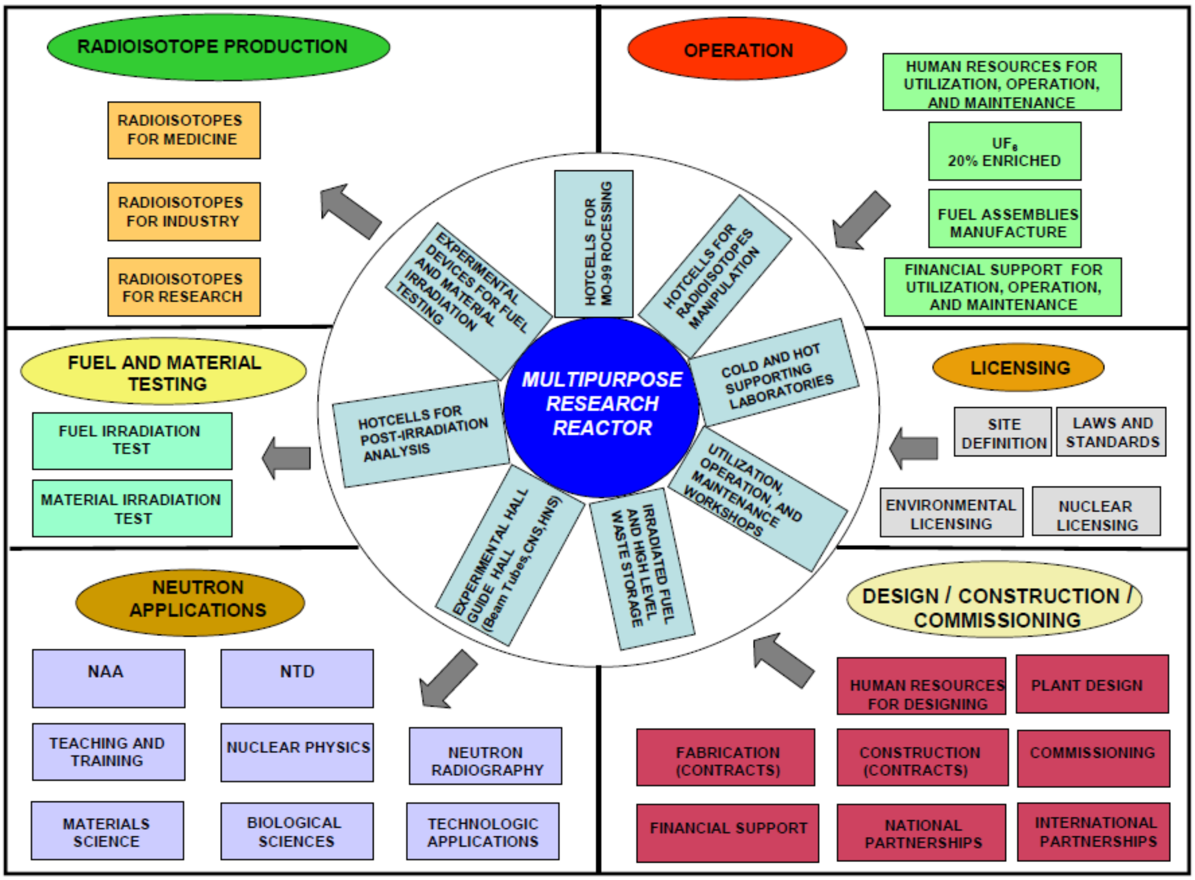

Figure 27 – RMB Project Scope

Core Design:

- Thermal Power: 30 MW.
- Fuel Assemblies: LEU – MTR.
- Core configuration: 5 x 5 grid with 23 FAs and 2 in core irradiation positions.
- Control Rods: 6 Hf plates (3 per Guide Box).
- Core Cooling: 3100 m^3/h upward direction.

The RMB will a new Nuclear Research and Production Centre that will be built at Iperó city about 110 kilometers from Sao Paulo city, in the southeast part of Brazil.

The Research Institutes of CNEN: IPEN, CDTN, IEN and CRCN, mainly IPEN, have completed the scope and conceptual design of RMB.

Regarding the preliminary design:

- coordinated and verified by CNEN.

- the conventional engineering of buildings, infrastructure and systems was carried out by INTERTECHNE, a Brazilian engineering company.
- the engineering of the reactor and its systems was carried out by the Argentinian nuclear engineering company INVAP.
- The basic design of the entire infrastructure, buildings and laboratories was carried out, which included the preparation of 6,739 engineering documents.

Regarding the detailed design:

- coordinated and verified by CNEN, in cooperation with the Brazilian company AMAZUL.
- the engineering of the reactor and its systems was carried out by INVAP.
- the engineering of buildings and conventional systems was carried out by AMAZUL.
- 9,299 engineering documents were generated in this stage of the project, completed in December 2021.

III.5.2 - Ad. Article 13: Quality assurance

The Directorate for Research and Development of the Brazilian Nuclear Energy Commission (DPD-CNEN) has established its quality assurance programs for RMB project, in accordance with the mentioned requirements in Article 13 and assessed by CGRC. The corresponding procedures have been developed and are in use. The program provide for the control of activities which influence the quality of items and services important to safety and is applied to Site Selection, Implementation (Design, Manufacture, Construction) and Commissioning. The Preliminary and Final Safety Analysis Reports will have specific Chapter dedicated to Quality assurance.

III.5.3 - Ad Article 17 – Siting

III.5.3.1 - Ad Article 17(1)

The Directorate for Research and Development (DPD – CNEN) to comply with regulatory framework for site approval, presented in Article 17(1), has considered the important elements of site study and characterization as described in following IAEA Safety Standards NS-R-3, NS-R-4 (Chapter 5 - Site Evaluation), Safety Series nº 35-G1 - *Safety Assessment of Research Reactor and Preparation of the Safety Analysis Report* and NSG.3.1- 3.6.

The evaluation of all site related factors affecting the safety of the nuclear installations was started in 2012. Also in 2012, a contract was signed, with a Brazilian company with tradition in environmental studies, to perform environmental and site studies. The report was finished by middle 2013, allowing the starting of environmental and nuclear licensing processes, with presentation of site and local reports, requirements for first license. They were also the basis for the three public hearings, done in October 2013. Site topography was already surveyed; geological sampling completed, and a meteorological tower was installed and it is operational since 2012.

The Site Safety Analysis Report was submitted to CGRC, in 2013, for regulatory evaluation and site approval.

After the technical evaluation of the Site Safety Analysis Report and gathering of supplementary information CNEN issued the Local Approved (RESOLUÇÃO Nº 184, DE 13 DE JANEIRO DE 2015) in January 2015.

the CNEN's Directorate for Research and Development (DPD) started up the environmental licensing process for the Brazilian Multipurpose Reactor (in 2010) and IBAMA issued the Term of Reference to the Environmental Impact Study (EIA) and the Report on Environmental Impact (RIMA).

After the technical evaluation of the Environmental Impact Study (EIA) and gathering of supplementary information the IBAMA issued the Prior License (LP N° 500/2015) in July 2015.

III.5.4 - Ad Article 18 – Design and Construction

The Preliminary Safety Analysis Report (PSAR) was submitted to CGRC, in December 2018, for regulatory evaluation and issuance of the Construction License.

The design of the Brazilian nuclear research reactor like power plants is based on established nuclear technology in countries with more advanced programs. The licensing regulation CNEN-NE-1.04[5] formally requires the adoption of a “reference plant” which shall have a similar power rating, shall be under construction in the country of the main contractor, and shall go into operation with sufficient time to allow the use of the experience of pre-operational tests and initial operation.

In that case, RMB has been designed with Argentine Technology, within the framework of the comprehensive technology transfer agreement between Argentine and Brazil. The Brazilian and Argentinian National Nuclear Energy Ccommissions, CNEN and CNEA formalized an agreement for a joint development of their own projects (the Brazilian RMB and the Argentinian RA-10) taking as a reference the OPAL reactor.

The INVAP (Argentinean company) was responsible for research reactor systems and components design.

III.6 - Research Reactor (reactor Prototype) – The Nuclear-Electric Generation Laboratory (LABGENE, acronym in Portuguese) – Navy Technological Center in São Paulo (CTMSP, acronym in Portuguese)/Brazilian Navy

III.6.1 - General information

Thermal Power	48 MWth
Type of reactor	PWR
Number of loops	2
Number of turbines	1 (1High Pressure/3Low pressure)
Containment	Dry Cylindric steel shell.
Fuel assemblies	XX
Main supplier:	Nuclebrás Equipamentos Pesados S/A - NUCLEP (Nuclebras Heavy Equipment) – www.nuclep.gov.br.
Architect Engineer:	Brazilian Navy
Civil Contractor:	
Mechanical Erection:	Nuclebrás Equipamentos Pesados S/A - NUCLEP (Nuclebras Heavy Equipment) – www.nuclep.gov.br
Construction start date	2000
Core load	N/A
First Criticality	N/A

III.6.2 - Ad. Article 13: Quality assurance

The Navy Technological Center in São Paulo (CTMSP, acronym in Portuguese)/Brazilian Navy has established its quality assurance programs for LABGENE construction, in accordance with the mentioned requirements in Article 13 and assessed by CGRC. The corresponding procedures have been developed and are in use. The program provide for the control of activities which influence the quality of items and services important to safety and is applied to Site Selection, Implementation (Design, Manufacture, Construction) and Commissioning. The Preliminary and Final Safety Analysis Reports have specific Chapter dedicated to Quality assurance.

III.6.3 - Ad Article 17 – Siting

III.6.3.1 - Ad Article 17(1)

The Brazilian siting regulation, CNEN 09/69[6] and CNEN-NE-1.04, Licensing of Nuclear Installations [5], require a site approval before the issuance of a construction authorization. As established in these regulations, a site approval is issued after Regulator review and acceptance of, at least, the following information:

- General and safety characteristics of the proposed plant design.
- Population distribution, existing and planned roads, use of the area surrounding the site and distances to population centers.
- Physical characteristics of the site, including seismology, geology, hydrology, and meteorology.
- Preliminary evaluation of potential effects on the environment resulting from plant construction and operation (normal and accident conditions).
- Preliminary site environmental pre-operational monitoring plan.

The evaluation of all site's related factors affecting the safety of the nuclear installations was started in 1999. The Site Safety Analysis Report was submitted to CNEN, in 1999, for regulatory evaluation and site approval.

After the technical evaluation of the Site Safety Analysis Report and gathering of supplementary information CNEN issued the Local Approved (Portaria Nº 106, DE 08 DE dezembro de 2000) in December 2000.

III.6.3 - Ad Article 18 – Design and Construction

The CTMSP in compliance with CNEN NE 1.04 Standard submitted in 1998 the PSAR of LABGENE and the current version is Rev.9 submitted in 2021.

LABGENE facility was designed incorporating the concept of defense in depth, including the use of multiple barriers against the release of radioactive material. Safety principles such as passive safety or the failsafe function, automation, physical and functional separation, redundancy, and diversity was also incorporated in the design.

Tha project used extensively of American codes and guides such as ASME section III, ASME section XI, IEEE standards, ANSI standards and US NRC Regulatory Guides.

Construction adopted a quality assurance program, in according with CNEN NN 1.16 Standard, which encompass all activities related to safety conducted by CTMSP and its contractors and subcontractors. CNEN has monitored the implementation of the quality assurance program through the regulatory inspection program.

In consequence of some innovative aspect related this project the strategy of issue partial authorization was adopted by CNEN. This strategy involves the issue of Partial Construction License to building structures or systems groups wich are functionally linked. To date, four partial licenses have been issued, the 1st Partial Construction was issued in 2000, the 2nd in 2012, the 3rd in 2019 and 4th in 2021.

III.7 – Add to Article 19 (8) Management of spent fuel and radioactive waste - Research Reactors

III.7.1 - On-site storage of spent fuel - Measures taken for research reactors.

Research reactors (RR) have been in operation in Brazil since the late 1950's and, as a result, some amount of spent fuel assemblies (SFA) has accumulated. Table 14 shows the RR operating in Brazil and Table 15 shows the fuel element characteristic these reactors. [3]

Table 14 – Research Reactor in Brazil

	IEA-R1	IPR-R1	ARGONAUTA	IPEN/MB-01
Criticality	September 1957	November 1960	February 1965	November 1988
Operator	IPEN-CNEN/SP	CDTN-CNEN/MG	IEN-CNEN/RJ	IPEN-CNEN/SP
Location	São Paulo	Minas Gerais	Rio de Janeiro	São Paulo
Type	Pool	Triga Mark I	Argonaut	Critical assembly
Power Level	2-5 MW	100 kW	170-340 W	100 W
Enrichment	19,9%	20%	19.9%	4.3%
Supplier	Babcock & Wilcox	General Atomics	USDOE	Brazil

Of the research reactors shown on Table 14, up to this present moment, the only one subject to concerns related to spent fuel storage is IEA-R1. Part of its spent fuel was returned to the USA, when in 1999 Brazil shipped 127 LEU and HEU fuel elements. Later, on November 2007, 33 spent fuel elements stored in the pool of the IEA-R1 reactor containing uranium of US origin were also shipped back to Savannah River Site Laboratory, South Carolina, USA [3].

IPR-R1 has no short- and medium-term storage problems, due to its low nominal power.

Table 15 – Fuel Elememt Characteristics

Facility	Fuel Type	Fuel Material	Enrichment	Cladding Material
IEA-R1	MTR	U_3O_8-Al U_3Si_2-Al	LEU 19.9%	Aluminum
IPR-R1	TRIGA	U-ZrH	LEU 20%	Aluminum/SS*
ARGONAUTA	MTR	U_3O_8-Al	LEU-19.0-19.9%	Aluminum
IPEN-MB-01	Pin PWR	UO_2 Pellets	LEU 4.35 %	SS

*04 units at the core (Stainless steel)

The present RR spent fuel inventory is shown on Table 16. The only reactor subject to concerns related to medium and long-term storage is IEA-R1. The other ones are low- and zero-power reactors with very low burn up. Taking these facts into consideration and the storage capacities presently available, some projections for the next 10-15 years have been made.

Presently, storage facilities at IEA-R1 consist of racks located in the reactor pool with a capacity of 108 assemblies. According to the newly proposed operation schedule (4.5/5 MW, 32 hrs per week), 2-3 assemblies will be spent annually. Currently, 72 storage positions are occupied, suggesting that within 4 - 6 years the wet storage facility at the reactor will be full. It should be noted that 24 positions should be free to maintain the reactor core. An aggravating factor to be taken into account is the project aiming to increase the operation for a shift cycle of 9 days of continuous operation and 4 days to maintenance, enhancing the operation time by a 3.5 factor per year, with 8 assemblies spent annually.

Table 16 – SFA Inventory at Braziliam Research Reactors

Facility	# of FA in Present Core	Average # used per year	SFA Storage		SFA % Average Burnup
			At RR	Outside RR	
IEA-R1	24 LEU, Silicide-24	~04, expected for 32 h/week, 4,5 MW	39 wet	0	~40
IPEN-MB-01	19 rods	NA	0	0	NA
IPR-R1	63 rods (LEU)	NA	0	0	~ 4
IEN-R1	8 LEU	NA	0	0	NA

NA = not applicable

III.7.2 - Regulatory review and control activities of On-site storage of spent fuel – Research Reactors

The Radioactive Waste Division (DIREJ), responsible for regulating and controlling all activities related to radioactive waste management in Brazil, comprises 18 people, being 7 with doctoral degree, 3 with master's degree, 3 with college degrees people and specialization and 5 administrative. The main activities of DIREJ are review and assessment of the submitted documentation and inspection of licensee's activities. Inspection and audits activities are conducted periodically and on a permanent basis in all storage facilities in Brazil. This division controls the transportation of radioactive materials and radioactive waste management in nuclear facilities, taking a close look at the facilities that manipulate, produce, use, transport or store radiation sources.

III.7.3 - Implementation of on-site treatment, conditioning and storage of radioactive waste – Research Reactors.

The radioactive waste of the research reactors is managed together with the radioactive waste of the institutes to which they belong.

- *IPEN (MB-01 and IEA-R1)*

The Radioactive Waste Management Service (SEGRR) was formally created in 2003 as a new research centre of the Nuclear and Energy Research Institute (IPEN), in order to perform research and development, teaching and waste treatment activities in the field of radioactive waste. The SEGRR is in charge of treating and temporarily storing the radioactive waste generated at IPEN, as well as those generated at many other radioactive facilities all over the country. The main features of the laboratory include units for: waste reception and segregation; decontamination; liquid waste immobilization and conditioning; in-drum compaction of compressible solids; spent sealed sources and lightning rods disassembly; primary and final waste characterization; storage of untreated and treated waste. [3]

- *CDTN (IPR-R1 - TRIGA)*

Besides the radioactive waste generated in its own laboratories, the Nuclear Technology Development Center (CDTN) has received waste coming from other radioactive installations to be treated and stored. In addition, disused sealed sources from other users like industries, hospitals and universities, are also being received. These sources include radioactive lightning rods and smoke detectors, among others. They are stored at CDTN's storage facility – Sealed Sources and Treated Waste Storage Facility (DFONTE) (see H.2.4, and Annex 1). In September 2020, 1,888 disused sealed sources; 2,993 lightning rods; 6,077 smoke detectors 241Am sources and 104 packages (200-liter drum) of treated wastes (very low activity) were stored at this facility. The waste fills 45% of DFONTE and the total activity is 137.5 TBq. Furthermore, there were 6 m^3 (4.5 t) of untreated waste of very low activity in the interim storage Untreated Waste Storage Facility (DRNT) [3].

The strategy implemented for the management of radioactive waste at CDTN is based on the standard CNEN-NN 8.01 and takes into account the available infrastructure. The main directives of the management program are:

- To minimize the waste generation by suitable segregation and characterization.
- To reduce the volume by chemical treatment of the aqueous liquid waste, and by compacting and cutting the solid waste.
- To solidify by cementation the sludge arising from the chemical treatment, and to immobilize the non-compactable solid waste in cement/bentonite.
- To register the waste and disused sealed source inventory using an electronic database [3].

- *IEN (ARGONAUTA)*

Until 2007, the Nuclear Engineering Institute (IEN) had a small area (120 m2) for storage of radioactive waste. In that year, the building of a new storage installation was completed, expanding the actual capacity of storage. This new installation has a total area of 972 m2 and a net storage area for radioactive waste of 324 m2. IEN stores radioactive waste that has similar characteristics to the waste received at the other CNEN storage installations, and the management follows the directives of CNEN. The institute has received, treated and stored waste generated in its own facilities and coming from other radioactive installations like industries, hospitals and universities. A laboratory for the treatment of radioactive waste was recently implemented at the IEN, according to CNEN NN 8.01.

III.7.4 - Regulatory review and control activities on-site treatment, conditioning and storage of radioactive waste – Research Reactors.

The Radioactive Waste Division (DIREJ), responsible for regulating and controlling all activities related to radioactive waste management in Brazil, comprises 18 people, being 7 with doctoral degree, 3 with master's degree, 3 with college degrees people and specialization and 5 administrative. The main activities of DIREJ are review and assessment of the submitted documentation and inspection of licensee's activities. Inspection and audits activities are conducted periodically and on a permanent basis in all storage facilities in Brazil. This division controls the transportation of radioactive materials and radioactive waste management in nuclear facilities, taking a close look at the facilities that manipulate, produce, use, transport or store radiation sources.

Annex IV

INTERNATIONAL, MULTILATERAL AND BILATERAL AGREEMENTS

AGREEMENTS WITH THE IAEA		
• IAEA Statute	Signature:	26 October 1956
• Amendments to the Article VI and XIV of the IAEA Statute	Acceptance of amendment of Article VI	01 June 1973
• Agreement on privileges and immunities	Entry into force:	13 June 1966
• Quadripartite safeguards agreement INFCIRC/435	Entry into force:	4 March 1994
• Safeguards agreement Brazil/Germany INFCIRC/237	Suspension signed:	16 October 1998
• Safeguards agreement Brazil/USA INFCIRC/110	Entry into force:	31 October 1968
• Amendment to the safeguards agreement Brazil/USA	Signature:	27 July 1972
• Technical assistance agreement between UN, its specialized agencies and the IAEA	Signature:	29 December 1964
• Supplementary agreement on provision of technical assistance by the IAEA	Entry into force:	27 February 1991
• ARCAL	Entry into force:	September 1984
• New ARCAL Agreement	Signed:	4 August 1999
MAIN INTERNATIONAL TREATIES		
• NPT	Entry into force:	18 September 1998
• Tlatelolco Treaty	Signed:	29 January 1968
• Amendment of the Treaty	Ratified:	30 May 1994
OTHER RELEVANT INTERNATIONAL TREATIES		
• Nuclear suppliers group	Member	
• Nuclear export guidelines	Adopted	
• Missile Technology Control Regime	Member	1995

• Treaty for prohibition of experiences with nuclear weapons in the atmosphere, cosmic space and under water	Signature:	5 August 1963
• Partial test ban treaty	Entry into force:	15 December 1964
• ILO Convention	Signature:	7 April 1964
• Treaty on the prohibition of the installation of nuclear weapons and other lethal weapons in the seabed, deep ocean floor and sub-seabed.	Signature:	3 September 1971
• Convention on civil liability in the field of maritime carriage of nuclear material	Signature:	17 December 1971
• Convention on prevention of marine pollution by dumping of wastes and other materials	Signature:	29 December 1972
• International Convention for the Suppression of Terrorist Bombings	Entry into force:	23 August 2002
MULTILATERAL AGREEMENTS		
• Antarctica Treaty	Signature:	1 December 1959
• Convention on the physical protection of nuclear material	Entry into force:	8 February 1987
• Convention on early notification of a nuclear accident	Entry into force:	4 January 1991
• Convention on assistance in the case of a nuclear accident or radiological emergency	Entry into force:	4 January 1991
• Vienna convention on civil liability for nuclear damage	Entry into force:	26 June 1993
• Convention on nuclear safety	Entry into force:	2 June 1997
• Joint convention on the safety of spent fuel management and on the safety of radioactive waste management.	Signature:	31 October 1997
BILATERAL AGREEMENTS		
Cooperation Agreement for the Development and Use of Peaceful Applications of Nuclear Energy	Argentina	1980
Agreement for Scientific, Technological and Industrial Cooperation	Belgium	1985

Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Bolivia	1966
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Canada	1996
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Chile	2002
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	China	1984
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Ecuador	1970
Cooperation Agreement for the Development of Peaceful Applications of Nuclear Energy	France	2002
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Germany	1975
Cooperation Agreement for the Peaceful Use of Nuclear Energy	Italy	1958
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Paraguay	1961
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Peru	1981
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Republic of Korea	2001
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Russian Federation	1994
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Spain	1983
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	United States of America	1997
Cooperation Agreement on Nuclear Energy for Peaceful Uses	Venezuela	1983

ANNEX V

FUKUSHIMA ACTION PLAN STATUS – DECEMBER 2021

PROTECTION FROM RISK EVENTS (PE)	
ACTIVITY*	**Status in December 2021**
PE 111: Updating and reevaluation of geological data basis.	Concluded
PE 112: Updating and reevaluation of seismic data basis and seismic threatening	Concluded
PE 113: Reevaluation of safety margins in the seismic design of Angra 1 and 2.	Concluded
PE 121: Updating of site geological and geotechnical survey.	Concluded
PE 122: Reevaluation of slope stabilization works and slope monitoring system.	Concluded
PE 123: Evaluation of extreme slope ruptures conditions.	Concluded
PE 124: Evaluation of stability and integrity of pre-treated water reservoir in case of landslides.	Concluded
PE 131: Implementation of acquisition, processing and monitoring systems for ocean and meteorological data	Suspended
PE 132: Reevaluation of maximum sea wave height at NP Station shore.	Concluded
PE 133: Reevaluation of mole integrity.	Concluded
PE 141: Revision of site flooding study for extremely severe weather conditions.	Concluded
PE 142: Update of site hydrological studies	Suspended
PE 143: Reassessment of flood barriers in rooms with safety equipment in Angra 1	Concluded
PE 151: Evaluation of impact of tornadoes on Angra 1 and 2 safety related structures, systems and components.	Concluded
PE 152: Reevaluation of threatening by hurricanes.	Concluded
PE 211: Completion of Angra 1 Internal Flood Analysis	Concluded
PE 221: Angra 1's "Fire Hazard Analysis -FHA" review conclusion	Concluded

COOLING CAPACITY (RF)	
ACTIVITY*	Status in December 2021
RF 111: Verification of Angra 1 plant conditions for performing "feed-and-bleed" operation through the Steam Generators, under beyond-design-basis conditions, including station black out.	Concluded
RF 112: Implementation of mobile water pumping units to feed Angra 1 Steam Generators	Concluded
RF 113: Modify the current seals of the RCPs in order to obtain greater resistance to operation in natural circulation for longer periods	Ongoing Deadline: December 2022
RF 121: Verification of Angra 2 plant conditions for performing "feed-and-bleed" operation through the Steam Generators, under beyond-design-basis conditions, including station black out.	Ongoing Deadline: July
RF 122: Implementation of mobile water pumping units to feed Angra 2 Steam Generators	Concluded
RF 131: Implementation of improvements in the NP Station Pre-Treated Water Supply System.	Concluded
RF 132: Feasibility study of alternative water supply for the nuclear power station from Mambucaba river.	Canceled
RF 133: Feasibility study of alternative water supply for the nuclear power station from Praia Brava.	Ongoing Deadline: December 2023
RF 134: Study of alternatives for a new water reservoir at site.	Ongoing
RF 211: Verification of existing conditions for "feed-and-bleed" operation in Angra 1	Ongoing Dedline: December 2023
RF 221: Implementation of systems and equipment for "feed-and-bleed" operation in Angra 2.	Concluded
RF 222: Conceptual study on passive reactor cooling using heat exchangers inside the containment	Concluded
RF 311: Calculation of Angra 1 spent fuel pool water temperature increase and water level decreasing in case of failure of all cooling systems.	Concluded
RF 312: Study on alternative cooling possibilities for the Angra 1 spent fuel pool .	Concluded

RF 321: Calculation of Angra 2 spent fuel pool water temperature increase in case of loss of cooling systems.	Concluded
RF 322: Study on alternative cooling possibilities for the Angra 2 spent fuel pool.	Ongoing In commissioning
RF 411: Implementation of manual interconnection of emergency power busbars in Angra 1.	Canceled
RF 412: Enabling a solution that allows the connection of mobile DG for battery recharging	Concluded
RF 413: Provide an alternative solution for cooling Angra 1 Emergency Diesel Generators in case of loss of cooling through the service water system	Ongoing In commissioning
RF 421: Implementation of power supply to Diesel System 2 consumers by Diesel System 1.	Concluded
RF 422: Enabling a solution that allows the connection of mobile DG for battery recharging	Concluded
RF 431: Implementation of manual interconnection of Angra 1 and Angra 2 emergency buses	Canceled
RF 432: Study of an additional source of emergency electricity supply for Angra 1 and Angra 2	Canceled
RF 433: Feasibility studies for the implementation of a Small Hydroelectric Power Plant (PCH acronym in Portuguese) on the Mambucaba River.	Canceled
RF 434: implement a strategy and resources for the resupply of diesel oil for the long-term operation of the Central DGs, under external event conditions.	Concluded
RF 435: Specify and acquire mobile diesel group and implement the means for quick connection of the mobile diesel group to the Angra 1 and 2 emergency buses	Ongoing
RF 511: Development of PSA Level 2 for Angra 1	Ongoing
RF 512: Preparation and implementation of Severe Accident Management Guidelines for Angra 1	Concluded
RF 513: Development of PSA for Low Power and Plant Shutdown conditions in Angra 1	Ongoing

RF 521: Complementation of PSA Levels 1 and development of PSA Level 2 for Angra 2	Concluded
RF 522: Preparation and implementation of Severe Accident Management Guidelines for Angra 2	Concluded
RF 613: Study on alternative radiological control equipment for extreme emergency situations.	Ongoing Deadline: December 2022
RF 611: Implementation of resources to open access doors to buildings and compartments in emergency situations	Concluded
RF 612: Implementation of additional means to assure internal building lighting under extreme emergency situations	Concluded
RF 731: Storage of Mobile Equipment	Concluded
RF 732: Implementation of procedures for connecting Mobile Equipment	Ongoing

MITIGATION OF RADIOLOGICAL CONSEQUENCES (CR)	
CR 111: Implementation of hydrogen passive recombiners in Angra 1	Concluded
CR 112: Implementation of filtered containment venting in Angra 1	Ongoing
CR 121: Implementation of hydrogen passive recombiners in Angra 2	Concluded
CR 122: Implementation of filtered containment venting in Angra 2	Ongoing
CR 211: Implementation a Containment sampling system for operating conditions in accidents beyond the design bases	Ongoing
CR 221: Implementation of primary circuit and containment sampling system in Angra 2 qualified for BDBA conditions	Ongoing
CR 311: Enlargement of wharves around the site for transportation of personnel and equipment.	Canceled
CR 312: Implementation of local alternative evacuation routes for emergency planning	Concluded
CR 313: Implementation of improvements in the Emergency Centers	Concluded

CR 314: Radiological Protection Aspects in Severe Accident Management	Ongoing Deadline: November 2022

TAGS:

Concluded = Activities completed.

Canceled = Activities canceled.

This 9th National Report was prepared by a Working Group composed by representatives from the following organizations:

Comissão Nacional de Energia Nuclear (CNEN)

Eletrobrás Termonuclear S. A (ELETRONUCLEAR)

Central Organization for the Protection of the Brazilian Nuclear Program (SIPRON)

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA)

Rio de Janeiro – Brazil

August 2022.

CNEN Comissão Nacional de Energia Nuclear

IBAMA MMA

Eletrobras Eletronuclear

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CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES

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