NATIONAL REPORT OF BRAZIL 2017
FOR THE 6th REVIEW MEETING OF THE JOINT CONVENTION ON THE SAFETY OF SPENT FUEL MANAGEMENT AND ON THE SAFETY OF RADIOACTIVE WASTE MANAGEMENT

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NATIONAL REPORT OF BRAZIL FOR THE 6th REVIEW MEETING

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República Federativa do Brasil

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FOREWORD

On 29 September 1997, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management was opened for signature at the headquarters of the International Atomic Energy Agency in Vienna. Brazil signed the Convention on October 11th, 1997 and ratified it by the Legislative Decree 1019 of November 14th, 2005. Brazil deposited its instrument of ratification on 17 February 2006.

Brazil has not participated in the First Review Meeting and presented its National Report for the Second Review Meeting under the condition of “late ratifier”. Notwithstanding, Brazil presented its National Report to the Parties on schedule for review in the 3rd, 4th and 5th Review Meetings of the Contracting Parties to the Joint Convention, in Vienna, Austria.

The National Report of Brazil 2017 was prepared by a group of representatives of the various Brazilian organizations with responsibilities related to safety of spent fuel and radioactive waste.

The present report is an update of the Brazilian National Report presented to the Joint Convention in October 2014, and contains a description of the Brazilian policy and program related to the safety of nuclear energy, and an article-by-article description of the measures Brazil is taking to implement the Convention obligations, according to the format of document INFIRC/604.

Brazil considers that its nuclear programme has fulfilled and continues to comply with the objectives of the Join Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, including a description of its policies and practices and an inventory of the related material and facilities. The Brazilian nuclear programme has established and maintained effective defenses against potential radiological hazards in order to protect individuals, the society and the environment from harmful effects of ionizing radiation and has also ensured the adoption of good practices on radioactive waste and spent fuel management.

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SECTION A - INTRODUCTION

A.1 - THE BRAZILIAN NUCLEAR POLICY

The Constitution of the Federal Republic of Brazil establishes in its articles 21 and 177 that the Union has the exclusive competence to operate nuclear energy services and facilities, including the operation of nuclear power plants. The Union also exercises monopoly over research, mining, enrichment and reprocessing, industrialization and trade in nuclear ores. The Union is also responsible for the final disposal of radioactive waste. All of these activities shall only be admitted for peaceful purposes and subject to approval by the National Congress.

The national policy for the nuclear sector is implemented in accordance with the Pluriannual Plan (PPA) 2016-2019. PPA is formulated by the Executive branch of the Federal Government four months before the end of the first year of the government. It defines the main strategic targets and programs of the Federal Government and must be analysed, amended and approved by the Congress. Nuclear Policy is one of the programs of the PPA, aiming at guiding research, development, production and safe use of all forms of nuclear energy.

Another important target of the current PPA is to increase the participation of nuclear energy in the national electric power production. This involves the continuous development of technology for the design, construction and operation of nuclear power plants and industrial facilities related to the nuclear fuel cycle. The development of human resources for the establishment and continuity of these activities is also addressed in this plan.

The plan for Science, Technology and Innovation also envisages the growth of nuclear technology use in other areas such as medicine, industry and food irradiation. To accomplish this goal, research and development institutions operate research reactors and isotope production facilities, as well as develop the related technology and provide training the required manpower.

The National Commission for Nuclear Energy (CNEN) was created in 1956 (Decree 40110 of 10/10/1956) to be in charge of all nuclear activities in Brazil. Later, CNEN was re-organized and its responsibilities were established by Law 4118/62 with alterations established by Laws 6189/74 and 7781/89. Thereafter, CNEN, a federal agency, through its Directorate for Radiation Protection and Nuclear Safety (DRSN), has assumed Regulatory Body roles and is in charge of regulating, licensing and controlling nuclear activities in Brazil concerning Nuclear Safety, Security and Safeguards. At the same time, nuclear power generation was transferred to the Ministry of Mines and Energy. Moreover, CNEN, through its Directorate for Research and Development (DPD), is in charge of research and development and production of radioisotopes and, according to Brazilian Legislation, is also responsible for receiving and disposing of radioactive waste from the whole country. Nevertheless, it is important to highlight that these two CNEN’s Directorates, DRSN and DPD, work in a totally independent way, despite belonging to the same organization (CNEN).

A.2 - THE BRAZILIAN NUCLEAR PROGRAMME

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

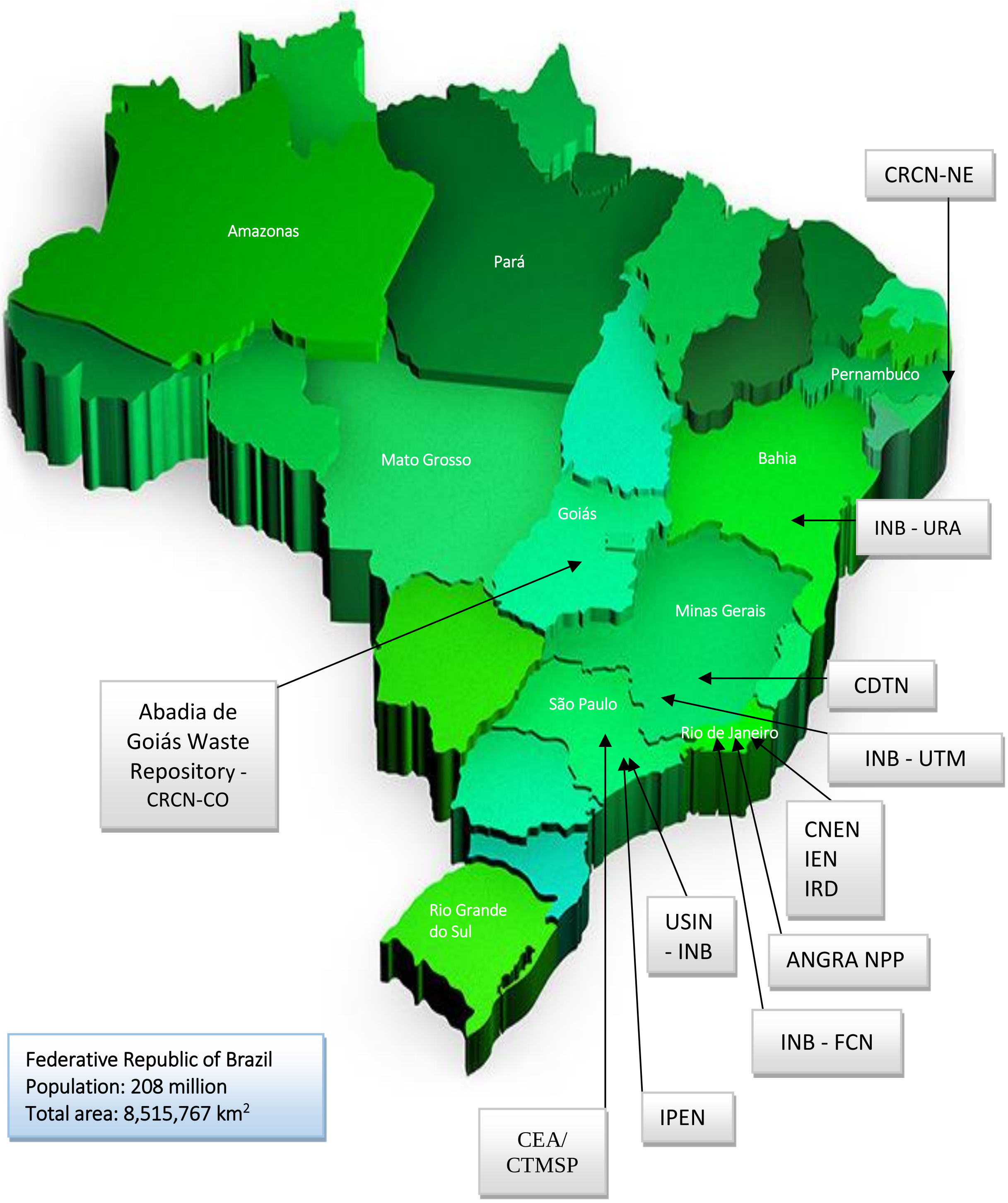

Figure A.1 - Main Brazilian Nuclear Installations and Organizations

A.2.1 - NUCLEAR POWER PLANTS

Brazil has two operating nuclear power plants: Angra-1, 640 MWe gross/ 610 MWe net, 2-loop PWR and Angra-2, 1,350 MWe gross /1,275 MWe net, 4-loop PWR. The construction of the third plant (Angra-3, 1,405 MWe gross /1,330 MWe net expected, 4-loop PWR) was stopped on September, 2015, and it is pending of Governmental decision to resume the Angra-3 project. Angra-1, 2 and 3 are located in a common site, near the city of Angra dos Reis, about 130 km south of the city of Rio de Janeiro.

Brazil has established in 1997 a nuclear power utility and engineering company, Eletrobrás Termonuclear S.A. - Eletronuclear (ETN), as a subsidiary of ELETROBRAS, a state holding company for the electric system, under the Ministry of Mines and Energy (MME) - see Figure E.1, a heavy components manufacturing company, Nuclebras Heavy Equipment Industry (NUCLEP), a Nuclear Fuel Factory (FCN) and a yellow-cake production plant belonging to the Brazilian Nuclear Industries - Indústrias Nucleares do Brasil (INB). Brazil also has the technology for uranium conversion and enrichment, as well as private engineering companies and research and development institutes devoted to nuclear power development. Over 15,000 individuals are involved in nuclear fuel cycle activities. Although approximately only one third of its territory prospected, Brazil possesses the world's sixth uranium ore reserves, which amounts approximately 310,000 t U_3O_8 *in situ*, recoverable at low cost.

Following another Governmental decision, the country started a complete research of possible sites for new nuclear power plants construction. Before the accident of Fukushima in Japan, Eletronuclear had already started the site selection for these Plants, in accordance with the National Energy Plan 2030 (PNE 2030), which considers, in its reference scenario, the nuclear expansion of 4,000 MW, being 2,000 MW in the Northeast region and 2,000 MW in the Southeast region. In this process of site selection, 40 suitable areas were preliminarily identified throughout the country.

Currently, the company awaits the release of the National Energy Plan 2050 (PNE 2050), which is expected to be issued by the government until the end of 2017. This document will determine the reviewed Brazilian energy planning for the coming decades and establish the future contribution of nuclear energy.

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 transfer 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.

According to the 10-year Energy Expansion Plan – PDE 2022 approved on January 24, 2014, by the Ministry of Mines and Energy, issued by the EPE – Brazil´s Energy Research Company, Angra-3 would enter in commercial operation by June 2018. However, due to unexpected impacts on the Project, the Plant construction schedule was revised and the date for the start of commercial operation of the Plant is now scheduled for January 2024.

A.2.2 - RESEARCH REACTORS (RR)

Brazil has 4 research reactors operating at CNEN institutes and 1 under licensing process.

A.2.2.1 - The IEA-R1 Research Reactor

IEA-R1 is the largest research reactor in Brazil, 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. IEA-R1 is currently operating at 4.0 MWth (until July 27, 2011) and 4.5 MWth (from August 01, 2011) with a 64-hour cycle per week. The reactor originally used 93% enriched U-Al fuel elements. Currently, it uses 19.9% enriched uranium (U_3O_8-Al and U_3Si_2-Al) fuel that is produced and fabricated at IPEN. The reactor is operated and maintained by the Research Reactor Center (CRPq) at IPEN, São Paulo, which is also responsible for irradiation and other services.

The IEA-R1 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 of IPEN routinely use the reactor for their research and development work. Scientists and students from universities and other research institutions also use it for academic and technological research. The largest user of the reactor is the Research Reactor Center from IPEN, which is interested in 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 ^{131}I, ^{32}P, ^{198}Au, ^{24}Na, ^{35}S, ^{51}Cr and labeled compounds for medical use. After 1980, it started producing ^{99m}Tc generator kits from the fission of ^{99}Mo imported from Canada. This production is continuously increasing, with the current rate of about 17,000 Ci of ^{99m}TC per year. The ^{99m}Tc 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 ^{131}I, ^{32}P, ^{51}Cr and ^{153}Sm are also produced at IPEN.

A.2.2.2 - The IPR-R1 Research Reactor

The IPR-R1 TRIGA Mark I Reactor has been operating for 53 years at Nuclear Technology Development Center (CDTN), at Campus of Federal University of Minas Gerais (UFMG), in Belo Horizonte. The IPR-R1 is a pool type nuclear research reactor, with an open water surface and the core has a cylindrical configuration (Figures A.2 and A.3). The first criticality was achieved in November 1960 and operates at 100 kW and under demand. The integrated burn-up of the reactor since its first criticality is about 2 GW.h. Due to the low nominal power, spent fuel is far from being a problem, except for aging concerns. There was not 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 ^{60}Co, ^{198}Au, ^{192}Ir, ^{56}Mn, ^{24}Na etc. that are used in the stainless steel industry, and environmental research activities. Additionally, it is also employed to train the Brazilian NPP operators.

Figure A.2 - IPR-R1 – Control Room and NPP Operator Training Course

Figure A.3 - IPR-R1 - Open View

A.2.2.3 - Argonauta Research Reactor

The third Brazilian RR is named Argonauta, 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 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 burn-up 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, sample irradiation and for the production of some radiotracers for industrial use.

A.2.2.4 - IPEN/MB-01 Research Reactor

The most recent Brazilian RR is IPEN/MB-01, 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 that date to March 2011, the reactor operated more than 2,587 times in order to measure Reactor Physics parameters to validate neutronic codes, train reactor operators and teach graduate and post-graduate courses. Some critical experiments are international benchmarks of the Nuclear Energy Agency (NEA-OECD). The IPEN/MB-01 reactor is a zero power reactor because the maximum power level is 100 watts with an average thermal neutron flux of about 5.0×10^8 n/cm^2.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, has a core that consists of up 680 stainless steel fuel pins with UO_2 pellets inside. The diameter of the pins is 9.8 mm, and their length is 1,194 mm. The pins have an active length of 546 mm, filled with 4.3% enriched UO_2 pellets. The remainder of the pins is filled with Al_2O_3 pellets.

The pins are manually inserted into a perforated matrix plane, making it possible to have any desired experimental arrangements within a 28 x 26 matrix. The control and safety rods are composed of a total 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 a moderator and for the natural cooling system.

A.2.2.5 - 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. The RMB will be a new Nuclear Research and Production Centre that will be built in a Sorocaba city, about 100 kilometers from Sao Paulo city, in the southeast part of Brazil. 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 $2x10^{14}$ neutrons per square centimeter per second. Upon completion of its conceptual project, the reactor site was chosen and environmental impact assessments were already conducted. CNEN and IBAMA have issued the Local Approval in 2015. 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. The layout can be seen bellow in Figures A.4.

This reactor will enable the production of radioisotopes for application in medicine, industry and environment; irradiation testing of advanced nuclear fuels; irradiation and materials testing and, if possible, to conduct fundamental scientific research with a beam of neutrons in various fields of knowledge.

Figures A.4 - RBM Project – Layout of the main buildings

Concerning the treatment and storage of radioactive waste, 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 life, 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 span more 50 years, reaching a total storage time of 100 years.

This extended time storage will allow conducting studies for the implementation of a geological repository for the spent fuel produced by the Brazilian nuclear power plants, as well as for the high level waste generated in the process for obtaining the isotope ^{99}Mo.

A.2.3 - NUCLEAR INSTALLATIONS

A.2.3.1 - Mining and Milling

Brazil has two uranium mining and milling facilities. The first, in Poços de Caldas (state of Minas Gerais), formerly known as Poços de Caldas Industrial Complex – CIPC, and now called Ore Treatment Unit (Unidade de Tratamento de Minério - UTM), operated between 1982 and 1995. All the economically recoverable uranium was extracted and currently no mining activity is underway. The conceptual plans for decommissioning and remediation for this unit have been prepared.

The other mining facility, called Uranium Concentrate Unit (Unidade de Concentrado de Urânio – URA) is operating since 2000 in Caetité (state of Bahia), with reserves of 100,000 tons of U_3O_8, and a capacity of 400 tons/year of yellow cake (U_3O_8) production, which is envisaged to be expanded to 800 tons/year.

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 2023. It is planned to produce 1,600 tons of U_3O_8 per year as a by-product of 240,000 tons of P_2O_5.

A.2.3.2 - Monazite Sand Extraction

Brazil has large natural deposits of monazite sand in its South-East Coast. These have been in exploration since the 50's. The only treatment facility in operation, called Heavy Minerals Processing Unit (Unidade de Minerais Pesados – UMP) is located at Buena, in the state of Rio de Janeiro. The facilities in the state of São Paulo are no longer in operation, one of those has been decommissioned, while two others remain as waste storage deposits.

A.2.3.3 - 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.

One building performs three activities: (*i*) uranium hexafluoride is converted into UO_2 powder; (*ii*) fuel pellets are manufactured and (*iii*) uranium hexafluoride is enriched (up to 5% enrichment). The nominal production capacity is 160 tons/year of UO_2 powder and 120 tons/year of UO_2 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 43 tons of SWU (Separate Work Unit).

In the other building, PWR fuel assemblies are manufactured using the UO_2 fuel pellets from the first unit and other additional components, either imported or produced locally. The nominal capacity is 170 tons/year of uranium oxide. Since 1982, this unit produces fuel assemblies for the Brazilian Nuclear Power Plants, Angra-1 and Angra-2.

A.2.4 - THE NAVY PROGRAMME

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), 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 UF_6 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.

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.

A.2.5 - RADIOACTIVE INSTALLATIONS

The National Commission for Nuclear Energy (CNEN) has implemented a huge regulatory policy which covers the authorization of radioactive facilities, control (transfer, import and export) of radioactive sources, the maintenance of the national inventory of the radioactive sources, inspection program, radioprotection officers certification and registration of legal persons (specialists). CNEN also provides facilities and services necessary to manage and store radioactive disused sources.

Published regulations are the main instrument of CNEN’s regulatory action. The CNEN has issued 44 Regulations covering nuclear and radioactive areas and 10 among them are currently used for the licensing, control of radioactive sources and facilities. The Radiation Facilities, including the ones which use radioactive sources, are classified in 8 groups covering 6 areas: medicine, industry, research and education, distribution, services and production of radioisotopes (cyclotrons/Centralized Radiopharmacies).

In order to ensure an integrated regulation concerning the access and use of radioactive sources, CNEN also acts in a coordinated way with other governmental organizations, such as the control on import and export of radioactive sources, carried out by the CNEN and Customs, in accordance with the import and export legislation, and the CNEN-Ministry for Health inter-ministerial regulatory cooperation, established in order to harmonize and improve the regulatory action implemented by both organizations.

Besides the control and licensing activities, CNEN gives support to safety and security complementary activities implemented by the other relevant actors. In this sense, CNEN has accompanied the installation of monitoring systems to detect radioactive scrap metal items as well as collecting the disused sources throughout the country to reduce the risk of radioactive scrap metal production. These control activities have been implemented by steel industries and include the operation of special monitoring systems such as gate and portal monitors, to identify potential contaminated scrap metal items.

Brazil has written a letter to the International Atomic Energy Agency (IAEA) Director General, expressing their support for the Code of Conduct and the Guidance as well as nominated a point of contact for the purpose of facilitating the export and/or import of radioactive sources in accordance with the Code Conduct and the Guidance. Finally, in the context of IAEA CoC, CNEN established bilateral agreements with some countries, namely United States, Argentina, and Canada, to support further cooperation on import/export control of radioactive sources.

Brazil has licensed more than 5,000 radioactive installations by 2017, but currently the national registry includes 3,070 active Radiation Facilities. Table A.1 shows the current distribution of the active facilities by the areas of application. About 300 new facilities start their licensing processes, every year. Concerning the Radiation Facilities, 474 facilities operate Category 1 or Category 2 radioactive sources, including industrial irradiation, blood irradiation, radiotherapy, industrial radiography and brachytherapy facilities.

Table A.1 - Distribution of Active Radioactive Installations by Area (2017)

Area:	Medicine	Industry	Research	Distribution	Services	Production (Cyclotrons)	**Total**
Number:	1,040	1,166	647	64	137	16	3,070

A.2.5.1 - Medical Installations

- Radiotherapy Services

A total of 386 facilities are in operation or in licensing process. In 2014 the Ministry for Health has started a new comprehensive national plan to equip and re-equip hospitals, with the acquisition of more than 80 LINACs and 10 HDR systems. Most of the accelerators are replacing ^{60}Co radiotherapy irradiators.

- Nuclear Medicine Services and Radiopharmaceuticals Production

The use of radioisotopes in medicine is increasing permanently. Positron emission tomography practice is well established (146 facilities) and 3 new facilities (cyclotrons) for the production of radioisotopes are being licensed and will be in operation in the next year.

A.2.5.2 - Industrial Installations

Currently, in the country, we have 1,166 industrial installations as described below.

- Industrial Radiography Services

The development of the Brazilian on-offshore oil and gas industry has significantly increased the demand for industrial radiography services. This has required a large effort to prepare the necessary personnel and develop the required procedures, especially for contractors. A total of 140 industrial radiography facilities are operating in the country.

- Utilization of Nuclear Measuring Instruments

The chemical, metallurgic, petrochemical, plastic, paper and other industry are increasingly using measuring instruments (gauges) based on radioactive sources. Portable instruments used for density measurement are becoming more widespread. Sources such as ^{137}Cs, ^{241}Am, ^{90}Sr and ^{85}Kr are the most used. A total of 642 gauges are being used in the country

- Oil Exploration Well Profiling

In 2017, 10 organizations operated 18 bases for exploring oil in the North, Northeast and the Central coastal region using radioactive sources. Sources such as ^{241}Am, ^{60}Co, ^{226}Ra, ^{137}Cs and ^{241}Am/Be neutron sources are being used.

A.2.5.3 - Industrial Irradiators

There are six ^{60}Co industrial irradiators operating in Brazil. They are used for sterilization of medical equipment and food irradiation. Among them, there are two small irradiators used at research centers.

A.2.5.4 - Research Facilities

The use of radioisotopes in research occurs at CNEN research institutes (IPEN, IEN, and CDTN), other research centers and universities. The type of research is diversified, including nuclear physics, biology, agriculture, health, hydrology and environment. Generally, small sources of ^{3}H, ^{14}C, ^{22}Na, ^{55}Fe, ^{63}Ni, ^{125}I, ^{226}Ra, ^{35}S e ^{32}P are used for research applications. However, small ^{60}Co irradiators are also used in some facilities. There are 647 active research facilities in Brazil.

A.2.6 - WASTE REPOSITORY AT ABADIA DE GOIÁS

Following the 1987 accident with a disused ^{137}Cs source that resulted in the contamination of a significant part of the city of Goiânia, two near surface repositories with a total volume of 3,134 m^3 of radioactive waste were constructed in Abadia de Goiás in 1995. The complete inventory is described in item **D.6**.

A long-term safety assessment of both repositories was done at that time confirming the safety of the two repositories. According to the requirements of the Final Safety Analysis Report (FSAR), the long-term safety assessment must be repeated as part of the institutional control reporting requirements. In 2002 and 2014, a second and a third safety reassessments were performed by CNEN to verify the safety of both systems. This is described in item **H.5.2.3**.

A.3 - STRUCTURE OF THE NATIONAL REPORT

This Report is a review of the fourth National Report of Brazil presented to the 5th Review Meeting in 2015. The fifth Brazilian Report for the 6th Review Meeting of the Joint Convention 2018 follows the same form and structure previously adopted, and it was prepared to fulfill Brazilian commitments with the Convention [1]. Whenever possible, the information provided by the report refers to the situation as of June 2017.

Section **B** to **K** present an analysis of the Brazilian structures, actions and activities related to the Convention's obligations, and follow the revised Guidelines for the preparation of National Report [2]. In Section **B**, some details are given on the existing policies and practices and an overview matrix is presented. Section **C** defines the scope of application of the Convention in Brazil. Section **D** presents the inventory of installations and facilities. Section **E** provides details on the legislation and regulations, including the regulatory framework and the regulatory body. Section **F** covers general safety provisions as described in articles 21 to 26 of the Convention. Section **G** addresses the safety of spent fuel management, including during siting, design, construction and operation. Section **H** addresses the safe management of radioactive waste. Section **I** presents a case of transboundary movement of spent fuel. Section **J** details the situation of disused radioactive sources.

In general, the report presents separately the different types of facility, whenever possible. Nuclear power plants, due to their complexity, are always treated separately.

Section **K** describes planned activities to further enhance nuclear safety and presents final remarks related to the degree of compliance with the Convention obligations.

The report also contains two annexes where more detailed information is provided with respect to spent fuel storage and radioactive waste facilities, and the Brazilian nuclear legislation and regulations. A third annex presents a list of used abbreviations

SECTION B - POLICIES AND PRACTICES (*Article 32 – § 1*)

B.1 - INTRODUCTION

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. Therefore, in the scope of this Convention, spent fuel will be not considered as such.

Regarding radioactive waste, the policy is to keep it safely isolated from the environment while a permanent solution is granted on national level. In this sense, in November 2008, a Project named Low and Intermediate Level Waste Repository, the "RBMN Project", was launched aiming at having a licensed and commissioned repository to dispose of the low- and intermediate-level waste. The *RBMN Project* is part of the Brazilian solution for the disposal of radioactive waste generated in Brazil. The site selection process aiming at the construction of the Brazilian Repository is still on course. Details can be found in Section **H.3.2**. It is noteworthy that waste classified as naturally occurring radioactive material (NORM) is not foreseen to be disposed of in this repository.

The basic legislations governing this policy are the Federal Brazilian Constitution, which establishes in its article 21 that "all the nuclear energy activities shall be solely carried out for peaceful uses and always under the approval of the National Congress"; Law 6189 of 16 December 1974, which attributes to CNEN the responsibility for receiving, storing and the final disposal of radioactive wastes; and Law 10308 of 20 November 2001 which establishes rules for the siting, licensing, operation and regulation of radioactive waste storage facilities in Brazil (see also **E.2**).

An overview matrix providing the types of liabilities and the general policies and practices in Brazil can be seen ahead, in Section **B.3**.

B.2 – RADIOACTIVE WASTE

B.2.1 - TYPES AND CLASSIFICATION

In 2014 Brazil adopted a new waste classification system, as shown on Table B.1 below. The CNEN Norm-NE-6.05 - Radioactive Waste Management in Radioactive Facilities [6], which established the waste classification still based on the IAEA Safety Series No. 111.G-1.1 from 1994 [21], was reviewed and a new waste classification scheme was adopted based on the IAEA General Safety Guide No. GSG-1 of 2009 [22]. The reviewed CNEN guide was approved and issued on 30 April 2014 with the new name CNEN-NN-8.01 - Radioactive Waste Management for Low- and Intermediate-Level Waste [25] and the old guide CNEN NE-6.05 was revoked.

The types of waste generated in Brazil are normally those ones related to the installations and organizations presented in Section **A** of this document and which are described in more detail in the inventory presented in Section **D**.

Table B.1 - Waste Classification

Category	**Characteristics**	**Disposal Option**
0. Exempt waste	Activity levels equal or bellow the exemption limits which are based on a maximum annual dose to members of the public of less than 0.01 mSv.	No radiological restriction
1. Very short lived waste (VSLW)	Waste containing radionuclides with half-lives of the order of 100 days or less, with activity concentrations above the clearance levels.	Stored for decay.
2. Low and Intermediate level waste	Activity levels above exemption limits, with half-lives greater than 100 days and heat generation equal or below 2 kW/m^3.	
2.1- Short lived	Waste containing radionuclides with half-life of less than about 30 years to beta/gamma emitters, with a limit of 370 Bq/g on average and up to 3,700 Bq/g for individual packages for long lived alpha emitters.	Near surface repository.
2.2- Containing naturally occurring radionuclides from the extraction and processing oil operations	Waste containing radionuclides from the decay series of Uranium and Thorium with activity concentrations above the clearance levels	Near surface or geological repository – to be defined by the Safety Assessment analysis.
2.3- Containing naturally occurring radionuclides from the mining or processing of ores and minerals	Waste containing radionuclides from the decay series of Uranium and Thorium with activity concentrations above the clearance levels.	Near surface or geological repository – to be defined by the Safety Assessment analysis.
2.4- Long lived	Long lived radionuclide concentrations exceeding limitations for short lived waste.	Geological repository
3. High level waste	Heat generation above 2kW/m^3 and long lived alpha emitting radionuclide concentrations exceeding limitations for short lived waste (2.1).	Deep geological repository

B.3 – BRAZIL MATRIX

Type of Liability	Long Term Management Policy	Funding of Liabilities	Current Practice / Facilities	Planned Facilities
Spent Fuel	Long term storage or reprocessing - Waiting for an economic and political decision	OPERATOR (ETN)	STORAGE ON SITE (POOLS) complementary dry storage unit is foreseen	ADDITIONAL ON-SITE WET STORAGE Long term cask storage (under examination)
Nuclear Fuel Cycle Wastes	Not defined yet	OPERATOR (INB)	STORAGE ON SITE	None
Application Wastes	LILW Repository	LICENSEES + CNEN	STORAGE AT CNEN INSTITUTES	LILW Repository
Decommissioning Liabilities	Not defined yet	OPERATOR (ETN)	None	Not defined yet
Disused Sealed Sources	Storage at CNEN Institutes while awaiting a final decision on borehole disposal (BOSS)	LICENSEES + CNEN	RETURN TO MANUFACTURER OR STORAGE AT CNEN INSTITUTES	Not defined yet

SECTION C - SCOPE OF APPLICATION (*Article 3*)

C.1 - DEFINITION OF SCOPE

A summary of the Brazilian nuclear policies and program is presented in Section **A** of this Report. Section **A.2**, specifically, describes the activities and facilities covered in the National Report, which includes all the spent fuel and radioactive waste related to the Brazilian nuclear programme.

According to the definition of the Convention, the main Brazilian policies and practices are described in Section **B.** As mentioned in **B.1**, spent fuel from NPP's is not considered radioactive waste in Brazil and there is a pending technical, economic and political decision of the Federal Government about the possibility of reprocessing this fuel or disposing it of as such. An overview matrix providing the types of liabilities and the general policies and practices in Brazil is provided in Section **B.3**.

Waste containing only naturally occurring radioactive material (NORM) will be included in the scope of this Report only to the extent that they are produced in the processing of uranium and thorium containing ores, such as Monazite sand processing, as described in Sections **H.2.2.2**, **H.2.2.3**, and **H.2.2.4.**

There is still no spent fuel within the military or defense program in Brazil. The management of waste generated in the nuclear submarine program of the Brazilian Navy, although of minor importance and small quantity, is described in Section **D.4**.

SECTION D - INVENTORY AND LISTS (*Article 32 – § 2*)

This section describes the facilities and activities that produce spent nuclear fuel and radioactive waste, and presents a description of the inventories. More detailed information is presented in Section **H** and on table format in Annex 1.

D.1 - NUCLEAR POWER PLANTS

As mentioned in item **A.2.1**, Brazil has two nuclear power plants in operation (Angra-1, 640 MWe gross/610 MWe net, 2-loop PWR and Angra-2, 1,350 MWe gross/1,275 MWe net, 4-loop PWR) and one under construction (Angra-3, 1,405 MWe gross/1,330 MWe net expected, 4-loop PWR,). Angra-1, 2 and 3 are located at a common site, near the city of Angra dos Reis, about 130 km from Rio de Janeiro.

D.1.1 - ANGRA-1

Site preparation for Angra-1, the first Brazilian nuclear unit, started in 1970 under the responsibility of FURNAS Centrais Eletricas SA. The initial work for construction of the plant began only in 1972 (Base Plate concrete works 29/03/1972), 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.

CNEN granted the construction license for the plant in 1974. The operating license was issued in September 1981 (Res. CNEN no. 10/81, 10/09/81), at which time the first fuel core was also loaded (20/09/81). First criticality was reached in March 1982 (13/03/1982 at 20:23 h), and the plant was connected to the grid in April 1982. After a long commissioning period due to a steam generator generic design problem, which required equipment modifications, the plant finally entered into commercial operation on 1st January 1985.

In 1997, plant ownership has been transferred to the newly created company Eletrobras Eletronuclear (ETN), which has absorbed all the operating personnel of FURNAS CENTRAIS ELÉTRICAS S.A. and part of its engineering staff, and the personnel of the design company Nuclebras Engineering (NUCLEN)..

D.1.1.1 - Angra-1 Spent Fuel Management

With respect to spent fuel of Angra-1, the 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 current status at Angra-1 fuel pools is presented on Table D.1.

Table D.1 - Spent Fuel Assemblies Stored at Angra-1

Storage place	Angra-1	
	Capacity	Occupied
New Fuel Storage Room	45	9
Region 1 Spent Fuel Pool	252	178
Region 2 Spent Fuel Pool	1,000	791
Reactor Core	121	121

Note: By definition of INFCIRC/546 "SPENT FUEL" means nuclear fuel that has been irradiated in and permanently removed from a reactor core. Included in this inventory there are fuel assemblies that are not yet considered "spent fuel", since they may be reused in future cycles.

D.1.1.2 - Angra-1 Radioactive Waste Management

Angra-1 nuclear power plant is equipped with systems for treatment and conditioning of liquid, gaseous and solid wastes. The Compressible Solid Wastes are compressed by a hydraulic press and then, conditioned in 200 litter drums. Evaporator Concentrates and primary spent resins are immobilized in cement in 1.0 m^3 liners. Spent filter cartridges are immobilized in cement in 200 litters drums and non-compressible solid wastes are immobilized in 1.5 m^3 metallic boxes.

Concentrates from liquid waste treatment are solidified in cement and conditioned in 200 litter drums (up to 1998) and 1 m^3 steel containers (after 1998). Solid waste may be conditioned in drums or in special boxes. Gaseous waste is stored in holdup tanks. These tanks have the capacity for long-term storage. The intermediate and low level waste is currently stored on-site in a separate storage facility (see **D.1.4**).

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, labelled and transported to the storage facility (Radioactive Waste Management Center).

D.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 that agreement Brazil accomplished the procurement of two nuclear power plants, Angra-2 and 3, from the German company, KWU – Kraftwerk Union A.G., later SIEMENS/KWU nuclear power plant supplier branch.

Considering that one of the objectives of the Agreement was a high degree of domestic participation, Brazilian company Nuclebras Engineering S.A. (NUCLEN) (now Eletrobras Eletronuclear (ETN), after merging with the nuclear part 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.

Angra-2 civil engineering contractor was Norberto Odebrecht Company and the civil works started on 9th September 1981. However, from 1983 on, the project suffered a gradual slowdown due to financial resources reduction. In 1991, Angra-2 works were resumed and in 1994, the financial resources necessary for its completion were defined. In 1995, a bid was called for the electromechanical erection and the winner companies formed the consortium UNAMON (seven Brazilian subcontracting companies joined to build nuclear power plants), which started its activities at the site on 1st June 1996.

Hot trial operation was started in September 1999. On 24th 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 21th July 2000. The power tests phase was completed in November 2000. The commissioning phase was also very successful. No major equipment problems occurred in spite of the very long storage time (~20 years), indicating the high quality of the component conservation program. The Angra-2 NPP has been operating at full power since mid-November 2000 and went into commercial operation on 1st February 2001. The Authorization for Initial Operation (AOI) has been extended periodically, up to June 15, 2011, when CNEN issued the Authorization for Permanent Operation (AOP).

D.1.2.1 - Angra-2 Spent Fuel Management

The current status at Angra-2 fuel pools is presented on Table D.2.

Table D.2 - Spent Fuel Assemblies Stored at Angra-2

Storage place	**Angra-2**	
	Capacity	**Occupied**
New Fuel Storage Room	75	0
Region 1 Spent Fuel Pool	264	34
Region 2 Spent Fuel Pool	820	670
Reactor Core	193	193

Note: By definition of INFCIRC/546 "SPENT FUEL" means nuclear fuel that has been irradiated in and permanently removed from a reactor core. Included in this inventory there are fuel assemblies that are not yet considered "spent fuel", since they may be reused in future cycles.

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 initial enrichment. This spent fuel storage capacity is sufficient for about 15 years (14 cycles) of operation, which means that additional spent fuel storage space will have to be provided in the medium term.

D.1.2.2 - Angra-2 Radioactive Waste Management

Angra-2 nuclear power plant is equipped with systems for treatment, conditioning and have an interim initial storage of solid radioactive waste. The Liquid radioactive waste are collected in the Storage of Liquid Radioactive Waste System and processed in the Liquid Waste Processing System in such a way that the final product form a radioactive concentrate and dischargeable decontaminated water. Regarding the gaseous radioactive Waste, only conditioning and treatment are considered. All Angra-2 waste treatment systems are highly automated to minimize human intervention and reduce operating personnel doses. Liquid waste is collected in storage tanks for further monitoring and adequate treatment, then, they are discharged to the environment. The wastes are separately processed according to their origin and level of radioactivity.

The concentrate resulting from the liquid waste treatment is further processed in order to reduce water content before being immobilized in bitumen and conditioned in 200-liter drums. Spent resins and filter elements are dried, then immobilized in bitumen and conditioned in 200-liter drums. Compactable solid waste is compressed by a Hydraulic Press and then, they are conditioned in 200-liter drums. Non-compactable solid waste are conditioned in 1.5 m^3 metallic boxes and sent to NPP Angra 1. Gaseous waste is 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 filters 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 on-site storage facility, still at the plant site.

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, labelled and transported to the initial storage of solid radioactive waste.

D.1.3 - ANGRA-3

On June 25, 2007 the Federal Government through its National Council for Energy Planning approved the resumption of Angra-3 construction after a 23-year interruption.

But, even before construction authorization for Angra-3 was given, some progress has been made. In 2005, following authorization for site preparation work issued by the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA), the rock excavation for the plant foundation was cleaned up and stabilized. Engineering work was continued with adaptation for Angra-3 of Angra-2 materials and equipment specifications, upgrading the design with basis on the Angra-2 plant and the international operational experience as well as continuation of contacts with the potential equipment suppliers. An important formal step on the Government side was inclusion, in March 2006, of Angra-3 in the Electric Energy Expansion Decennial Planning, covering the period 2006/2015, following a detailed evaluation of Brazil’s viable energy generation alternatives.

Many of its imported components were already in Brazil and the site was ready for concrete pouring. Most of the required engineering was essentially available since for economy and standardisation reasons Angra-3 is to be as similar as possible to Angra-2. This concept has been submitted to and accepted by CNEN, proposing “Angra-2 as-built” as the reference plant for Angra-3. In this context, the major technical modifications planned for Angra-3 are: the replacement of the conventional instrumentation and control by a modern digital system and the implementation of a digital Human System Interface (HIS) in the Main Control Room (MCR). Another difference between the two units refers to the site: Angra-2 was constructed on pile foundation, while Angra-3 is being built on sound rock.

Concerning supplies, a great part of the imported equipment is already stored in the warehouses, including not only the primary circuit heavy components and the turbine-generator set parts but also special pumps, valves and piping material. Excellence of the preservation plan for long-term storage has been demonstrated during Angra-2 completion, whereby no relevant equipment malfunction due to long-term storage had adverse impact on plant commissioning or initial operation. The preservation measures, including the 24 months inspection program, continues to be applied for the Angra-3 components stored at the site.

For the plant construction, two licenses were required: the Construction License from the National Nuclear Energy Commission - 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).

The Preliminary Safety Analysis Report (PSAR) for the Nuclear Licensing procedure was reviewed and delivered to CNEN. In 2010, Eletrobras Eletronuclear (ETN) received a Construction License from CNEN.

The environmental licensing proceeded with the preparation and submission of the Angra-3 Environmental Impact Assessment (EIA) to IBAMA. Still in the frame of the environmental licensing process, public hearings to inform the population of the contents of the EIA were held in all municipalities bordering the emergency planning zones of the Plant. ETN received the Pre-installation License from IBAMA in July 2008 and the Installation License in March 2009, both with several conditions to be fulfilled either before or during the construction phase.

Angra-3 will be the third nuclear power plant in Admiral Álvaro Alberto Nuclear Power Station, located at Itaorna beach, in the municipality of Angra dos Reis (RJ).

This new plant will have 1,405 MWe of gross electrical output, producing about 10.9 million MWh per year - such power output is equivalent to one third of the power consumption of the state of Rio de Janeiro - and it will be similar to Angra-2, its reference plant.

Operational tests were performed for Angra-2 in 2003, when the plant operated at a gross electrical output of 1,436 MWe. Based on these tests and on Safety Analysis Calculations prepared for Angra-2, it was verified that the gross electrical output could be increased from 1,350 MWe to 1,405 MWe without major changes to the equipment.

Based on the fact that Angra-2 is the reference plant for Angra-3, the procedures for the modification of the Angra-3 design documents have been conducted. Application for increasing Angra-3 to gross electrical output of 1,405 MWe have been submitted to the National Commission for Nuclear Energy (CNEN) through document SM.G-484/12 dated August, 10, 2012; CNEN is presently duly evaluating the documentation for approval.

By means of the Ministerial Order nº 12 of the Secretariat for Energy Planning and Development of the Ministry for Mines and Energy (SPE/MME), issued on June 22nd, 2010, the physical guarantee for Angra-3 was established taking into account the rated output of 1,405 MWe.

Owing to this similarity, a great portion of the engineering design for Angra-3 is already prepared. In addition, the experience with the construction and erection of Angra-2 showed the noteworthy technical competence of the Brazilian companies for working in this branch of activity. A significant amount of imported equipment was already bought, specially the mechanical heavy components, such as the main components of the nuclear island (reactor vessel, steam generators, pressurizer and main pumps) and the most important equipment of the BOP (turbine and electrical generator).

Angra-3 will increase the reliability of the Southeast region's grid because, together with the existing plants, Angra-1 and Angra-2, the new plant will supply approximately 70% of the electricity demands of the state of Rio de Janeiro.

On the following are described the main actions and activities related to Angra-3 construction, Figure D.1.

- **Nuclear Licensing**

  On May 31, 2010, the Brazilian National Commission for Nuclear Energy (CNEN) granted the Construction License, which authorizes the concrete laying of the foundation slab of the reactor building (UJB), provided that Eletrobras Eletronuclear (ETN) submits to CNEN designs and calculations for the next stages of construction.

This license allowed ETN to start the concrete laying of the foundation slab of the Reactor Building on June 1st, 2010, which is the ground zero of the General Executive Schedule..

Figure D.1 - Angra-3 construction evolution – 2010/2017

➢ Environmental Licensing

The Preliminary License and the Installation License were granted by the Brazilian authority on environmental matters (IBAMA), respectively in June-2008 and March-2009, after all requirements of the environmental licensing were fulfilled. Among those requirements, there are the approval of the EIA/RIMA (Environmental Impact Study/Environmental Impact Report) by the licensing entity and the carrying out of 17 Public Meetings with the neighboring communities to the Nuclear Power Station and of 8 Official Public Hearings, two in Angra dos Reis, Paraty, and Rio Claro, and one in Rio de Janeiro, and Ubatuba.

➢ Civil Works Evolution

The current progress of the civil works had reached approximately 67 %, when the Angra 3 Project was suspended in 2015.

Additionally to the infrastructure site installations such as concrete factory, carpentry, steel reinforced bars workshop, embedded pieces warehouse, 5 provisory substations etc, and the main structures which were being constructed before the suspension were: reactor building, reactor auxiliary building, control building and turbine building.

D.1.3.1 - Angra-3 Spent Fuel Management

The spent fuel will be stored similarly to Angra-2.

D.1.3.2 - Angra-3 Radioactive Waste Management

The radioactive waste will be treated and initially stored within the plant, similarly to Angra-2, and then forwarded to the Waste Repository at the proper time.

D.1.4 – ON-SITE INITIAL STORAGE 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.

For additional information, see Section **H.2**.

D.1.5 - OLD STEAM GENERATORS STORAGE FACILITY

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. In the future, it also will store the complete radioactive waste evaporator and one residual heat exchanger.

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 [12] standard and annual limit of operational dose.

D.1.6 - WASTE REPOSITORY for LOW and INTERMEDIATE LEVEL WASTE

The plans for final disposal of waste generated by Angra nuclear power complex (units 1, 2 and in the future 3), are under development, as described in items **H.3.2** and **H.5.2.2**.

D.2 - RESEARCH REACTORS

D.2.1 - SPENT FUEL MANAGEMENT

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 D.3 shows the RR operating in Brazil.

Of the research reactors shown on Table D.3, up to this present moment, the only one subject to concerns related to spent fuel storage is the IEA-R1. Part of its spent fuel was returned to U.S.A., 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 and containing uranium of US origin were also shipped back to Savannah River Site Laboratory, South Carolina, USA.

Table D.3 - Research Reactors 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

These storage concerns were the driving force for Brazil to also join an IAEA Regional Project. The objectives of the Project are to provide the basic conditions to define a regional strategy for managing spent fuel and to provide solutions taking into consideration the economic and technological realities of the countries involved. In particular, to determine the basic conditions for managing RR spent fuel during operational and interim storage as well as final disposal, and to establish forms of regional cooperation for spent fuel characterization, safety, regulation and public communication.

IPR-R1 has no short- and medium-term storage problems, due to its low nominal power.

The Brazilian part of the Latin American Spent Fuel Database is presented on Table D.4, showing the main characteristics of the fuel elements used in the Brazilian research reactors.

Table D.4 - Fuel Element 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 D.5. The only reactors subject to concerns related to medium and long-term storage are 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.

Table D.5 - SFA Inventory at Brazilians Research Reactors

Facility	# of FA in Present Core	Average # used per year	SFA Storage		SFA % AverageBurnup
			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	680 pins	NA	0	0	NA
IPR-R1	63 rods (LEU)	NA	0	0	~ 4
IEN-R1	8 LEU	NA	0	0	NA

NA = not applicable

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), 4-5 assemblies will be spent annually. Currently, 49 storage positions are occupied, suggesting that within 6 - 7 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.

Finally, Brazil has defined a technical solution for spent fuel or high-level waste disposal. The proposed project aims at doubling the storage capacity using BORALCAN^{TM}, which is a metal matrix composite (MMC) made by Rio Tinto Alcan (comprising an aluminum alloy (1100 or 6351) added with nuclear grade B_4C powder and titanium) in the construction of the new high density storage racks, increasing the reactor's operational autonomy around 25 years.

D.2.2 – RADIOACTIVE WASTE MANAGEMENT

The radioactive waste of the research reactors is managed together with the radioactive waste of the institutes to which they belong, as described in Section **D.5**.

D.3 - OTHER NUCLEAR INSTALLATIONS

D.3.1 – BRAZILIAN NUCLEAR INDUSTRIES (INB)

D.3.1.1 - Waste from Fuel Cycle and Monazite Processing Facilities

Formerly known as Poços de Caldas Industrial Complex - CIPC, the uranium mining and milling industrial complex is now called Ore Treatment Unit (UTM). Located at the Poços de Caldas plateau, in the state of Minas Gerais, the unit produced, from 1982 to 1995, 1,170 ton of ammonium diuranate (yellow cake). The waste generated in this process is kept in a 29.2 hectare tailing dam system, with an actual volume capacity of 1 million cubic meters. It is estimated that 4.8 TBq (130 Ci) of ^{238}U, 15 TBq (405 Ci) of ^{226}Ra and 4.2 TBq (112 Ci) of ^{228}Ra were disposed of in this site, to the present date (See also **H.2.2.3**).

The operation of the rare-earth production line of Santo Amaro Processing Plant (USAM) in São Paulo has generated Mesothorium (a material containing ^{226}Ra and ^{228}Ra) and Cake II (called Torta II - composed basically of thorium hydroxide concentrate). These materials, although not formally classified as waste, are presently stored in Poços de Caldas (UTM) and São Paulo (USIN and Botuxim). In Poços de Caldas there are about 1,200 m^3 of Mesothorium and 7,250 m^3 of Cake II presently stored. In the São Paulo - Interlagos facility (USIN), there are about 39 m^3 of Mesothorium and 325 m^3 of Cake II presently stored and in the Botuxin storage facility (also in the state of São Paulo) there are about 2,190 m^3 of Cake II presently stored (See **H.2.2.2**)

D.3.1.2 - Nuclear Fuel Factory - FCN

The waste volume generated by the fuel element assembly unit and by all other pilot scale fuel cycle facilities is negligible when compared to the above mentioned figures. All the material has been transferred to the licensed low-level-waste initial storage facility, called DIRBA - *Depósito Inicial de Rejeitos de Baixa Atividade* (Low-level Waste Storage Facility), Figure D.2.

Figure D.2 – Low-level waste storage facility (DIRBA) at FCN

D.3.1.3 - Uranium Concentrate Unit - URA

The Uranium Concentrate Unit (URA) project, located at Caetité, in the state of Bahia, adopted as a basic design assumption the minimization of effluent generation. Treatment and containment systems were introduced in order to reduce the residue, waste and effluent generation, thus minimizing the environmental impact of the facility.

The waste management systems were developed with the requirements of preserving the local environment by recycling industrial waters, as much as possible. Mine tailings are piled up on the sides of the hills in a dry condition. The depleted ore is placed together with the mine tailings, using procedures that eliminate or reduce the production of dust. Water consumption is reduced by promoting liquid effluent recycling, thus reducing treatment needs. The sludge resulting from liquid residue treatment is kept in closed tailing ponds equipped with bottom and side drainage, in order to retain solid phase and allow liquid recycling.

The URA facility produces up to 2,100,000 tons/year of mine tail with approximately 0.002% U_3O_8 (cut-off 0.1% U_3O_8) and 180,000 tons/year of leaching ore with approximately 0.05 % U_3O_8 (uranium and the natural uranium series radionuclides). These materials are stored in the unique solid waste deposit. This deposit consists of an area surrounded by channels constructed for keeping rainwater out of the deposit. The rainwater that falls over the deposit is retained in the sediment tank from where it can be pumped to the mill process or to the environment, after monitoring and comparing uranium concentration in water with the predetermined maximum limit for discharge of this liquid effluent. The deposit is constructed in modular way with leaching ore piles surrounded by mine waste rocks. After the end of each module construction, its surface is covered by top soil and is re-vegetated. This construction process permits decommissioning of the solid waste deposit during the same period of mine production.

The mine tailings were located considering that the area has good geological conditions and the component rocks have good mechanical stability. The top soil was removed and retained for further recovery of the site. The area does not have any water source or surface water body. The rain water that percolates the tailing is retained in ponds and is used in the industrial process. The inclination of the side of the hill is less than eighteen percent (18 %), which enhances the efficiency of rainwater drainage

The liquid effluent of the mill is stored in ponds constructed with coverage of high-density plastic sheets with drainage pipes in the bottom were the solid particles of the effluent are separated from the liquid part. This liquid part returns to the mill process and the solid part is kept stored in the pond. After a pond is filled up, the decommissioning process starts. The liquid effluent will be drained and the dry waste will be isolated from the environment. Currently, the Uranium Concentrate Unit produces about 7,200 tons of dry waste per year. At the end of the lifetime of each pond, layers of impermeable material and top soil will cover the pond and the surface will be re-vegetated.

D.4 - NAVY INSTALLATIONS AT SÃO PAULO (CTMSP) AND IPERÓ (CEA)

The volume of waste generated by these activities, which is very small compared to the figures mentioned above, is currently kept at an initial storage.

At CTMSP headquarters, the radioactive waste, consisted mainly of contaminated laboratory material, is transferred to IPEN, situated on a contiguous site.

At CEA, an initial waste storage facility is available in the form of a warehouse. Two hundred and sixteen drums containing about 11,777.9 kg of waste, from LEI, USIDE and LABMAT, are currently stored in the aforementioned facility. These are mainly contaminated materials such as plastic, paper, evaporator sludge and tools (See also **H.2.3**).

A new initial storage facility, having an area of approximately 780 m², dedicated exclusively to store waste from the fuel cycle installations mentioned in **A.2.4**, is being designed at CTMSP. It will be located near USEXA and should be ready by the end of year 2019.

It should be pointed out that LABGENE has its own initial waste storage facility, named Intermediate Storage Building ("*Prédio de Armazenamemto Intermediário de Rejeitos*") - PAIR, which is already built since June of 2012.

D.5 - CNEN INSTITUTES

D.5.1 - IPEN

The Radioactive Waste Management Department (GRR) was formally created in 2003 as a new research centre of the Institute for Energy and Nuclear Research (IPEN), in order to perform research and development, teaching and waste treatment activities in the field of radioactive waste. The GRR 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. For further description, see item **H.2.4.1**.

D.5.2 - CDTN

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**, Table J.5 and Annex 1). In September 2017, 1,560 disused sealed sources; 3,142 lightning rods; 6,763 smoke detectors ^{241}Am sources and 99 packages (200-liter drum) of treated wastes (very low activity) were stored at this facility - DFONTE. The waste occupies 22% of DFONTE and the total activity is 6.34×10^{13} Bq. Furthermore, there were 6 m^3 of untreated waste of very low activity in the interim storage Untreated Waste Storage Facility (DRNT)

The strategy implemented for the management of radioactive waste at CDTN is based on the standard CNEN-NN 8.01 [25] 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.

D.5.3 - IEN

Until 2007, the Nuclear Engineering Institute (IEN) had a small area (120 m^2) 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 m^2 and a net storage area for radioactive waste of 324 m^2. 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.

D.5.4 – CRCN-CO

The Midwest Regional Center for Nuclear Sciences (CRCN-CO) is the CNEN's branch in charge of institutional management of the storage facility that contains the radioactive waste produced during the Cesium-137 accident in 1987 in Goiânia – Goiás. The CRCN-CO provides public information about the situation of the storage and about nuclear science in general.

The only final storage in Brazil, according to the federal law 10.308, operates in an authorized zone, with operational control, since 2002. This area is located in a State Park of Goiás, Telma Ortegal Park, with 1.600.000 m^2. The CRCN-CO area is about 145.514 m^2 -

140.000 m^2 for the storage area and other 5.514 m^2 for facilities, laboratories, research, administration and public visitation).

It has also a very small interim storage facility for radioactive waste collected in the Midwest region. This waste is periodically transferred to CDTN.

D.5.5 –- LAPOC

The Poços de Caldas Laboratory (LAPOC) has built an access-controlled temporary storage with area of 61.6 m^2. All material previously stored in the old deposit (which was cleaned, decontaminated and deactivated) was moved to this new place. The radioactive materials stored at LAPOC were collected in police apprehensions or are residues from research activities carried out in the past (Table D.6).

Table D.6 - Waste stored at LAPOC

RAD	Type of Source	Quant	Total Activity (Bq)	Date of Storage
Th-232	Mesothorium/ residue	825 kg	1.06E+17	1990
U-238	Ammonium uranium oxide $(NH_4)_2U_2O_7$	345 L	1.1E+16	1995
U-238	Ammonium uranium oxide $(NH_4)_2U_2O_7$	37 kg	1.4E+16	1995
U-238/ Th-232	Mineral Uranium Thorianite	2,450 kg	8.5E+13	2007
TOTAL			**1.17E+17**	

Besides those listed above, 9 smoke detectors (Am-241) were received from the local population and are also stored at the same storage facility. Eventually, they are going to be transferred to IPEN Institute in São Paulo.

D.5.6 – CRCN-NE

The radioactive waste storage facility of the Northeast Regional Center for Nuclear Sciences (CRCN-NE) was created in 2005 at the state of Pernambuco with the aim at assisting the North and Northeast regions of Brazil in the receiving and storing sealed sources, radioactive lightning rods and smoke detectors. The facility has approximately 366 m^2.

The facility has a drainage system with central gutter and a collection tank for contaminated water in case of leakage, high strength floor and external walls with 6 meters height to prevent access of particles, objects and animals.

D.6 - WASTE REPOSITORY AT ABADIA DE GOIAS (Closed)

The waste generated in the decontamination process following the radiological accident with a ^{137}Cs medical source in Goiânia is currently stored in a final repository at Abadia de Goiás, a small town circa 23 km from Goiânia. This site was chosen to meet the requirements of the standard CNEN-NE-6.06 [7] for a surface repository. At that site it was conducted an extensive site characterization work to ensure its feasibility in terms of radiological and environmental safety and it was built a complex of facilities needed to ensure the safety and security during its operational stage and the institutional control. To build the complex facilities, an agreement was signed between the Federal and State governments establishing a land granting system which expires each fifteen years (15) and that can be automatically renewed for up to four successive and equal periods.

Approximately 3.500 m^3 of waste were generated, with an estimated overall activity lying between 47.0 TBq (1,270 Ci) and 49.6 TBq (1,340 Ci). The waste was temporarily stored in open-air concrete platforms, occupying an area of about 8.5 x 10^6 m^2 at a site near the village of Abadia de Goiás.

The drums and the metal boxes containing waste were classified into five groups, taking into account the decay period needed for the contents of the package to reach a ^{137}Cs concentration level not greater than 87 Bq/g, as described on Table D.7.

Table D.7 - Waste from Goiânia Accident

GROUP (Time - years)	Number Metallic Boxes	Volume (m^3)	Number of Drums	Volume (m^3)	Storage Activity * (TBq)	Total Volume (m^3)	Current Activity ** (TBq)
I (t=0)	404	686.8	2,710	542	0.06	1,228.80	0.037
II (0 < t < 90)	356	605.2	980	196	0.476	801.20	0.290
III (90 < t < 150)	287	487.9	314	62.8	1,44	550.70	0.877
IV (150< t <300)	275	467.5	217	43.4	13.67	510.90	8.322
V (t > 300)	25	42.5	2	0.4	30	42.90	18.263
Total	1,347	2,289.9	4,223	844.6	45.71	3,134.50	27.827

*NOTE: * Storage Activity: at the time of disposal / ** Current Activity: as of September 2017.*

The following packages were also used in Goiânia:

- 1 metal package for the headstock, with the remaining source (4.4 Tbq and with 3.8 m^3, of Group V);
- 10 ship containers (374 m^3, with 0.4 TBq, from Group I); and
- 8 special concrete packages (1.4 m^3, with 0.7 Bq, from Group V)

According to the IAEA classification, all the radioactive waste collected in Goiânia falls into the category of “low level - short lived” waste and this allows its disposal at shallow depths, in engineered storage facilities. The Group I waste, having specific activities below 87 Bq/g, could actually be exempted from regulatory control – which means that it could effectively have been released into ordinary waste systems. Nevertheless, it was decided to build two repositories in Goiânia: a more simplified one, called Great Capacity Container (Figure D.3 - FRONT) for the disposal of Group I waste (about 40% of the total) and a repository with more elaborate engineered barriers for the disposal of Groups II to V waste, called Goiânia Repository (Figure D.3 - BACK).

Figure D.3 - FRONT: Great Capacity Container; BACK: Repository at Abadia de Goiás

In conclusion, the problem of providing final disposal for the waste generated in the Goiânia Accident is thoroughly addressed. All the waste has been disposed of in two near surface repositories, which have already been closed and with environmental restoration performed. More information on the Environmental Monitoring Program (PMA) for the repository is provided in Section **H.7** of this document.

SECTION E - LEGISLATIVE AND REGULATORY SYSTEM

E.1 - IMPLEMENTING MEASURES (*Article 18*)

The Federal Brazilian Constitution of 1988 establishes the distribution of responsibilities among the Union, the states, the federal district and the municipalities with respect to the protection of the public health and the environment, including the control of radioactive products and installations (Articles 21, 22, 23 and 24). The Federal Government is the sole responsible for nuclear activities related to electric power generation, and also for regulating, licensing and controlling nuclear safety (Articles 21 and 22). The National Commission for Nuclear Energy (CNEN) is the national regulatory body, in accordance with the National Nuclear Energy Policy Act (Law 6189/74).

Furthermore, the constitutional principles regarding protection of the environment (Article 225) require that any installation, which may cause significant environmental impact, shall be subject to environmental impact studies that shall be made public. More specifically, for nuclear facilities, the Federal Constitution (Article 225, paragraph 6) provides that a specific law shall define the site of any new nuclear facility. Therefore, nuclear installations are subject to both a nuclear license by CNEN and an environmental license by the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA), which is the national environmental agency, 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, licensing of these power plants followed slightly different procedures, as will be described in **E.2.2.1**.

Effective separation between the functions of the regulatory organizations (CNEN and IBAMA) and the organization in charge of the promotion and utilization of nuclear energy for electric power generation (Eletrobras Eletronuclear - ETN) is provided by the structure of the Brazilian Government in this area. While CNEN is linked to the Ministry for Science, Technology, Innovations and Communications (MCTIC) and IBAMA is linked to Ministry for Environmental (MMA)**,** ETN is fully owned by ELETROBRAS, a state holding company of the electric system, which is under the Ministry for Mines and Energy (MME), as can be seen in Figure E.1.

Brazil has also signed several international conventions (see Annex **L.2.1**) that, once ratified by the National Congress, become national legislation, and are implemented through detailed CNEN regulations.

As can be noted, Brazil has taken legislative, regulatory and administrative measures to ensure the safety of its nuclear facilities, including spent fuel and radioactive waste facilities.

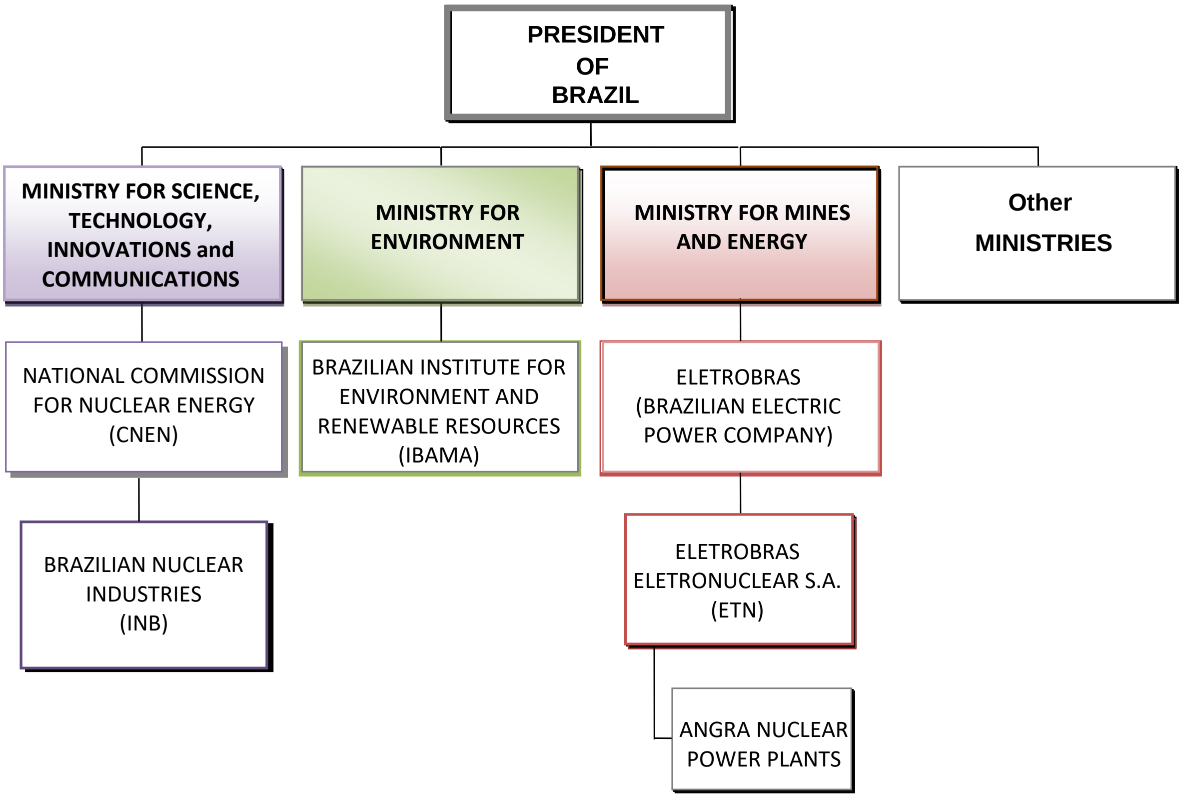

Figure E.1 - Brazilian Organizations Involved in Nuclear Safety

E.2 - LEGISLATIVE AND REGULATORY FRAMEWORK (*Article 19*)

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. A list of relevant Conventions, existing norms and regulations is presented in Annex **L.2**.

Notwithstanding, it should be emphasized once again that the policy adopted in Brazil with regard to spent fuel is to keep it in safe storage until a technical, economic and political decision is reached about reprocessing and recycling the fuel, or disposing of it as such. Therefore, spent fuel is not considered radioactive waste in the sense of this Convention.

As mentioned before, 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 regulation CNEN-NN-8.02 - Licensing of storage and disposal facilities for low- and intermediate-level radioactive waste [26]. 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, the CNEN Norm-NE-6.05 - Radioactive Waste Management in Radioactive Facilities, from 1985, was reviewed and a replaced by a new guide on 30 April 2014 with name of Norm-NN-8.01 - Radioactive Waste Management for Low- and Intermediate-Level Waste [25]. The old guide CNEN NE-6.05 was revoked.

Additional regulations from CNEN related to waste disposal were already in place and are on revision process to be conform to Law 10308. These include the regulations CNEN-NN-6.09 on Acceptance Criteria for Disposal of Low and Intermediate Level Radioactive Waste and CNEN-NN-1.10 [32] from 1980 on safety of waste dam systems containing radionuclides.

E.2.1 - NUCLEAR LICENSING PROCESS

CNEN was created in 1956 (Decree 40110 of 10/10/1956) to be responsible for all nuclear activities in Brazil. Later on, CNEN was re-organized and its responsibilities were established by Law 4118 of 1962 with alterations determined by Laws 6189 of 1974 and 7781 of 1989. Thereafter, CNEN became the Regulatory Body in charge of regulating, licensing and controlling nuclear activities. Since 2000, CNEN has been under the Ministry for Science, Technology, Innovations and Communications (MCTIC).

CNEN responsibilities related to this Convention include, among others:

- the preparation and issuance of regulations on nuclear safety, radiation protection, radioactive waste management, nuclear material control and physical protection;
- receiving, treat, store and dispose of radioactive wastes;
- licensing and authorization of siting, construction, operation and decommissioning of nuclear facilities, what includes storage and disposal facilities for radioactive waste;

- regulatory inspections and audits;
- acting as a national authority for the purpose of implementing international agreements and treaties related to nuclear safety, security and safeguards;
- participating in activities related to the national preparedness and response to nuclear emergencies;

Under this framework, CNEN has issued radiation protection regulations and regulations for the licensing of radioactive installations of medicine, research, industry, nuclear facilities and for licensing of storage and disposal facilities for the low- and intermediate-level radioactive waste. Still regarding radioactive waste, CNEN has issued regulations for management of radioactive waste, siting of waste repositories and acceptance criteria for final disposal of radioactive waste. (see Section **L.2.3** of Annex II for a list related to CNEN regulations).

The licensing regulation CNEN-NE-1.04 [3] establishes that no nuclear installation shall operate without a license. 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 license.

The licensing process is divided in several steps:

- Site Approval;
- Construction License;
- Authorization for Nuclear Material Utilization;
- Authorization for Initial Operation (AOI);
- Authorization for Permanent Operation (AOP);
- Authorization for Decommissioning

Federal Law 9765, approved in 1998, establishes taxes and fees for each individual licensing step, as well as for the routine work of supervision of the installation by CNEN.

For the first step, site selection criteria are established in Resolution CNEN 09/69 [4], 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 adoption of the principle of “proven technology”, the regulation CNEN-NE-1.04 [3] requires for the site approval of a nuclear power plant the adoption of a “reference plant”.

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). The construction is followed closely by a system of regulatory inspections.

For the Authorization for Initial Operation (AOI), CNEN reviews the construction status, the commissioning program including results of pre-operational tests, the final

Physical Protection Plan, updates its review and assessment of facility design based on the information submitted in the Final Safety Analysis Report (FSAR), and authorizes the nuclear material utilization. In case of NPPs, startup is closely followed by CNEN inspectors and hold points are established at different stages.

Authorization for Permanent Operation (AOP) 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 should 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.

Reporting requirements are also established through regulation CNEN-NE-1.14 [5] and CNEN-NN-2.02 [19]. These reports, together with a system of regulatory inspections performed by resident inspectors and headquarters personnel, are the basis for monitoring safety and nuclear material control during operation. Inspection activities are conducted on a permanent basis at the whole Angra site, including its Radioactive Waste Management Center (CGR).

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 Institutional Security Cabinet of the Presidency of the Republic - GSI/PR, with respect to emergency planning aspects.

E.2.1.1 - Licensing of Storage and Disposal Facilities for Radioactive Waste

The licensing regulation CNEN-NN-8.02 [26] establishes general criteria and basic requirements of safety and radioprotection for the licensing of storage and disposal facilities for the low- and intermediate-level radioactive waste. This safety regulation, in compliance with Law 10308 of 2001, furnishes the specific guidelines to the licensing of the storage facilities in Brazil, including the existing ones, as well as to the planned Brazilian repository.

Following the same principles applied to regulation CNEN-NE-1.04 [3], the licensing regulation CNEN-NN-8.02 establishes the necessary assessment process, including the specification of the documentation and its content that must be presented to CNEN at each phase of the licensing process. It also establishes a system of regulatory inspections and audits 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 license.

The licensing process is divided in following steps:

- Site Approval;
- Authorization for Construction;

- Authorization for Operation;
- Authorization for Decommissioning, only for storage facilities (as defined by Law 10308: initial, intermediate; and temporary storage facilities);
- Authorization for Closure, only for disposal facilities.

The site selection criteria are established in regulation CNEN-NE-6.06 - Site Selection for Radioactive Waste Disposal Facilities. The site selection process for radioactive waste repositories requires a series of sequential activities as the identification of regions of interest, of preliminary areas, of potential areas and, finally, of candidate-sites. The selection procedure should take into account four factors: ecological, geological, physiographic and socio-economical. At the end of the process, the applicant must present a comprehensive Report of the Selected Site (RL) to CNEN for approval. This report (RL) should contain the general features about the project and operation of the proposal disposal facility and detailed information on site characterization, with documentation of all data and analytical work, including the preliminary safety assessment performed by the applicant. CNEN will review the results and will also perform an independent safety assessment to decide whether the selected site is suitable for construction of a disposal facility and, consequently, approve it or not.

For the construction authorization, CNEN performs a detailed review and assessment of the information received from the applicant in the Preliminary Safety Analysis Report (PSAR). The construction is followed closely by a system of regulatory inspections and audits and quality assurance.

The Authorization for Operation is issued by CNEN after verification whether the installation construction parameters are in accordance with the PSAR information, after checking the compliance with the waste acceptance criteria established in the regulation CNEN-NN-6.09, and after a complete and detailed assessment of the Final Safety Analysis Report (FSAR). Based on FSAR information, CNEN reviews 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. Furthermore, CNEN will also perform an independent safety assessment to decide whether operation authorization is granted or not.

In the case of the radioactive waste storage facilities which were already in operation in Brazil before the issue of regulation CNEN-NN-8.02 (2014), the facility operators have submitted a Final Safety Analysis Report (FSAR) within the delay of two (2) years as established by the regulation. The reports are currently under assessment by the nuclear regulator – DRSN/CNEN. Notwithstanding, it must be emphasized that these existing storage facilities operate on safety and security conditions and under permanent inspections and audits. They were constructed before Law 10308 of 2001 and, of course, previously the licensing regulation CNEN-NN-8.02. However, despite of not have had a specific licensing process in the past, the licensing of these storage facilities occurred along with the licensing process of the nuclear installations in which they are sited.

E.2.2 - ENVIRONMENTAL LICENSING PROCESS

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 the 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 Brazil’s 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 with the Federal Government. The *nuclear licensing* and the *environmental licensing*[1] processes are independent, parallel, and complementary acts. CNEN, a federal agency, through its 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. IBAMA is responsible for the environmental licensing of any installation with potentially significant socio environmental 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, hydro-geology, 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 (bio-accumulation, 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. 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

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[1] IBAMA is responsible for the Environmental Licensing, as stated in the National Environmental Policy Act, while CNEN is the nuclear regulatory body in accordance with the National Nuclear Energy Legislation.

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.

Transparency is one important requirement for the environmental licensing process. Public participation is ensured by legislation through public hearings prior the issuing the Prior License (CONAMA Resolution 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.

E.2.2.1 - 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 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 around 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.
- 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.
- IBAMA issued the Preliminary License No. 279/08 for Angra-3, in July 2008. In March 2009, after evaluation of compliance of conditions of the Preliminary License Nº 279/08, IBAMA issued the Installation License Nº 591/09 for Angra-3.

- On February of 2016, Eletronuclear presented a new strategy to solve the problem of irradiated fuel storage in the CNAAA – a storage dry unit. Ibama will evaluate the Environmental Studies for this Spent Fuel Complementary Dry Storage Unit - UAS.

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 auxiliary facilities for ten years.

As already mentioned the issuance of the combined environmental operational license 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.

E.2.2.2 - Environmental Licensing of the Repository at Abadia de Goiás

In 1996 IBAMA issued an Installation License to the repository of Abadia de Goiás, facility owned by CNEN. Currently, IBAMA is following up the initial operation of the repository through reports and inspections. An Environmental Plan including air samples, sediments samples, surface water and underground water as well as external radiation doses around the two repositories has been executed every year since its construction. Further details of this environmental plan can be found under item **H** of this report.

This year IBAMA approved the request for Renewal the Operation License of the Repository of Abadia de Goiás.

E.2.2.3 - Other Pre-existing Storage Facilities

Other pre-existing radioactive waste storage facilities that are now also being licensed by IBAMA, are located at IPEN, CDTN and IEN (see **D.5**. and **H.2.4**).

In 2002, IBAMA licensed CDTN facilities, including the Sealed Sources and Treated Waste Storage Facility (DFONTE) (IBAMA Operation License 225/2002, of 8 August 2002). On 28 November 2006 this license was renewed for additional six years. A new license process was performed and the license is now valid until 2018.

Apart of the environmental license (IBAMA) the nuclear regulatory body in Brazil – DRSN/CNEN, is licensing the CDTN storage facility. The Safety Analysis Report (FSAR) for DFONTE is currently under assessment by the regulator (DRSN).

At IPEN, a storage facility with 850 m^2 is divided in two twin sheds, one to receive treated wastes and another to receive untreated wastes. IBAMA has been licensed IPEN installations and the storage facility is included in this process. Regarding the nuclear licensing, the Safety Analysis Report (FSA) is also under assessment by the DRSN.

At IEN, the licensing of the radioactive waste storage facility has come to a halt, as IEN now prepares to propose to IBAMA a new "Conduct Adjustment Term" (*Termo de Ajuste de Conduta* - TAC) which comprises other nuclear installations at the Institute.

E.2.3 - EMERGENGY PREPAREDNESS LEGISLATION

As a result of the publication of the Law 12731 of 21 November 2012, which established additional objectives for the System for Protection of the Brazilian Nuclear Program (SIPRON), the Central Organization for SIPRON (Institutional Security Cabinet of the Presidency of the Republic - GSI/PR) has divided its responsibilities into two areas: safety and security. The Decree 9031 of 12 April 2017 formalized this division with the of the Coordination-General of Nuclear Emergency and the Coordination-General of Nuclear Security.

The SIPRON`s structure includes organizations at the federal, state and municipal levels involved with licensing and control activities as well as those involved with public safety, civil defence, law enforcement and communication to the public. Operators of nuclear installations and facilities and supporting organizations are also part of SIPRON.

Decree 2210 of 1997, which established, among other regulatory aspects of the SIPRON, a Coordination Commission for the Protection of the Brazilian Nuclear Program (COPRON) composed of representatives of the agencies involved, is in the final process of being reviewed in the aftermath of the Law 12731 of 21 November 2012. Besides Eletrobras Eletronuclear (ETN), as the operator, and CNEN, as the nuclear regulatory body, other agencies are involved as supporting organizations of SIPRON, such as the Angra Municipality municipal civil defence, the state of Rio de Janeiro civil defence, the IBAMA, the National Road Authority, the Armed Forces, and the Ministries of Health, External Relations, Justice, Finance, Planning and Budget, Transportation and Communications.

Within SIPRON, the Central Organization issued a set of General Norms for Emergency Response Preparedness [13, 14], consolidating all requirements of related national laws and regulations. These norms establish the planning, the responsibilities of each of the involved organizations and the procedures for the emergency management centers, communications, intelligence and information to the public (SIPRON General Norms are listed in item **L.2.5** of Annex II). Studies are in place to consolidate those Norms into the National Plan for Nuclear Emergency Preparedness and Response.

E.3 - REGULATORY BODY (*Article 20*)

As mentioned in item **E.1.1**, the 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 and radioactive installations. Other governmental bodies are also involved in the licensing process, such as the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA).

E.3.1 - CNEN

CNEN authority is a direct consequence of Law 4118/62, which created CNEN, and its alterations determined by Laws 6189/74 and 7781/89. These laws established that solely CNEN is empowered “to issue regulations, licenses and authorizations related to nuclear installations”, “to inspect licensed installations”, “to enforce laws and its own regulations” and “to receive, store and dispose of radioactive waste”.

The effective separation between the functions of the nuclear regulatory body (CNEN) and the organization in charge of the promotion and utilization of nuclear energy for electric power generation (Eletrobras Eletronuclear - ETN) is ensured by the structure of the Brazilian Government in this area, as mentioned in **E.1**.

The structure of CNEN is presented in Figure E.2. The organizational unit involved with the regulating, licensing and controlling of nuclear activities is the Directorate for Radiation Protection and Nuclear Safety (DRSN). Reviews, assessments and audits are performed by the General Coordination of Nuclear Reactors and Fuel Cycle (CGRC), which is in charge of nuclear power plants, research reactors and fuel cycle installations, and also by the Safeguards and Physical Protection Coordination (COSAP). The General Coordination for Medical and Industrial Installations (CGMI) is in charge for controlling the use of radioisotopes in medicine, industry, research and education, distribution, services and production of radiopharmaceuticals (cyclotrons), beyond the control (transfer, import and export) of radioactive sources and the maintenance of the national inventory of radioactive sources. The Radioactive Waste Division (DIREJ) is responsible for regulating and controlling all activities related to radioactive waste management in Brazil, as well licensing of storage and disposal radwaste facilities**.** The regulations and standards are developed by working groups under the coordination of the Norms Division (DINOR)**.** In the areas of radiation protection and environmental monitoring, Directorate for Radiation Protection and Nuclear Safety (DRSN) may now obtain direct technical support from Institute for Radiation Protection and Dosimetry (IRD) and Poços de Caldas Laboratory (LAPOC), once they were transferred from Directorate for Research and Development (DPD) to DRSN in 2016, details will be explained later.

The Brazilian Government has assured the independency of regulatory activities in the nuclear area, in charge of CNEN, through the effective separation of assignments between its Directorate of Radiation Protection and Nuclear Safety (DRSN) and the Directorate for Research and Development (DPD). As can be seen below in Figure E.2, within the framework of CNEN the Directorate for Radiation Protection and Nuclear Safety (DRSN) is in charge of CNEN’s regulatory functions and does not operate any interim storage facility, nor nuclear or radioactive installation. This allows for the effective separation from the production and promotion activities performed by the Directorate for Research and Development (DPD). Therefore, the activities of receiving, treating, storing and disposing of radioactive waste carried out by the DPD's institutes get the same treatment from DRSN as any other licensee and are subjected to the same rules and regulations as them.

Although it has been assured a functional independency between nuclear regulatory activities and the others as promoting and research and development activities, the Federal Government took the political decision to create an administratively and legally independent nuclear regulatory agency. The reason for this proposal is not a deficiency in the existing regulatory system, but rather a perspective of expansion of the nuclear energy sector. The proposal is based on the existing structure of the Directorate of Radiation Protection and Nuclear Safety (DRSN) of CNEN, adapted to the existing Law for others Regulatory Agencies present in Brazil. The new agency shall be created by a federal law and the proposal was submitted to the concerned Ministries before being sent to the National Congress for public discussion and approval. Nevertheless, due to political changes in Brazil in 2015, many changes have also happened in high governmental and organizational positions. This fact led the new top managers to ask back the draft legislation for a revaluation.

Adequate human resources are provided to CNEN. A total staff of 2,065 people, out of which 66% are technical staff, is available at CNEN and its research institutes. Sixty one percent (61%) of the staff is comprised of university graduates, 18% having a master degree and 21% having a doctoral degree. DRSN had 179 people in its technical staff in 2014, contrasting with the current staff of 495 people in total, where 128 have doctoral degree and 115 master degree, from the remaining staff the majority has college degree, some others are technicians and a minority, around 12%, is administrative support. Actually, after a technical decision the CNEN´s framework has been changed in 2016, and both the Institute for Radiation Protection and Dosimetry (IRD) and the Poços de Caldas Laboratory (LAPOC), which were under the Directorate for Research and Development (DPD), were transferred to the Directorate of Radiation Protection and Nuclear Safety (DRSN). As consequence, the DRSN’s staff increased considerably. These changes were done to meet and fill in a DRSN’s gap in the areas of radiation protection and environmental monitoring. Thus, the DRSN can now work in a completely self-sufficient manner, without requiring the technical support of the DPD’s institutes, which were acting as TSOs to DRSN in the past.

The Radioactive Waste Division (DIREJ) itself comprises 25 people, being 6 with doctoral degree, 6 with master degree, 9 with college degrees, 3 technicians and 1 administrative. The staff qualification and its maintenance has been attained through specific trainings, including both academic training and courses attendance, technical visits, participation in congresses, participation in workshops, training courses and on committee meetings, many of those sponsored by AIEA.

The main activities of Radioactive Waste Division (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.

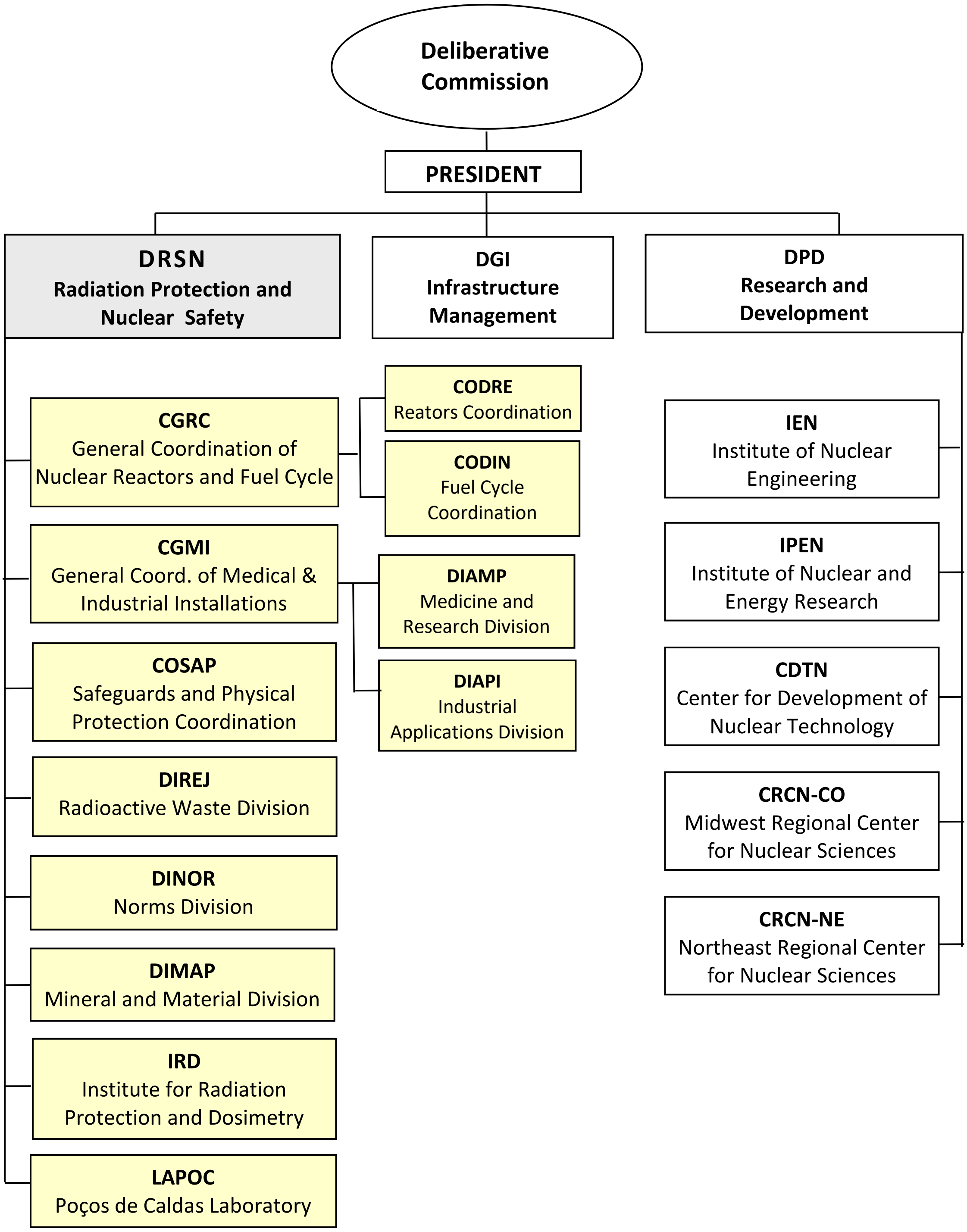


Figure E.2 - Simplified CNEN Organization Chart

DRSN technical staff receives nuclear general training and specific training according to the field of work, including both academic training and course attendance, technical visits, participation in congresses and national and international seminars.

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

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

E.3.2 - IBAMA

The Law 7735 created IBAMA in 1989, which is responsible to implement and enforce the National Environmental Policy (PNMA - Brazilian Law 6938 of 1981). The structure of IBAMA is presented in Figure E.3. 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).

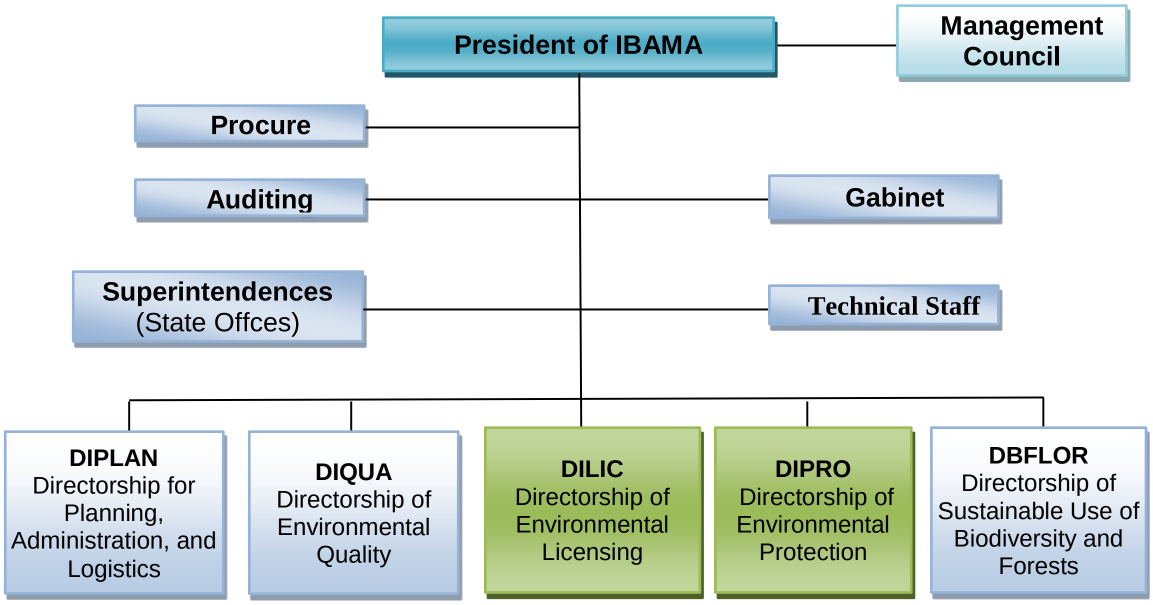


Figure E.3 - IBAMA Structure

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.

Three divisions of the Directorship of Environmental Licensing (DILIC) carry out the environmental licensing of nuclear activities and facilities: the Coordination of Electrical Power, Nuclear and Pipelines (COEND); the Coordination of Mining and Civil Infrastructure Projects (COMOC); and the Coordination of Ports, Airports and Waterways (COPAH). The structure of DILIC is presented in Figure E.4.

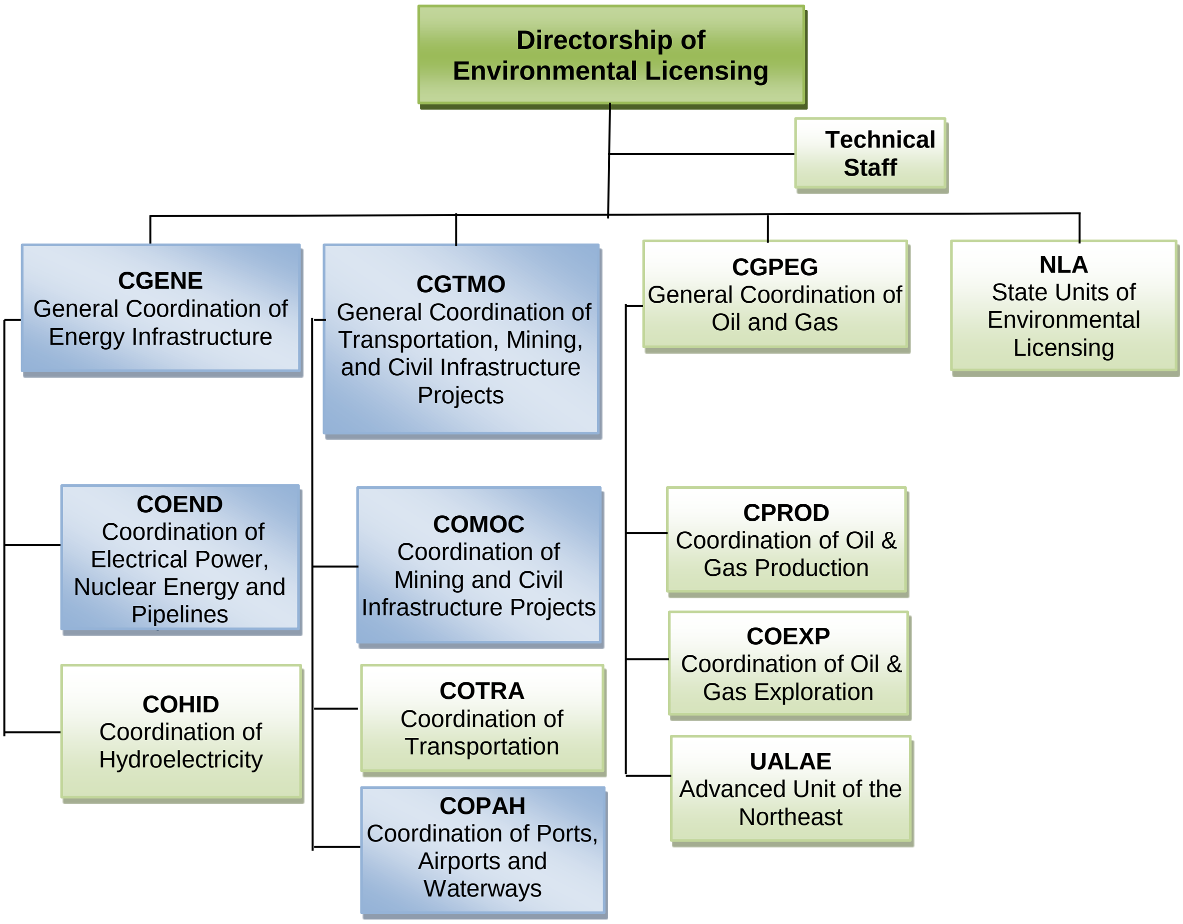


Figure E.4 - DILIC Structure

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

- With respect to Nuclear Fuel Factory, COEND has also unified the environmental licensing of the three units in operation and issued 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 COEND: *i*) COEND 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 *ii*) 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.

COMOC 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 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 issued the Installation License (LI 1057/2015) of the Engenho mine in the site.
- The Ore Treatment Unit of Poços de Caldas (UTM), is currently undergoing decommissioning. COMOC has approved the conceptual project of the unit's decommissioning. INB has yet to present the executive project to be evaluated and approved by COMOC.

COPAH performs the environmental licensing of the Brazil's nuclear submarine. In April 2010, IBAMA issued the LP 351/2010, and In December 2014, IBAMA issued the LI 1031/2014 to this project.

SECTION F - OTHER GENERAL SAFETY PROVISIONS

F.1 - RESPONSIBILITY OF LICENCE HOLDER (*Article 21*)

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 inspections 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 **L.2**.

F.1.1 - NUCLEAR POWER PLANTS

In the case of nuclear power plants, the regulation CNEN-NE-1.26 [8] defines the operating organization as the prime responsible for the safety of a nuclear installation by explicitly stating: "**The operating organization is responsible for the implementation of this regulation.**"

Eletronuclear (ETN), as the owner and operator of the Angra-1 and Angra-2 plants, and Angra-3 (on hold, pending governmental resumption authorization), has issued an Integrated Safety Management Policy stating its commitment to safe operation.

Therefore, its staff commitment to perform all safety-related activities in an integrated manner is essential, laying emphasis upon Nuclear Safety, which includes Quality Assurance and Environmental as well as Occupational Safety, Occupational Health and Physical Protection.

The following principles must be heeded:

1. Nuclear Safety is a priority, precedes productivity and economic aspects and should never be impaired for any reason.
2. Legal requirements and other requirements related to the various integrated safety aspects should be complied with.
3. Personnel and service supplier qualification training should ensure knowledge on the various integrated safety aspects required for proper performance of safety-related work.
4. People health and safety hazards and also environmental impacts should be preventively minimized or eliminated.
5. Communication procedures inside and outside the Company should be transparent and appropriate so that any unsafe condition can be promptly reported.

6. The Company should seek to improve continuously its Integrated Safety Management practices.

For the proper implementation of this safety policy, ETN established a program comprising all levels of the organization that complies with the concept included in the IAEA´s document Safety Series 75, INSAG 4, of the International Nuclear Safety Group (INSAG), in line with the safety objectives and requirements, considering the appropriate management structures, the necessary resources, training, adequate self-assessment, external reviews and human performance programs and tools with good results in the last years.

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-NE-1.14 [5]. In addition, CNEN maintains a group of resident inspectors on the site, who can monitor licensee performance on a daily basis. Finally, a number of regulatory inspections by headquarter staff take place every year, focusing on specific topics or operational events.

F.1.2 - INB FACILITIES

At INB industrial nuclear installations, safety is prioritized in all of its activities, as a basic principle. The oversight organization, CNEN, maintains a program of constant inspections, in addition to the presence of resident inspectors at INB facilities, whose job is to track the operating routine of the units and report any occasional abnormality. Internal audits in the areas of Quality Assurance, Environment and Workplace and Occupational Safety are routinely performed, in order to detect any situation that may represent a potential unsafe operating condition. Additionally, it may be mentioned that INB, in the past, counted on the cooperation of the International Atomic Energy Agency, for the realization of the safety review mission, called project SEDO (Safety Evaluation During Operation), at FCN in 2007, with a follow up mission held in 2010, with valuable results in terms of safety management improvement. INB counted as well as the organization of the IAEA Mission UPSAT (Uranium Production Site Appraisal Team), which took place at URA, also in 2010, achieving the objective of improving the operational and safety performance of the uranium production facility, by means of a peer review based on the IAEA Safety Standards.

Section **F.3.4** presents the FCN’s systems which are certificated in the areas of quality assurance, environment and occupational safety, collaborating with the security system of the company.

F.2 - HUMAN AND FINANCIAL RESOURCES (*Article 22*)

F.2.1 - HUMAN RESOURCES

F.2.1.1 - Nuclear Power Plants

Adequate human resources are available for ELETRONUCLEAR from its own personnel or from contractors. Currently ELETRONUCLEAR has 1,949 employees on its permanent staff which 717 have a university degree, 884 are technicians and the remainder 348 are administrative personnel.

During 2017 the company has been focused on its restructuration, according to holding company alignment. Because of that, some organizational units were extinguished and the employees were distributed in others areas. Another change was the reduction of the number of supervisors and the establishment of a new retirement incentive program. 194 employees joined the retirement program, which the remaining 174 will leave the company throughout the year.

In 2014 was developed an Eletronuclear's Programmed Employees Replacement Plan – PSPE. This Plan is a complementary tool of Human Resources Department constituted by a set of rules and programs that enable the company to ensure a good performance through the succession plan and allows it to reduce the risk of human performance factors arising from unplanned outputs. The PSPE was supported for three projects, being one of them the Substitutes Preparation Program – PPS. The goal to this program was the systematic mapping of the current workforce in order to identify and prepare substitutes.

We present below the steps of PPS.

Step 1
- Mapping of needed compentences (CHAs) which are likely to be developed in the context of the PPS

Step 2
- Planning of training, development and education related to PPS

Step 3
- Implementation of educational actions

Step 4
- Evaluation of actions of Qualification, development and education and indication of other actions to be developed under the scope of PPS

Step 5
- Eletronuclear Training, Development and Education Management Model

The Human Performance Program was implemented in 2007 and since then, it has been increasing in terms of actions and areas. The Human Performance Program can be considered a key role in terms of reinforcement of safety culture in the company. 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.

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 movement 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 professional, to provide uniform guidance related to Human Performance.

A summary of the main activities from this program is 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.
- Application of Team Work Training for operator for some areas of the company. This training was structured to develop skills and attitudes for a good relationship, communication and integration of the team.

Since 2011, the psychologist staff of Eletronuclear has been effectively included in the root-cause analysis group working at the plants Angra 1 and Angra 2 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 2016, the psychologists analyzed 119 events from Angra 1 and Angra 2.

Activities related to qualification, training and retraining of plant personnel are performed by the Training and Simulator Department of ETN which reports to the Site Superintendent. Four main areas exist at the training facilities, close to the site:

- General Training Center
- Angra-2 Simulator Training Center
- Maintenance Training Center
- Angra-1 Simulator Training Center

The construction of two new blocks (~700 m^2) for practical radiation protection training, 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 was completed in end of 2010.

A new building for housing the new Angra-1 simulator was completed in August 2014. Angra-1 simulator Site Acceptance Test (SAT) and Availability Tests were completed in November 2014 and February 2015, respectively.

Due to the additional activities of training of instructors in the operation of the simulator and preparation and running of the simulator training, this simulator started to be effectively used for training in June 2015.

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.

A contract for a major software and hardware upgrade was signed in mid-2009 to improve the simulator capabilities. The work involved substitution of the computers and of the old operational system, provision of a new instructors station with modern features, review of the models programming language and provision of new models for the core, primary system and containment. This upgrade took longer than expected and was finally completed by end of 2012 after a long verification and validation period.

A third simulator, for the Angra-3 plant, presently under construction, is intended to be acquired. Technical specification for this simulator, which will feature the same digital instrumentation to be installed in the Plant, is almost completed and ETN is waiting for government definition to restart Angra-3 Project.

Future Angra-3 operators are being trained in the Angra-2 simulator taking advantage of the similarity between the Angra-2 and 3 plants. These operators will be licensed for Angra-2 so that they will be able to acquire 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 digital control room, which is the most important difference between the two plants.

The requirements for organization and qualification of the entire 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. Licensing of new operators has to comply with the regulations CNEN NN 1.01 [5] and NE-1.06 [10].

Specialized training is also provided for the different groups of plant personnel, as listed below:

- Maintenance and Chemistry personnel follow an extensive qualification program established in the Plant Operations Manual, which is subject to CNEN audits.

- Radiological Protection technicians, the Fire Brigade and Security personnel follow an extensive qualification program based on CNEN regulations, which is also subject to CNEN audits.

A detailed training program for the Angra-3 future staff was developed in 2008, as well as the planning for the needed training infrastructure. Hiring of personnel has started in beginning of 2009 followed by the implementation of the referred training program. About about 266 new employees performed initial training and are in practical training at the plants. The training duration was dependent on the specific position to be occupied by the trainee, varying from 1-2 month up to 2 years for licensed operators.

Beyond 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. 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 their areas and Operations.

Technical Exchange Visits and Reviews of the training program and training center by experts from the International Atomic Energy Agency, the Institute of Nuclear Power Operations (INPO) and the World Association of Nuclear Operators (WANO) have provided valuable contribution to the identification and implementation of good practices for enhancing the quality of the training activities.

A total of 36 qualified personnel are directly involved in waste and spent fuel management, as described in the Table F.1.

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.

Table F.1 - Personnel involved in spent fuel and radioactive waste management at Angra-1 and Angra-2 NPPs

Qualification	Quantity	Education
Radiological Protection Supervisor	4	University degree
Senior Reactor Operator	2	University degree
Nuclear Physicist	2	University degree
Nuclear Engineer	4	University degree
Engineering Support	1	University degree
Operators	7	Technical degree
Radiological Protection Technician	6	Technical degree
Auxiliary Technician	10	Secondary

Radiation Protection Supervisor certification is done in accordance with regulation CNEN-NN-7.01 “Certification of the Qualification of Radiation Protection Supervisors” [9]. There are seven Radiation Protection Supervisors qualified for Angra-1 and Angra-2, and four qualified for Waste Management. Other four Radiation Protection Supervisors are qualified for the Environmental Monitoring Laboratory.

F.2.1.2 - INB Facilities

Activities related to training planning and management are a shared responsibility between the Personnel Assignment and Training sections. Three main employee qualification events are normally undertaken:

Compulsory Courses: Training programs essential to performing a specific task. The participation on such courses is mandatory, as a consequence of the requirements of control, oversight and licensing bodies.

Education Scholarships: Masters Degree, undergraduate and graduate training programs, and foreign language courses. The application of the knowledge acquired in these courses is expected to contribute to improving employee's job performance and the company's results.

Nonregular courses: Other personnel training programs as deemed necessary to improve employee's professional performance and the company's results.

At present, INB has a total of approximately 1,400 employees. Table F.2 shows INB regular workforce by location at each of the company units.

Table F.2 - INB personnel – regular workforce by location

Location	University degree	Technical degree	Secondary	Primary	Total
Resende, RJ	330	125	233	38	726
Rio de Janeiro, RJ	104	5	43	12	164
Caetité, BA	72	74	124	7	270
Buena, RJ	8	11	15	37	71
Caldas, MG	31	39	16	8	94
São Paulo, SP	3	1	2	2	8
Fortaleza, CE	3	0	0	1	4
Santa Quitéria, CE	0	0	0	2	2
Total	551	255	433	107	1346
Percentage	40,94%	18,95%	32,17%	7,95%	100%

Tables F.3 to F.6 show the qualification of INB personnel directly involved with radioactive waste management at INB's facilities: Caetité (URA), Caldas (UTM), Buena (UMP) and São Paulo (USIN/ BOTUXIM), and Resende (FCN).

Table F.3 - INB personnel involved in radioactive waste management at Caetité (URA)

Qualification	Quantity	Education
Radiological Protection Supervisor	3	University degree
Engineering Support	1	University degree
Radiological Protection Technicians	2	Technical degree
Auxiliary Technicians	3	Secondary

Table F.4 - INB personnel involved in radioactive waste management at Caldas (UTM)

Qualification	Quantity	Education
Radiological Protection Supervisor	4	University degree
Engineering Support	3	University degree
Radiological Protection Technicians	13	Technical degree

Table F.5 - INB personnel involved in radioactive waste management at Buena (UMP) and São Paulo USIN / BOTUXIM sites

Qualification	Quantity	Education
Radiological Protection Supervisor	3	University degree
Radiological Protection Technicians	4	Technical degree
Auxiliary Technicians	1	Secondary

Table F.6 - INB Personnel involved in radioactive waste management at Resende (FCN)

Qualification	Quantity	Education
Radiological Protection Supervisor	4	University degree
Engineering Support	4	University degree
Radiological Protection Technicians	19	Technical degree

Certification of radiation protection supervisors is done in accordance with the regulation CNEN–NN-7.01 "Certification of the Qualification of Radiation Protection Supervisors" [9].

F.2.1.3 - Other Installations

All nuclear or radioactive installations licensed by CNEN must have a certified Radiation Protection Supervisor, authorized in accordance with regulation CNEN-NN-7.01 [9]. The regulation requires different qualification for each different type of installation.

Besides that, sufficient qualified staff should be available for handling radioactive waste. For instance, at IPEN, the staff of the radioactive waste unit is shown on Table F.7, together with the spent fuel management staff.

Table F.7 - Personnel involved in spent fuel and radioactive waste management at IPEN

Qualification	Quantity	Education
Radiological Protection Supervisor	2	University degree
Senior Reactor Operator	7	University degree
Physicist	2	University degree
Chemist	4	University degree
Nuclear Engineer	4	University degree
Engineering Support	4	University degree
Operators	14	Technical degree
Radiological Protection Technicians	1	Technical degree
Auxiliary Technicians	5	Secondary

At CDTN a total of 19 qualified people are directly involved in waste and spent fuel management. Table F.8 shows the profile of the CDTN staff that is involved on the waste and spent fuel management activities. Among them, four have doctoral degrees and seven have master degrees.

Table F.8 - Personnel involved in spent fuel and radioactive waste management at CDTN

Qualification	Quantity	Education
Radiological Protection Supervisor	2	University degree
Senior Reactor Operator	3	University degree
Senior Reactor Operator	2	Technical degree
Engineering	4	University degree
Radioactive Waste Technicians	5	Technical degree
Radiological Protection Technicians	2	Technical degree
Administrative	1	Secondary

At CDTN, all the staff that works with radioactive waste management received training in Brazil and abroad in this subject. They are trained to work with administrative and technical activities. Specialized internal and external training is available for the whole staff, including radiation protection and safety courses. Technical visits, courses and meetings are included in this training, and the majority of the staff has had some training in other countries, through IAEA and CNPq (Brazilian Research and Development Council) programs.

At IEN, 9 people are involved in waste management and radiation protection. Table F.9 shows the profile of the IEN staff that is involved on the waste and spent fuel management activities.

Table F.9 - Personnel involved in spent fuel and radioactive waste management at IEN

Qualification	Quantity	Education
Senior Reactor Operator	1	University degree
Radioactive Waste Technicians	2	Technical degree
Radiological Protection Technicians	2	Technical degree
Reactor Operator	3	University degree
Chemist	1	University degree

As presented in Table F.10, the Midwest Regional Center for Nuclear Sciences (CRCN-CO) has 22 employees in its current staff; being 8 of them directly involved with radioactive waste management activities and with the Radiological Environmental Monitoring Program (PMRA).

Table F.10- Personnel involved in radioactive waste management and execution of the Radiological Monitoring Environment Program (PMRA) at CRCN-CO

Qualification	Quantity	Education
Radiological Protection Supervisor	1	University degree
Operators	1	University degree
Operators	2	Technical degree
Radiological Protection Technicians	2	University degree
Operators	2	University degree

At Northeast Regional Center for Nuclear Sciences (CRCN-NE) a total of 7 qualified people are directly involved in waste management. Table F.11 shows the profile of the CRCN-NE staff involved on the waste management activities. Among them, two have doctoral degrees, two master degrees and three have the graduate degrees.

Table F.11 - Personnel involved in radioactive waste management at CRCN-NE

Qualification	Quantity	Education
Radiological Protection Supervisor	2	University degree
Radioactive Waste Technicians, Radiological Protection Technicians and Operator	5	University degree

F.2.2 - FINANCIAL RESOURCES

F.2.2.1 - Nuclear Power Plants

As a state-owned company, Eletrobras Eletronuclear has its financial situation subjected to the holding company ELETROBRAS, which manages all federal electric facilities in Brazil.

The sale of energy produced by nuclear power plants Angra-1 and Angra-2 (1,885 MWe of net installed capacity) was amended by Law 12111 and regulated by Normative Resolution No. 530 from December 21th, 2012. Under this Normative Resolution, the National Electric Energy Agency has established through the Chamber of Electric Energy Commercialization the Selling Contract of Nuclear Energy of Angra 1 and 2 nuclear power plants. This contractual change is effective since January 1st, 2013 and sets the mandatory purchase of the generated energy by all concessionaires for public distribution service of the National Interconnected System. The tariff value in January-December 2013 amounted to R$ 135.69/MWh (~68 US$/MWhr, in January 2013). The National Electric Energy Agency approved for the year 2017 the tariff value for sale of power from Angra 1 and Angra 2 in the amount of R$ 224.21/MWh (~72 US$/MWhr, in January 2017).

Adequate funds are made available through annual budgets, which include the waste management program. For illustration purposes, the 2017 ETN budget for the waste management program is estimated in about R$ 62,9 million (~US$ 20 million, in January 2017).

The provision of funds for decommissioning activities is obtained from ratepayers, and is included in the tariff structure, during the same period of depreciation of the plant (3.3%/year). For Angra-1, presently, a reference decommissioning cost of 431 million dollars is estimated. For Angra-2 the decommissioning costs are estimated in about 529 million dollars, in Dec 2013.

F.2.2.2 - Nuclear Fuel Cycle Plants

Brazilian Nuclear Industries (INB) is a mixed-economy company (state and privately-owned), under the share control of CNEN and linked to the Ministry for Science, Technology, Innovation and Communications (MCTIC). INB is in charge of conducting the monopoly of the Union in the nuclear fuel cycle area that covers the stages from the uranium mining to the manufacturing of the fuel elements used in the Angra-1, Angra-2 and, in the future, Angra-3 nuclear power plants.

The company headquarters is located in the city of Rio de Janeiro. There are regional offices in the cities São Paulo and Fortaleza, as well as industrial installations located in the following places:

- Caetité, state of Bahia: the Uranium Concentrate Unit (URA) is in operation. At URA, the uranium ore is extracted and processed for the production of uranium concentrate (U_3O_8);
- Resende, state do Rio de Janeiro: the Nuclear Fuel Factory (FCN) comprises: manufacturing of components and assembly of fuel elements, uranium enrichment plant (seven cascades in operation), conversion of UF_6 to UO_2 powder and UO_2 pellets manufacturing;
- Buena, in the state of Rio de Janeiro: the Heavy Minerals Processing Unit (UMP) is in operation. This activity is not associated to the nuclear fuel cycle, but it is where the following minerals are extracted: zirconite, rutile, ilmenite and monazite;
- Caldas, in the state of Minas Gerais: the first uranium mine of Brazil, along with the mill facility called Ore Treatment Unit (UTM). The industrial activities at the site have been discontinued because they ceased to be economically viable. Currently, decommissioning and environmental remediation are being developed;
- City of São Paulo, in the state of São Paulo: the facility USIN is a waste storage of residues from the chemical processing of monazite sands. This site has some degree of contamination in its soil with monazite sands. In 2010, the work of decontamination of the soil was initiated and in 2012 a partial area with 18,400 square meters was decontaminated. In 2013, CNEN made a final characterization of this area and confirmed that the area can be used unrestrictedly,
- Itu City, in the state of São Paulo: there is the waste storage facility of Botuxim.

Operational Revenue:

- The company's main client is Eletronuclear (ETN), operator of the nuclear power plants Angra-1 and Angra-2, and responsible for the construction of Angra-3, currently in progress;
- Gross revenue from the sale of goods and services comprises the revenue relative to the contracts of *i*) uranium concentrate, *ii*) conversion, enrichment and management and *iii*) fuel element manufacturing, signed with ETN for the reloads of Angra-1 and Angra-2, as well as the sale of products of the Heavy Minerals Unit – Buena.

Budget resources of the National Treasury - resources of the tax budget of the Union, passed on by the National Treasury Secretariat, intended for payment of expenses with personnel (salaries, benefits and labor sentences).

F.2.2.3 - Other Installations

At all CNEN's institutes the funds for the spent fuel and waste management come from the general budget that is provided by the Ministry for Science, Technology Innovations and Communications (MCTIC). At CDTN, some additional funds come from the FAPEMIG (Minas Gerais State Foundation for Research Support), FINEP (Research and Projects Financing), CNPq (National Council for Scientific and Technological Development) and other governmental Institutions, through special projects. In addition of that, funds were provided from the US and Canada – respectively through the National Nuclear Security Administration, NNSA, and the Department of Foreign Affairs, Trade and Development, DFATD – to carry out the operation to remove from the Brazilian territory disused high activity sources.

F.3 - QUALITY ASSURANCE (*Article 23*)

The requirement for a quality assurance program in any nuclear installation project in Brazil is established in the licensing regulation CNEN-NE-1.04 - Licensing of Nuclear Installations [3]. Specific requirements for the programs are established in a specific regulation, Quality Assurance for Safety in Nuclear Power Plants and Other Installations, CNEN-NN-1.16 [10], which is based on the IAEA code of practice 50-C-QA Rev.1 - Quality Assurance for Nuclear Power Plants, but with the introduction of the concept of an Independent Technical Supervisory Organization (OSTI) [11].

F.3.1 - NUCLEAR POWER PLANTS

Eletrobras Eletronuclear (ETN) has established its quality assurance program in accordance with the requirements mentioned above. The corresponding procedures have been developed and are in use. The program provides the control of the activities influencing the quality of items and services important to safety. These activities include both spent fuel storage and radioactive waste management. Quality assurance programs are described in Chapter 17 of the FSAR.

The Quality and Environment Superintendency (SQ.T), reports to the Technical Directorate (DT) and is responsible for the establishment and supervision of the ETN 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. During the period of January 2015 through July 2017, 115 external audits and 63 internal audits were conducted.

Audits and inspections 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. During the period of January 2015 through July 2017, CNEN conducted 48 audits or regulatory inspections in Angra 1, 2 and 3.

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 analyze 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.

F.3.2 - CNEN INSTALLATIONS

CNEN has also established its own Nuclear Safety Policy [17] and Quality Assurance Policy [18]. Under these policies, all units have to establish their own quality assurance system.

Besides, some units which are involved with industrial production have been independently certified by external organizations, such as the ISO 9000 certification obtained in 2002 by IPEN for its 4 centres: Cyclotron Accelerator Centre, Nuclear Engineering Centre, Radiopharmacy Centre and Research Reactor Centre.

As another example, the Radioactive Waste Management Program of CDTN is also subject to Quality Assurance procedures. The Quality Assurance (QA) System is divided in two parts. The first one contains CDTN's QA Manual, with the general policies and nine general procedures. The second part comprises the specific QA Manuals for the laboratories and special services. They are in force within the scope of the Program, establishing the applicable standards and the responsibilities for the different sections of the Institute involved. The Radioactive Waste Management Program describes the responsibilities and the main orientation for all personnel involved with the waste. The operational activities are specified in twenty specific procedures, such as waste segregation, collection, treatment and tests for waste product quality assessment. In 2016 the CDTN's Radiological Protection Section promoted a Radioprotection Course to updating all CDTN's staff with the best practices, including Waste Management and all the documents involving the Quality Assurance System.

In the last 3 years IEN has established technical procedures associated with the waste management of its installation, in particular those associated with the safety of the radioactive waste. Although there are not so many people involved in the management of radioactive waste in IEN, the staff has established several procedures with the aim of improve the management standards already in use.

In 2014 CRCN-NE started to develop its own Radioactive Waste Management Program and the implementation of Quality Assurance procedures aiming to meet the CNEN regulations requirements. At the moment, the group involved in radioactive waste management are working on the elaboration and revision of standard operational procedures, on the characterization of sealed sources, and implementation of a new software to control the entries of new sources and do the inventory of the whole source deposit

F.3.3 - QUALITY ASSURANCE AT NAVY INSTALLATIONS

The quality required by the projects developed at the Navy Technological Center in São Paulo (CTMSP) has been assured by the application of procedures and instructions prescribed by a Quality Management System, since the beginning of the activities, in accordance with Standard CNEN- NN-1.16 – Quality Assurance for Safety of Nuclear Power Plants and Other Installations [10], applicable during the lifetime of the installation, including: siting, design, construction, commissioning, operation and decommissioning. For the stages of commissioning and operation of the nuclear facilities, the requirements of CNEN-NN-1.16 are complementary to those of the Standard CNEN-NE-1.26 - Operational Safety of Nuclear Power Plants [24].

Within the CTMSP organizational structure, the Quality and Nuclear Safety Superintendence, directly subordinated to the Director, is responsible for the Quality Management System, being independent of all other organizational sectors of CTMSP.

F.3.4 - QUALITY ASSURANCE AT INB FACILITIES

According to the requirements of the standard CNEN-NN-1.16 [10], INB systematically submits to CNEN updates of the Quality Assurance Program Procedures (PGQ) for its facilities.

In 1996, the company implemented and certified, per NBR ISO 9001 Standard, the Quality Assurance System for the Nuclear Fuel Factory at Resende. Subsequently, in 2007, by adopting management standards NBR ISO 14001 and OHSAS 18001, INB expanded the scope of certifications in the areas of environment and occupational safety, respectively, through its Integrated Management System - SIG. The unit was re-certified in 2015 by a team of BR TÜV (company responsible for the certification of nuclear facilities in Brazil).

It is worth noting that the requirements of the referred standards, besides being in line with CNEN-NN-1.16, prioritizes customer satisfaction, management responsibility, process control and the use of quality indicators with pre-established targets.

The greatest advantage of adopting such standards through an integrated management system at the FCN consists in the fact that the company controls and continually improves its processes for activities pertaining to nuclear safety, quality, environment, safety, health and physical protection.

Other units of INB operate with the Quality Assurance System on the basis of CNEN-NN-1.16 standard, with particular focus on nuclear safety.

F.4 - OPERATIONAL RADIATION PROTECTION (*Article 24*)

Radiation protection requirements and dose limits are established in Brazil in the standard CNEN-NN-3.01 - Radiation Protection Directives [12]. This regulation requires that doses to the public and to the workers be kept below established limits and as low as reasonably achievable (ALARA).

Implementation of this regulation is performed by developing the basic plant design in accordance with the ALARA principle and by establishing a Health Physics Program at each installation. The plant design is assessed by the regulator at the time of the licensing review by evaluating the dose records during normal operation.

The Role of CNEN

Regulation CNEN-NN-3.01 [12], of July 2005, is the primary regulatory standard with which all practices have to comply. The main aspects regarding radiation protection and discharge requirements are as follows:

- Controls are established in terms of effective dose for all nuclear facilities on an annual basis, considering 12 consecutive months;
- The primary annual dose limit to members of the public is 1 mSv effective dose applied to all practices during all their life stages, i.e., past, present and future;
- For each single justified practice, the discharges should not reach activity concentrations that exceed the maximum authorized annual limit of 0.3 mSv to the critical group, taking into account all exposures pathways and all radionuclides present in the effluents. The assessment shall consider conservative hypotheses. This limit is intended to be applied during the licensing stage and used as a ceiling in the optimization process;
- Under normal operation conditions, the demonstration of optimization may be exempt provided that the following criteria are met:
  - an effective dose to workers less than 1 mSv/y;
  - an effective dose to public less than 10 µSv/y;
  - a collective effective dose less than 1 man.Sv/y.

The dose constraint is used to establish upper operational levels of activity concentration for effluent discharges to the environment. There are two ways of establishing such levels:

- The operator proposes the upper levels, based on environmental modelling during the licensing. The whole process is verified and approved by the regulatory body.
- In cases where the procedure is not presented or is not accepted, the regulatory body establishes these levels.

In both cases, CNEN performs an independent assessment to establish or approve upper levels for effluent discharges to the environment. The procedure used is based on the critical group approach and follows the model proposed by IAEA as described in Safety Series 57, adapted to the local conditions and the uses of the environment. The definition of the critical group follows the recommendations of ICRP Publication 43.

To the extent possible, local data are used in the model. These data are assessed from licensing documentation provided by the operator, including those from the Environmental Impact Report (RIMA) provided to IBAMA.

Basic controls for effluent releases required by the regulation CNEN-NN-3.01 - Radiation Protection Directives [12] include:

- Nuclear installations that release radioactive effluents into the environment should make use of internal and external monitoring and control systems;
- All radioactive material discharged to the environment should be analyzed, accounted for and registered;
- Periodic inspections are carried out by the regulatory authority, in order to verify compliance with the standards;

CNEN regulation NE-1.04 - Licensing of Nuclear Installations [3] also requires the establishment of basic controls such as:

- The installation must provide systems to control and limit radioactive releases into air and water;
- Technical specifications related to the release limits and monitoring of radioactive effluents must be approved by CNEN;
- The operator must establish and carry out appropriate monitoring programs;
- Documented management systems are required to ensure compliance with authorization conditions;
- Effluents release accounting, dose calculation, environmental monitoring and the amount of disposed waste shall be registered and made available for further inspections;
- Operational reports that shall be provided by the operator according to regulation CNEN-NE 1.14 [5] include:
    - Monthly historical operation report;
    - Semi-annual Effluents Release Report;
    - Dose Assessments to the Critical Group;
    - Annual Environmental Monitoring Program Report – Impact Evaluation;
    - Unusual Events Report.

From 2007 to 2016 the Institute for Radiation Protection and Dosimetry (IRD/CNEN) did not belong to DRSN’s structure and, consequently, during this period IRD did not perform regulatory inspections on the Brazilian radioactive and nuclear installations. Actually, during this period, IRD worked as a technical support organization (TSO) to the Directorate for Radiation Protection and Nuclear Safety (DRSN). However, as mentioned in E.3.1, IRD was moved on from the Directorate for Research and Development (DPD) to DRSN in 2016, which allows IRD to perform assessments of the radiological protection aspects directly to DRSN, including assessments of licensing documents, such as safety analysis reports and operational documents such as radiation protection plans, monitoring programs and operational procedures.

F.4.1 - NUCLEAR POWER PLANTS

The Health Physics Program of Angra-1 and Angra-2, included in Chapter 12 of the Final Safety Analysis Reports, sets forth the philosophy and basic policy for radiation protection during operation. The general policy is to maintain radiation exposure of the workers below the limits established by CNEN and to keep exposures as low as reasonably achievable (ALARA), taking into account technical and economic considerations.

The administrative annual dose limits to workers are 20 mSv for effective dose in a single year, 15 mSv averaged over five years, and 400 mSv for dose equivalent for individual organs and tissues, except in the case of the eye lens, for which the limits are 20 mSv in a single year and 15 mSv averaged over five years. For pregnant women, the limit is reduced to 1 mSv for the entire pregnancy period. Pregnant or breastfeeding condition women, they shall not work inside controlled areas.

The actual personnel radiation doses for workers at Angra Nuclear Power Plants are much lower than the established limits. The dose distribution for workers at the Angra site demonstrates an adequate radiological protection program, with more than 90% of the occurrences of the year 2016 in the dose range of less than 1 mSv, which is the dose limit for the individual members of the public. Dose distributions for the year 2016 are presented in Figures F.1 and F.2. The collective doses over the past recent years are shown in Figures F.3 and F.4.

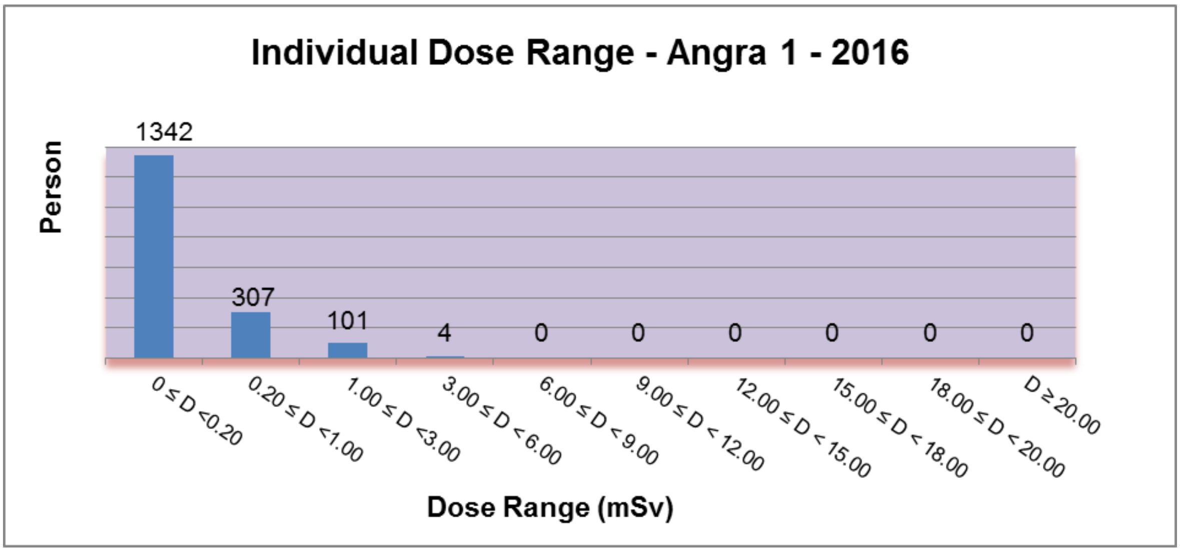


Figure F.1 - Individual Dose in Angra-1

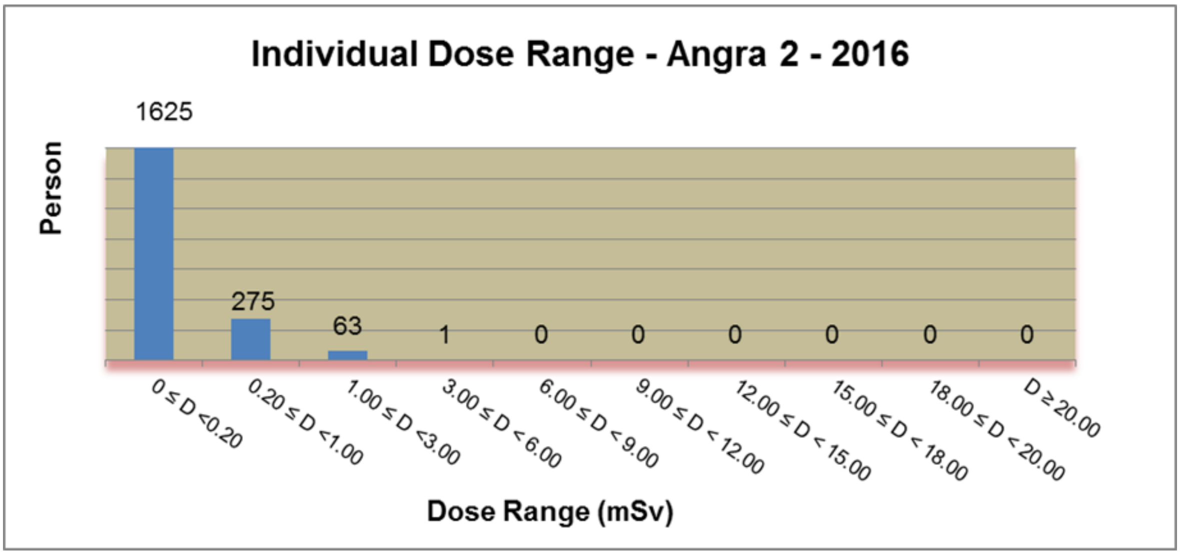


Figure F.2 - Individual Dose in Angra-2

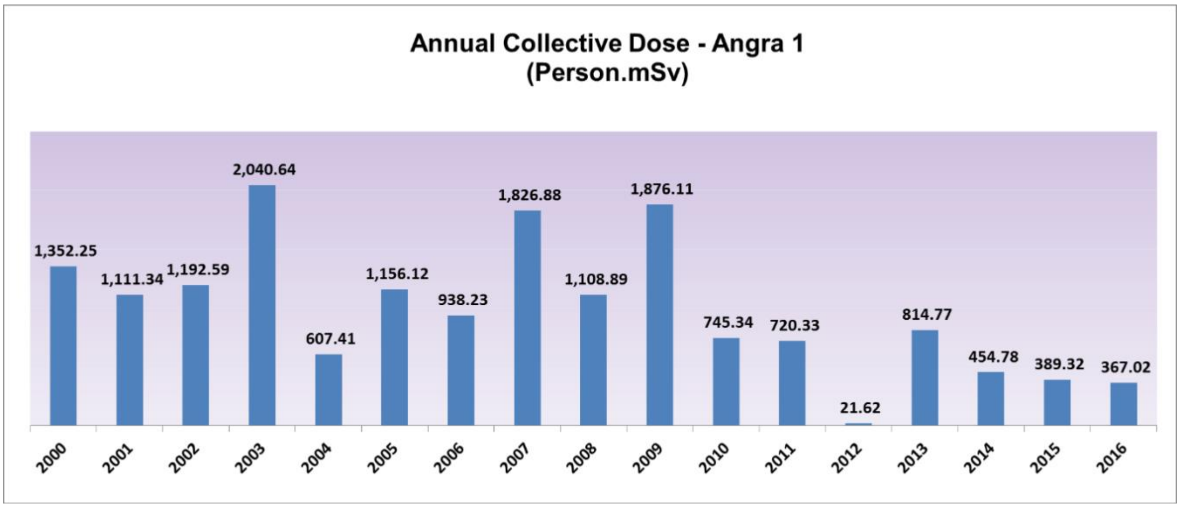


Figure F.3 - Collective Dose in Angra-1

Obs: In 2013 Angra-1 replaced the reactor vessel head, which caused an increase of manpower and respectively collective dose for the year.

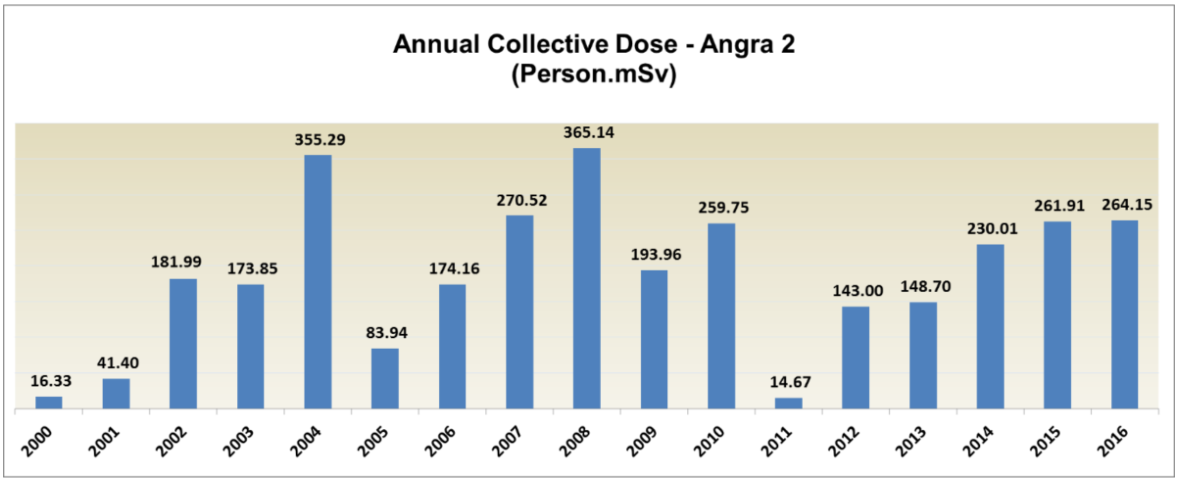


Figure F.4 - Collective Dose in Angra-2

The release of radioactive material to the environment is controlled by administrative procedures and is kept below the limits established by CNEN. Additionally, the amount of radioactive waste and the radioactive effluents discharged to the environment also follow the ALARA principle.

The effluent limits are in accordance with the reference levels 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 CNEN regulation [5], a report of solid waste and effluents is issued every semester, documenting the liquid and gaseous effluents (reporting the present radionuclides and concentration) and solid waste quantity sent to the on-site storage facility. Also, the effective dose for the critical individual is presented. In 2016, this dose reached a value of 1.65×10^{-3}mSv for Angra-2 operation and a value of 4.76×10^{-4} mSv for Angra-1 operation, which are much lower than the 1.0 mSv/year value established in regulation CNEN-NN-3.01 [12].

An ALARA Commission for the plant, composed of different groups (Operation, Maintenance, Chemistry, System Engineering and Radiation 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.

A Radiological Environmental Monitoring Program, based on CNEN requirements, is conducted by ETN to evaluate the possible impacts caused by nuclear power plants operation. This program defines the frequency, places, types of samples and types of analyses for the assessment of possible contamination and exposure rates. The evaluation of exposure rates is 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 programme are compared with the pre-operational measurements taken, in order to evaluate any possible environmental impact.

Annual reports are presented to CNEN. Until the present date, no impact has been detected.

IBAMA also monitors the impact of the plants on the environment through a system of inspections in which the Rio de Janeiro State Institute for Environment (INEA), previously called State Foundation for Environmental Engineering (FEEMA), and the City Administration of Angra dos Reis also participate.

Typical results of the monitoring program are presented in Figure F.5.

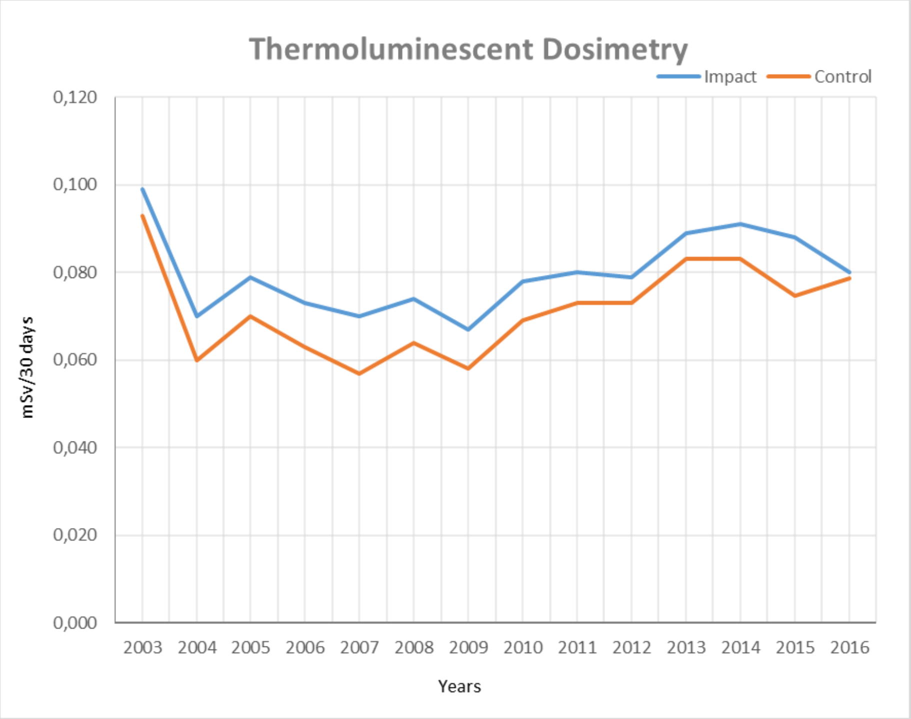


Figure F.5 - Environmental Monitoring Program Results for 2003-2016

F.4.2 - INB FACILITIES

The primary purpose of the Radiation Protection Program is to keep the radiation exposure of the workers as low as reasonably achievable (ALARA).

All occupationally exposed individuals in the supervised and controlled areas are monitored by means of individual dosimeters (TLD badges). The dosimeters are supplied by a laboratory duly certified by CNEN and are changed on a monthly basis. Individuals not exposed occupationally are monitored with prompt reading dosimeters when they access the supervised and controlled areas.

All occupationally exposed individuals attend radiation protection, emergency preparedness, first aid, and industrial safety training sessions on a yearly basis.

For occupational exposure, the legal primary dose limits for occupational exposures are an effective dose of 20 mSv per year, averaged over five consecutive years, provided an effective dose of 50 mSv is not surpassed in any single year. For public exposures, the dose limit is an effective dose of 1 mSv in a year.

The main monitoring method used for internal dose calculation is the determination of uranium concentration in urine and faeces of the occupationally exposed individuals. The uranium excretion fractions are those published by International Commission on Radiological Protection (ICRP) - Individual Monitoring for Internal Exposure of Workers - ICRP 78 (1997) and the uranium dose conversion factors are extracted from the CNEN-NN-3.01 Standard [12].

In order to achieve effectiveness in the radiological control, all the radiometric data is classified according to pre-established reference levels which determine the actions to be performed according to their magnitude.

At FCN the dose constraint values are established at 16 mSv per year, for any worker.

Regarding the URA mining and milling facility, the mean effective annual doses resulting from occupational activities performed in the plant are shown in Figure F.6, from 2000 to 2016, compare to the annual production of uranium.

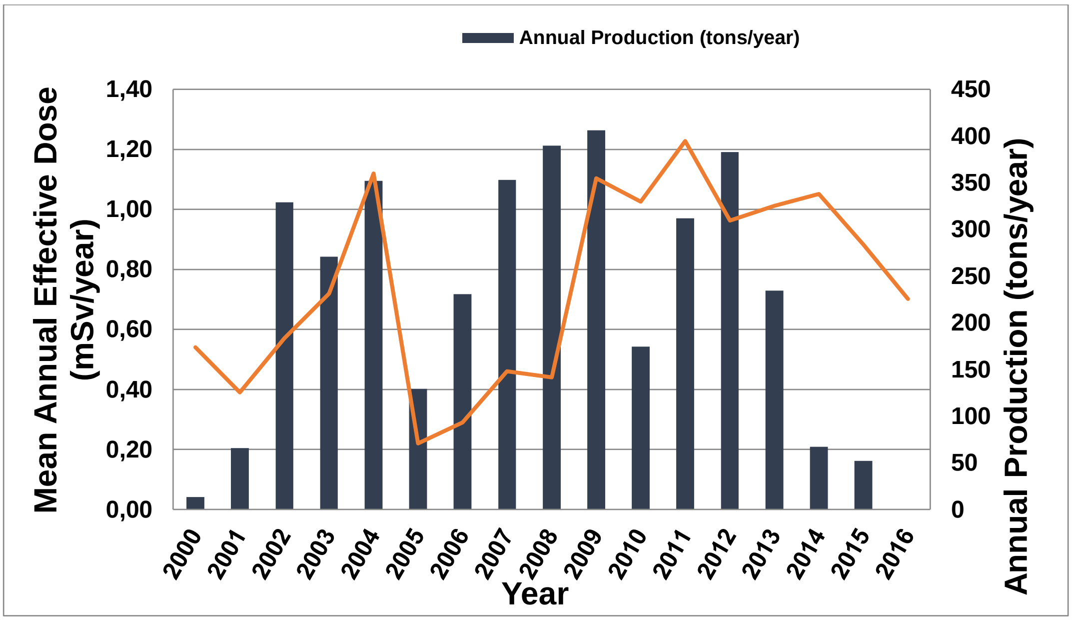


Figure F.6 - Mean Annual Effective Dose from Occupational Exposures – URA

F.5 - EMERGENCY PREPAREDNESS (*Article 25*)

As mentioned in **E.2.3**, Brazil has established an extensive structure for emergency preparedness under the so-called System for Protection of the Brazilian Nuclear Program (SIPRON). This includes organizations at the federal, state and municipal level involved with licensing and control activities as well as those involved with public safety, civil defence, law enforcement and communication to the public. Operators of nuclear installations and facilities and supporting organizations are also part of SIPRON.

SIPRON was established by Law 12731 of 21 November 2012, which revoked Law 1809 of 7 October 1980.

The emergency response is based in the following structure:

a) A central organization – that is the Institutional Security Cabinet of the Presidency of the Federative Republic of Brazil;

b) Three nuclear emergency response centers, and

c) Four collegiate bodies.

Both the nuclear response centers and the collegiate bodies include organizations at the federal, state and city levels involved with nuclear emergency preparedness and nuclear security activities as well as those involved with public safety and civil defence.

The National Center for Management of Nuclear Emergency (CNAGEN), in the Institutional Security Cabinet of the Presidency of the Republic (GSI/PR), is responsible to coordinate the actions related to SIPRON and to support the decision-making at the highest level of the country. The State Center for Management of Nuclear Emergency (CESTGEN) has been established in the city of Rio de Janeiro, to manage the support requested by on-scene responders. Finally, the Center for Coordination and Control of Nuclear Emergency (CCCEN) and its internal Center for Information in Nuclear Emergency (CIEN) have been established in the city of Angra dos Reis, in the vicinity of the power plant, to coordinate the response on scene and to communicate to the local people. These centers’ activities during an emergency have been established in SIPRON General Norms [13] and [14]. As previously mentioned, SIPRON is carrying out studies to consolidate those norms into the National Plan for Nuclear Emergencies.

Corresponding plans have been prepared for CNEN, for its supporting Institute for Radiation Protection and Dosimetry (IRD) and for other agencies involved, and detailed procedures have been developed and are periodically revised.

SIPRON General Norms’ prescriptions and CNEN plan’s technical information are converted into detailed plans for both the Operator (Plan for Local, on-site, Response) and the responders (Plan of External, off-site, Response, of the State of Rio de Janeiro). The latter, in its turn, subsidizes complementing plans from other agencies who contribute for the response or directly respond along with the state civilian defense system.

F.5.1 - NUCLEAR POWER PLANTS

- **Legislation**

With respect to emergency preparedness, as mentioned bellow, additional requirements have been established by the creation of the Brazilian System for Protection of the Brazilian Nuclear Program (SIPRON).

Since 2009, a Governmental restructuring has designated the Institutional Security Cabinet of the Presidency of the Republic (GSI/PR) as the Central Organization for SIPRON.

At the off-site level, a National Center for the Management of Nuclear Emergency (CNAGEN) has been created in Brasilia, which now is also in the Institutional Security Cabinet of the Presidency of the Republic (GSI/PR).

The Decree 2210 also establishes the Coordination Commission for the Protection of the Brazilian Nuclear Program (COPRON) composed of representatives of the agencies involved.

SIPRON guidelines, issued by COPRON, require that ETN, the Municipal and State Civil Defenses prepare, update and practice a plan for nuclear emergency situations. The guidelines also require that all organizations and agencies involved have their complementary emergency plans.

- **Emergency Preparedness**

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 (EPZ) concept.

The Emergency Planning Zones encompass the area within a circle with radius of 15 km centered on the Unit 1 reactor building at the nuclear power plants. This EPZ is further subdivided in 4 smaller zones with borders at approximately 3; 5; 10 and 15 km from the power plants.

- **On-Site Emergency Preparedness**

The On-site Emergency Plan covers the area of property of ETN, and comprises the first zone. For this area, the planning and all actions and protection countermeasures for control and mitigation of the consequences of a nuclear accident are responsibilities of ETN.

Specific Emergency Groups (Power Plants - Units 1 and 2, Support Services, Head Office and Medical) under the coordination of the Site Manager are responsible for the implementation of the actions of the On-site Emergency Plan. Emergency Centers for coordination of the Emergency Plan activities, equipped with redundant communication systems and emergency equipment and supplies are established in different locations inside this area.

A redundant meteorological data acquisition and processing system composed of 4 meteorological towers, provides continuous data on wind temperature, speed and direction, as well as air temperature gradient, to a computerized system in the Technical Support Center / Control Room of Units 1 and 2, through which follow up and calculation of the spreading of the radioactive cloud can be made.

The On-site Emergency Plan involves several levels of activation, from Facility Emergencies, Alert, Emergency Area, to General Emergency.

The initial notification for activation of the On-site Emergency Plan is done by the Shift Supervisor from the Control Room, which notifies the Plant Manager, as Emergency Group coordinator, which alerts the coordinators of the other Emergency Groups, the Site Manager and the Regulatory Body (resident inspector and Headquarter). The plant personnel 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 Manager, ensure the prompt actuation of the Emergency Groups.

Training and exercises (7 per plant) are performed yearly.

- **Off-Site Emergency Preparedness**

Brazil has established an extensive structure for emergency preparedness under the System for Protection of the Brazilian Nuclear Program.

SIPRON issued a set of General Norms for Emergency Response Planning, consolidating all requirements of related national laws and regulations. These norms establishes the planning, the responsibilities of each of the involved organizations and the procedures for the emergency centers, communications, intelligence and information to the public.

COPRON has established a Committee (COPREN/AR) for planning for the preparedness and the response to a nuclear emergency at Angra Nuclear Power Plant. This committee conducts an off-site emergency plan practice every year. In even years, the practice is a partial exercise with only the communication system and the emergency centers activated. In odd years, a general exercise includes deployment of response teams, sirens actuation, evacuation and sheltering of part of population, external monitoring, road and air and sea navigation control.

At the off-site level, a National Center for Management of Nuclear Emergency Situation (CNAGEN) has been created in Brasilia (capital of Brazil). A Regional Center for Management of Nuclear Emergency Situations (CESTGEN) has been established in the city of Rio de Janeiro. A Center for Coordination and Control of Nuclear Emergency Situation (CCCEN) and a Public Information Center (CIEN) have been established in the city of Angra dos Reis. The activities of these centers during an emergency have been established in SIPRON General Norms and were approved by the state governor in the revised Rio de Janeiro State Plan for External Emergency.

Corresponding plans have been prepared for CNEN, with the support of Institute for Radiation Protection and Dosimetry (IRD) and other involved agencies, and detailed procedures have been developed.

F.5.2 - OTHER FACILITIES (RESEARCH REACTORS)

The safety analysis performed for other installations such as research reactors indicates that only "on-site emergency is required". The on-site emergency plan covers the area within the operator's property, and comprises the reactor building and surroundings. It involves several levels of activation, from single alert status, to reactor building evacuation and isolation.

Specific Emergency Groups, under the coordination of the COGEPE (General Coordination for Emergency Plan), are responsible for the implementation of the actions of the on-site emergency plan. COGEPE is also responsible for plant personnel emergency training and exercises planning.

IPEN also maintains a Nuclear and Radiological Emergency Response Team. Training activities in nuclear and radiological emergency for fire brigade companies, professionals of medical area, safety officers and employees are carried out systematically, with the participation of qualified observers.

At CDTN, a Nuclear and Radiological Emergency Service is also available around the clock, including weekends and holidays. The most common tasks carried out by the this Service is to attend emergency calls and to investigate possible contamination in buildings and areas, stealing of lightning rods and other radioactive sources, possible presence of orphan radioactive sources and the disappearance of medical sources from hospitals and industries. During the events occurring in Belo Horizonte, FIFA World Cup and Olympic Games Rio 2016, a support emergency team, headed by the Radiological Protection Section, acted with other security organizations and was able to deal with radiological control and situations arising from radioactive source losses, on route accidents with vehicles transporting radioactive sources, or source mishandling at the user’s premises.

At IEN, there is a trained radiological emergency team which attends to all radiological emergency situations at the Institute. Periodically, this group is trained in radiological emergency procedures and associated items, in order to achieve a better performance in attend the emergency situations.

F.5.3 – INB FACILITIES

The Nuclear Fuel Factory (FCN), located in the city of Resende, has a Local Emergency Plan, comprising the municipality, mainly focused on the possible accident occurrences within its facilities. Risk analysis indicates that there is no postulated accident reaching the surrounding areas, outside the plant.

The Local Emergency Plan can be activated by a wide variety of possible incidents, such as fire, radiological accidents, and intrusion scenarios into the facilities. There is an organizational emergency structure establishing the responsibilities, as well procedures for each emergency group formed by the plant technical personnel.

Although there are no indications that accidents in that facility would reach the surrounding areas, an emergency general coordination was established with supporting groups such as the municipal civil defense, the fire brigade, the police, and CNEN emergency group. The Emergency Response Planning Committee in Resende - COPREN/RES, has been coordinating this task besides supporting SIPRON.

The effectiveness of the Local Emergency Plan is verified through simulated emergency exercises. The plan coordinator prepares a scheduled program on an annual basis with various scenarios of possible accidents. Emergency exercises are performed on monthly basis and the performance of the exercises is thoroughly evaluated.

At the Uranium Concentrate Unit (URA), the Emergency Plan aims to establish preventive measures to minimize effects of accidents that may disturb the normal operation of the unit and establish procedures for the routine returns to normality after the response to a possible accident. The risk analysis and identification of possible types of accidents are supported by operational experience of mining and other industrial facilities, also considering the constructive characteristics of the regiment of URA and rules of CNEN, considering the possibility of fires, landslides or radiological incidents.

The unit has an organizational structure, multidisciplinary teams, equipment and a scheduling of theoretical and practical training. The effectiveness of Local Emergency Plan is verified through simulated emergency exercises. Moreover, evaluations are made by internal and external auditors belonging to the regulatory body.

F.5.4 - EMERGENCY PREPAREDNESS AT NAVY INSTALLATIONS

As previously mentioned in **A.2.4**, the only nuclear facility at CTMSP headquarters, which is situated in the city of São Paulo, is a small research laboratory, whose inventory of nuclear material is actually very small, thus requiring emergency action only within the boundaries of the facility.

The safety analysis studies, performed for all the nuclear facilities located within the site of CEA, have demonstrated that no off-site emergency actions are required.

The CEA Local Emergency Plan (PEL-CEA) was conceived to ensure the integrated planning and the coordinated response, required in an emergency situation, intended to protect the activities, the facilities and the environment; and to guarantee the safety and health of the workers and the public.

The PEL-CEA is applicable to all the operational facilities located, or to be located, within the site of CEA. However, for planning purposes, the PEL-CEA must be complemented by specific local emergency plans, conceived for all those facilities, both conventional or nuclear, situated within the site of CEA, that may need emergency response. These facilities are called emergency planning unities (UPE), and their specific local emergency plans should be considered as being part and parcel of the PEL-CEA.

In the event of an emergency, the PEL-CEA will be activated in order to implement precautionary and/or protective measures for possible hazards. Decisions will be taken by the Emergency Plan General Coordinator (COGEPE), assisted by the Local Emergency Coordinator (CEL-UPE) and the Support Actions Coordinator (CAAp), the Radiological and Chemical Advisory Group, the Head of the Medical Team, the Head of the Radiological Protection Team, the Commander of the Battalion of Nuclear, Biological, Chemical and Radiological Defense of Aramar (BtlDefNBQR-Aramar) and by a Technical, Administrative and Communications Group.

The BtlDefNBQR-Aramar is strategically located at the CEA site, for fast delivery of equipment and personnel in emergency situations. The Battalion, under the command of COGEPE, is involved in rescue actions, decontamination of personnel, radiological field surveys and area isolation.

The CEL-UPE is responsible for preparing an annual schedule of on-site emergency exercises, which must be submitted to and approved by the COGEPE. The CEL-UPE is also responsible for implementing exercises and for writing evaluation reports of the exercises.

F.6 - DECOMMISSIONING (*Article 26*)

CNEN issued in November 2012 the regulation CNEN-NN-9.01- Decommissioning of Nuclear Power Plants [29]. This safety regulation establishes technical and administrative activities to be performed for partial or total removal of NPPs regulatory control; covering local, buildings and associated equipment, including the safe radioactive waste management until its transfer to a final disposal facility. Furthermore, CNEN has issued in October 2016 the new regulation NN-9.02 - Financial Management for Decommissioning of Nuclear Power Plants [30], that established the basic requirements for the management of financial resources, complementary to those established in article 15 of the CNEN-NN-9.01, including the management of radioactive waste generated during decommissioning.

F.6.1 - NUCLEAR POWER PLANTS

Based on the IAEA SRS45 - Standard Format and Content for Safety Related Decommissioning Documents Nº45 [31] and according to the CNEN regulation NN-9.01-Decommissioning of Nuclear Power Plants [29], the decommissioning of a nuclear facility involves activities that are different from those carried out during normal operation. New safety issues arise during the implementation of decommissioning activities. The regulatory body, which has the responsibility to ensure that workers, the public and the environment are protected during decommissioning activities, is required to ensure that the facility’s operator has identified and resolved these safety issues. In connection with this, the principal document that provides the regulatory body with safety related information is the decommissioning plan, which is the cornerstone of a successful decommissioning project. The decommissioning plan brings together all the information on the proposed decommissioning activities and identifies relevant safety issues, as well as the financial guarantees for the activity.

A preliminary decommissioning plan (PDP) was made by Eletrobras Eletronuclear (ETN) and sent to CNEN on November, 2014. It has presented two alternatives for the future decommissioning of Angra 1, Angra 2 and Angra 3 Nuclear Power Plants and an estimate of the minimum cost of these plant`s decommissioning based on 10CFR 50.75 and NUREG 1307.

Thus, the main objective of the CNAAA Decommissioning Plan, prepared by Eletronuclear, is to identify and describe the decommissioning process for the facilities, considering state-of-the-art technology and including the management of the resulting radioactive waste, among other activities. Moreover, it estimates the cost of the activities in order to adjust the necessary financial resources.

In this regard, CNEN-NN-9.01 establishes that:

- Art. 10 – The decommissioning strategy selected by the operating organization must meet the following requirements:
    - I – consider the international experience, as well as the current national polices for the decommissioning and waste management, and;
    - II – provide ways to and storage wastes of all classes to be generated during the decommissioning activities.

It is worth mentioning that the studies for selection of the strategy involve subjective aspects that are subject to evaluations and, therefore, the conclusions may change. The key point is to ensure that there is a connection among the shutdown condition of the installation, the proposed decommissioning activities, the risks associated with the performance of these activities, the necessary actions arising from the safety analysis and the resulting costs.

CNEN has issued on October 2016 a new regulation NN-9.02 - Financial Management for Decommissioning of Nuclear Power Plants [30], that established the basic requirements for the management of financial resources, complementary to those established in article 15 of the CNEN-NN-9.01, including the management of radioactive waste generated during decommissioning.

The financial resources for the decommissioning of Angra-1 and Angra-2 are being subsidized through electrical energy taxes, included in the tariff structure of ETN, with governmental authorization.

A new revision of the PDP is being prepared by Eletronuclear with support of a Brazilian University, using the decommissioning experience of an international consultancy. This new revision will consider site-specific data and a detailed cost estimating approach. The idea of involving a Brazilian University in this process is to develop knowledge in the country so that Eletronuclear can use their support in future needs.

F.6.2 - RESEARCH REACTORS

No decommissioning policy has been still planned for research reactors in Brazil. However, for the IPR-R1 of CDTN a preliminary decommissioning plan was prepared to make part of its FSAR. Nowadays cost estimation for this decommissioning is carried out as part of IAEA DACCORD Project.

F.6.3 - INB FACILITIES

F.6.3.1 - Decommissioning of Santo Amaro Processing Plant (USAM)

As described, in detail, in the former National Report, the first activity of decommissioning executed in Brazil was the decommissioning of Santo Amaro Processing Plant (USAM) which happened in the 90’s.

The radioactive waste generated by the decommissioning process led to the choice of the Interlagos Processing Plant (USIN), also in the state of São Paulo, as the interim storage facility to these waste (see **H.2.2.2**).

F.6.3.2 - Decommissioning of the Ore Treatment Unit at Poços de Caldas (UTM)

The Ore Treatment Unit (UTM) at Poços de Caldas mining and milling complex is currently being decommissioned by INB. In September 2009, it was initiated the Preparation of the Remediation Plan - PRAD (Degraded Areas Reclamation Plan). This Plan has been completed in 2011 and includes all areas of the UTM. A revision was concluded in January 2012, and it has been delivered to IBAMA and CNEN in April of the same year, for analysis.

In 2016, faced with the challenging scenario for the site, it was decided to adopt the best practices of project management as established in the PMBOK Guide. As a result, a robust and consistent management plan has been developed, where the major problems were listed and integrated, and an estimate of financial expenditure over the years was calculated.

F.6.3.3 - Decommissioning of the Interlagos Processing Plant (USIN)

- **Precedents**

During the operation of USAM, big amounts of mineral fractions with no commercial value (Silica) containing a heavy minerals fraction that included percentages of Monazite were transferred to USIN and disposed in the land.

Moreover, radioactive minerals from mineral research activities conducted during the 60’s to 80’s were stored in USIN sheds, in sufficient quantities for the execution of development tests of physical and chemical processes for uranium recovery. The storage was made in sheds (named B and C) that did not receive suitable maintenance and lacked a suitable floor, and such minerals gradually got dispersed.

The monazite contaminated packages were also stored in these sheds. As such packages got deteriorated; the floor was contaminated with small quantities of products containing thorium and uranium. By that time, any environmental law or procedures had been established in the country related to contaminated land.

The terrain underwent a few radiometric evaluations in the 90’s, and the first investigations determined the extent of the anomalies by means of a scintillometer. The measurements allowed generating radiometric maps of the area and locating contaminated points.

New scintillometric surveys performed after remediation procedures demonstrated the existence of 14 anomalous points that remained from the remediation carried out early in the 90’s. Additionally, anomalous points were detected in the entire floor area of sheds B and C.

After the remediation done at the end of the 90’s, a test bore of the terrain was planned, and four different areas were defined: A, B, C, D. In Area A were made 213 test bores using an irregular spacing guide. For the other areas, the spacing format was a regular one, 6 x 6 meters, with 264 points in Area B, 208 points in area C and 302 points in area D. Soil sampling was made at 30 cm and 100 cm depths. Alpha and total beta emissions were determined on the samples collected.

Then, the remediation process was suspended. Notwithstanding, in compliance with the requirement of CNEN and the São Paulo State Institute for Environment (CETESB), concerning the execution of a hydrogeological study of the site, two new test boring campaigns were carried out. The first one, with 28 holes up to 6 meters deep, and installation of an equal number of underground water monitoring wells.

On the samples were analyzed the radionuclides of radiological interest (238U, 232Th, 228Ra, 226Ra and 210Pb) and geochemical parameters (pH, CE, Tª, Eh) metals. During the second test boring phase, nine supplemental test bores were made.

Hence, the contamination evaluation was executed in three occasions and 1,000 points in the area were analyzed. In the last hydrogeological characterization (occurred in 2006) 07 contaminated points in the site were identified.

The site environmental radiological monitoring was revised in accordance with this final characterization and the quarterly monitoring results showed there was not any contamination migration going out of the site limits.

The remediation procedure estimates that 680 m3 of soil will be moved by the decontamination work, of which approximately 80 m3 will be segregated as low-level radioactive waste and temporarily stored in USIN's Shed A.

According to the analysis results for specific radionuclides activities, the soil will be used as follows:

- for 0.5 Bq/g of 226Ra and 0.5 Bq/g of 228Ra will be used for land restoration,
- for equal to or below 30 Bq/g will be disposed of in a sanitary landfill, and
- for above 30 Bq/g will be packed and stored as radioactive waste.

INB started decontamination work in 2010. This activity has not been completed because the activity can only be performed during the period when it is not raining.

INB is expecting the definition of the position of CNEN on the national repository for low- and intermediate-level radioactive wastes so that studies and plans can be developed for transferring the waste stored at USIN. From the establishment of that position, a new radiological assessment of Shed A and of the local soil will be done, along with the decontamination plan and the subsequent total decommissioning of the facility.

- **Decontamination of the soil of USIN (utility area of 18,400 m^2)**

In June 2010, the work of decontaminating the soil of USIN was initiated, at the INB unit in São Paulo, which has 60,000 m^2 of total area.

Figure F.7 - USIM - the red range represents the decontaminated area - 18,400 m^2

The municipality of São Paulo decided to use an area of 18,400 m^2 for the construction of public roads. INB started the decontamination of the soil in this area, in order to attend this request. Since 2012, INB has been working on the decontamination process of of the site. In 2013, CNEN did the characterization of the remaining soil, which culminated in the release for unrestricted land use, for this part of the terrain. During the descontamination operation, the activities performed included: soil characterization; radiological monitoring; application of the methodology of the MARSSIM (Multi Agency Radiation Survey and Site Investigation Manual); and application of the RESRAD software for dose calculation.

Thus, using the dose calculation and the results of activity concentrations in the samples collected after remediation in the area of interest, it was concluded that the selected area was decontaminated. The release criteria established reminiscent doses to be lower than 1 mSv/year. The next step is to perform the decontamination of the whole site, for unrestricted use.

SECTION G - SAFETY OF SPENT FUEL MANAGEMENT

G.1 - GENERAL SAFETY REQUIREMENTS (*Article 4*)

Since the current situation is the storage of spent fuel in the plant pools, the general safety requirements for the management of spent fuel are contained in the safety requirement for siting, design and operation of the nuclear reactors. Regulation CNEN-NE-1.04 [3] applies to the fuel stored in the nuclear power plant. Additional requirements are established in Regulation CNEN-NE-1.26 [8], for the operational phase, and Regulation CNEN-NE-1.14 [5] establishes the necessary reporting requirements.

G.2 - EXISTING FACILITIES (*Article 5*)

G.2.1 - NUCLEAR POWER PLANTS

The design of the fuel pools and associated cooling systems and fuel handling systems assure adequate safety under authorized operation and under postulated accident conditions.

Both units are provided with facilities that enable safe handling, storage and use of nuclear fuel. The facilities are designed, arranged and shielded such as to rule out inadmissible radiation exposure to the staff and the environment, release of radioactive substances to the environment, and criticality accidents.

In Angra-1 the new fuel dry storage room and the spent fuel pool are located in the Fuel Handling Building, having connections with the reactor via the fuel transfer system and the refuelling machine. The path of the nuclear fuel inside the plant up to the reactor is: the entrance gate, the cask opening area inside the fuel building, the new fuel storage area, the transfer canal (or temporarily in the spent fuel pool), the fuel transfer system, the refuelling machine and the reactor core.

In Angra-2 the dry new fuel storage room and the spent fuel pool are located inside the Reactor Building. The path of the nuclear fuel inside the plant up to the reactor is: the entrance gate, the auxiliary portico, the equipment lock, the cask opening area, the new fuel storage area, the refuelling machine, the spent fuel pool, and the reactor core.

In both units the Spent Fuel Pools are equipped with fuel storage racks of two different designs. The first group, named Region 1, or compact racks, is designed to receive fresh and irradiated fuel assemblies at maximum reactivity for the specified core design, without taking credit for burnup. The second group, named Region 2 or supercompact racks, is designed to receive fuel assemblies that have reached a certain minimum burnup.

The compact and supercompact racks, made of stainless steel, have boron coupons between the storage cells in Angra-1. In Angra-2 the compact and supercompact racks use borated steel plates as the construction material of the cells. The technical specifications have curves of discharge burnup versus initial enrichment to direct the storage of fuel assemblies in region 2 because the smaller center-to-center distance of the cells.

Structures, components, and systems are designed and located such that appropriate periodic inspection and testing are performed.

In both units, all storage places are supported by criticality safety studies. Criticality in new and spent fuel storage areas is prevented both by physical separation of fuel assemblies, by boron shields and by borated water as appropriate.

The evaluated multiplication factors of the fuel storage configurations include all uncertainties arising from the applied calculation procedure and from manufacturing tolerances. The factors are less than or equal to the adequate upper bound margin of subcriticality (1-deltaK) under normal operation and all anticipated abnormal or accident conditions.

The criticality evaluation codes used by the ETN are all codes accepted by the international industry and also licensed by CNEN.

The storage capacity is shown on table G.1 below:

Table G.1 - Spent fuel storage capacity at Angra – Number of fuel assemblies

	Angra-1	**Angra-2**
New Fuel Storage Room	45	75
Region 1 Spent Fuel Pool	252	264
Region 2 Spent Fuel Pool	1,000	820
Reactor Core	121	193

Assuming a regular lifetime of 32 operating cycles for each unit and that in each cycle 1/3 of the core is replaced, then Angra-1 has enough storage capacity for its entire lifetime and Angra-2 has storage capacity for about 14 cycles.

In Angra-1, the Spent Fuel Pit Cooling system is able to remove the amount of decay heat by a circuit with two pumps and one heat exchanger. In the case of maintenance or malfunction of the main pump, a redundant spare pump is operated. This spare pump is supplied by the emergency bus control and, in the case of loss of offsite power, can be supplied by the diesel generator.

In Angra-2, the Fuel Pool Cooling system consists of two trains which are integrated into the Residual Heat Removal (RHR) system and a third independent train. In each integrated train a fuel cooling pump is connected in parallel with the RHR pump. These two trains are equipped with connections to the fuel pool via the RHR system. The independent fuel pool cooling train consists of a fuel pool cooling pump which is connected in parallel with the fuel pool purification pump, the fuel pool cooler and separate connections to the fuel pool. The redundancy of the power supply of the Fuel Pool Cooling system is ensured by connection to the normal power supply system and to the emergency power supply systems.

Each unit is designed for a regular lifetime of 32 operating cycles. According to the national electric power demand, the refuelling policy is to operate with 11 equivalent full power monthly cycles, with an one-month refuelling outage. Studies are being carried out to increase the cycle lengths gradually up to 18 months, since longer cycles reduce waste generation and doses during refuelling outages. Shutdowns, refuelling and startups of the plants are conducted in such a way to reduce the amount of radioactive waste generated (see also items D.1.1.1 and D.1.2.1).

The role of the Eletronuclear (ETN) on the nuclear fuel management can be summarized as follows:

- Definition of operating strategy
- Definition of core composition
- Procurement of fuel manufacturing together with manufacturers
- Follow up of fuel manufacturing
- Transport of new fuel from the factory to the site
- New fuel reception on-site
- Fuel storage on-site
- Fuel operation
- Refuelling Operations

Nuclear power plants fuel supply is planned several years in advance. In-core fuel management provides the basic data for this long-term planning. For this purpose, several burnup cycles have to be calculated in advance. The corresponding core loading schemes, or loading patterns, have to be determined considering safety-related and operational requirements as well as economic aspects. The main results of long-term fuel management are the required numbers of fuel assembly reloads and their enrichments for future cycles.

Of special interest in the long-term fuel management are the equilibrium cycles. To calculate the equilibrium cycles, the same loading pattern is used for several successive cycles. The equilibrium cycle is reached when the characteristic parameters do not change significantly from cycle to cycle. The most important characteristic parameters are:

- Type of loading strategy
- Number and enrichment of the fuel assembly reload
- Natural length of the cycle
- Average discharge burnup for the fuel assemblies
- Availability of storage places. In this sense, the interdependence of spent fuel (non-returnable to the reactor core) management is to be defined with CNEN.

G.2.2 - RESEARCH REACTORS

See item **D.2**.

G.3 - SITING OF PROPOSED FACILITIES (*Article 6*)

Siting requirements for the spent fuel storage facilities at reactor sites are the same for siting the nuclear power plants or research reactors, respectively.

If the decision is taken to store fuel in “dry storage” on-site, new detailed requirements will have to be established by CNEN.

G.4 - DESIGN AND CONSTRUCTION OF FACILITIES (*Article 7*)

Design and construction requirements for the existing spent fuel storage facilities at reactor sites are the same for design and construction of the nuclear power plants or research reactors.

The spent fuel storage racks are easily installed and removed. They are manufactured from stainless steel. Their purpose is to receive and store fresh and spent fuel assemblies as well as any core inserts, like control rods, primary and secondary sources and flow restrictors to be inserted into fuel assemblies.

The storage racks consist of load bearing structure supporting non-load bearing absorber cells. The load bearing structures comprise:

- The lower support structure (base plate)
- Rack foot
- Centering grid
- Steel channels

The non-load bearing structures are provided with features to assure safe subcriticality, each fuel assembly position is provided with one absorber cell. The absorber cells are made of neutron absorbing sheets with grooved edges. The absorber sheets are manufactured from a boron-alloyed austenitic stainless steel.

The absorber cells are fixed in the rack structure by means of welded clamps. To facilitate the insertion of the fuel assembly into the absorber cell, the upper part of the cell is provided with lead-in slopes, or chamfers and, where applicable, with guide for the refuelling machine centering device.

Only about 40% of the volume of a fuel assembly consists of fuel rods; the remaining volume is filled by water.

For Angra-1 and 2, as well as for Angra-3, a spent fuel complementary dry storage unit is being foreseen, in order to increase the current on-site storage capacity of the plants. This installation is under ETN responsibility as a complementary and initial storage unit of the plant. ETN has already contracted a supplier to construct dry storage and to perform the transference of Spent Fuel Assemblies corresponding to 5 cycles Angra 1 and Angra 2 operation.

G.5 - ASSESSMENT OF SAFETY OF FACILITIES (*Article 8*)

A comprehensive safety assessment is a requirement established by the licensing regulation in Brazil [3].

G.5.1 - NUCLEAR POWER PLANTS

For the Angra-1 and Angra-2 plants, both a Final Safety Analysis Report (FSAR) were prepared. For the Angra-3 plant, a Preliminary Safety Analysis Report (PSAR) was also prepared. The FSARs and PSAR followed the requirements of US NRC Regulatory Guide 1.70 - Standard Format and Contents for Safety Analysis Report of LWRs.

Chapter 9 of the FSAR contains the information related to spent fuel storage on-site, including cooling requirements, subcriticality requirements, and radiation protection aspects.

These reports were reviewed and assessed by CNEN, and extensive use was made of the US NRC - Standard Review Plan (NUREG - 0800).

G.5.2 - RESEARCH REACTORS

The design and additional modifications of the Brazilian Research Reactors have been made in accordance with IAEA Safety Standards, Safety Guides and Safety Practices of IAEA Safety Series, in particular Safety Guide 35-G2 (Safety in the Utilization and Modification of Research Reactors), Safety Guide 35-S2 (Code on the Safety of Nuclear Research Reactors: Operation), Safety Series 116 (Design of Spent Fuel Storage Facilities), and Safety Guide 117 (Operation of Spent Fuel Storage Facilities). Such documents present the fundamental principles of safety for research reactors and associated facilities for handling, storage and retrieving of spent fuel before it is reprocessed or disposed of as radioactive waste. The adoption of these principles assures that the spent fuel represents no hazard to health or to the environment, and the maintenance of the following conditions for the spent fuel:

- Subcriticality
- Capacity for spent fuel decay heat removal
- Provision for radiation protection
- Isolation of radioactive material

G.5.3 – INB FACILITIES

INB has the following facilities:

- Uranium Concentrate Unit (URA), located in the municipality of Caetité, state of Bahia;
- Ore Treatment Unit (UTM), located in the municipality of Caldas, State of Minas Gerais;

- Nuclear Fuel Factory (FCN), located in the municipality of Resende, state of Rio de Janeiro, consisting of the following nuclear installations:
    - Conversion of UF_6 to UO_2 powder
    - UO_2 Pellets Fabrication
    - Fuel Components and Assembly
    - Enrichment Plant
- Heavy Minerals Processing Unit (UMP), located in Buena, state of Rio de Janeiro.
- Interlagos (USIN) and Botuxim storage units, located in the state of São Paulo.

To ensure that building and operation of the facilities are in accordance with the safety principles required by national and international authorities, all facilities owned by INB are subject to nuclear licensing procedures stablished by CNEN. To this effect, a Preliminary Safety Analysis Report and a Final Safety Analysis Report are prepared and submitted in accordance with regulatory guide CNEN-NE-1.04 – "Licensing of Nuclear Installations" [3], which is further supplemented by regulatory guide CNEN-NE-1.13 - "Licensing of Uranium and/or Thorium Mining and Milling Facilities" [20], in the case of uranium ore mining and milling operations.

Additionally, all such facilities go through an environmental licensing process, including an Environmental Impact Study in which the safety conditions relating to the environment and the population are discussed. For nuclear facilities, this process is conducted by IBAMA; in the case of UMP and in the case of USIN and Botuxim sites this is responsibility of the corresponding State environmental bodies.

G.6 - OPERATION OF FACILITIES (*Article 9*)

Operational requirements for the existing spent fuel storage facilities at reactor sites are the same for operating the nuclear power plants or research reactors.

Detailed limits and conditions for operations (LCOs) are established for the nuclear power plant spent fuel pools, including the related surveillance requirements and the actions to be taken in case of deviations.

G.7 - DISPOSAL OF SPENT FUEL (*Article 10*)

G.7.1 - FUEL FROM NUCLEAR POWER PLANTS

The decision regarding reprocessing or disposal of spent fuel has not been taken in Brazil. The current policy adopted in Brazil with regard to spent fuel is to keep it 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 emphasized that, by the Federal Brazilian Law, spent fuel is not considered as radioactive waste.

For Angra-1 and 2, as well as for Angra-3, in the future, a spent fuel complementary dry storage unit is being implemented, in order to increase the current on-site storage capacity of the plants. This installation is under ETN responsibility as a complementary and initial storage unit of the plant.

G.7.2 - FUEL FROM NUCLEAR REACTORS

The situation of research reactors was discussed in item **D.2.1**.

On November, 2007, 33 spent fuel elements stored in the pool of the IEA-R1 reactor and containing uranium of US origin were shipped back to Savannah River Laboratory, South Carolina, USA. This operation, which was very similar to the one concluded in 1999, when 127 spent fuel elements were shipped back to the USA, used a different transport cask (LWT) supplied by the US company NAC.

SECTION H - SAFETY OF RADIOACTIVE WASTE MANAGEMENT

H.1 - GENERAL SAFETY REQUIREMENTS (*Article 11*)

General safety requirements for the management, storage and disposal of radioactive waste are established, respectively, in regulations CNEN-NN-8.01 - Radioactive Waste Management for Low and Intermediate-Level Waste [25], and CNEN-NN-8.02 - Licensing of storage and disposal facilities for low- and intermediate-level radioactive waste [26]. Additional requirements for safety of waste management are established in regulations CNEN-NN-3.01 [12] - Radiation Protection Directives, CNEN-NE-6.06 [7] - Site Selection for Radioactive Waste Storage and Disposal Facilities, CNEN-NN-6.09 - Acceptance Criteria for Disposal of Low and Intermediate Level Radioactive Wastes [23], CNEN-NE- 5.02 [27] - Transport, receiving, storage and handling of fuel elements in nuclear power plants, CNEN-NN-1.16 [10] - Quality Assurance for Safety in Nuclear Power Plants and other installations and CNEN-NE-2.01 [28] Physical Protection in Operating Units in Nuclear Area.

H.2 - EXISTING FACILITIES AND PAST PRACTICES (*Article 12*)

H.2.1 - NUCLEAR POWER PLANTS

H.2.1.1 - Gaseous Waste

To minimize the radiation released to the environment and to prevent the formation of explosive mixtures due to high hydrogen concentration, the gases are continuously removed from the primary systems and processed in the Gaseous Waste Processing System, before being discharged to the environment.

In Angra-1, the Gaseous Waste Treatment System removes the fission gases and stores them in the gas decay tanks. The safety criteria are the assumption of 1% of fuel failures being released to the Reactor Coolant System.

In Angra-2, in order to avoid a release of radioactive gases to the building atmosphere and subsequently to the environment, or the formation of explosive mixtures due to any high concentration of hydrogen that could arise inside the tanks in the auxiliary systems, the Gaseous Waste Disposal System removes such gases by continuous purging with nitrogen and processes the dissolved gases released from the reactor coolant. To fulfill the required functions, the gaseous system has the following tasks:

- To retain radioactive gases until they have largely decayed before discharging then to the exhaust air stack.
- To prevent any release of radioactive gases from the components into the building atmosphere.

- To limit the hydrogen and the oxygen concentrations in the connected components in order to prevent the formation of explosive mixtures and to reduce the presence of oxygen in the reactor coolant, which would lead to corrosion in the reactor coolant system.
- To operate with the Hydrogen Reducing System, following a loss of coolant accident.

In Angra-2, the gaseous effluents are released continuously through the vent stack, depending on the ventilation system pressure.

H.2.1.2 - Liquid Waste

The Liquid Waste Processing and Storing Systems in Angra-1 and in Angra-2 are designed to collect the active and inactive liquid waste produced in the controlled area, treating them when necessary. After that, they may be discharged from the power plants in accordance to the safety rules established by nuclear and environmental authorities (CNEN, IBAMA and state regulators).

According to the activity and the chemical characteristics of the liquid waste, the following processes are provided for treatment:

- Evaporation
- Chemical precipitation (Angra-2 only)
- The Liquid Waste Processing and Storing Systems are designed to collect the liquid waste arising from the controlled area to specific storage tanks, and to separate different types of liquid waste for further processing

The systems are sufficiently automatic to minimize the human intervention, consequently reducing the occupational doses. The capacity is determined by the amount of liquid waste arising from the controlled area during normal plant operation and outages.

The liquid waste is collected separately in three groups of storage tanks, in accordance with its chemical and radiochemical composition (waste holdup tank, floor drain tank and laundry tank in Angra-1.

In NPP Angra 2, the liquid waste is collected in two groups; group I – Active Liquid Waste with activity in the range 3.7 to 3.7×10^3 Bq/cm^3 and group II – Low level active and inactive Liquid Waste with activity up to 3.7×10^{-1} Bq/cm^3.

In Angra-2, the Liquid Waste Processing and Storage Systems are designed to process approximately 20,000 m^3 of liquid waste per year.

To assure the protection of the workers, of the population and of the environment against the effect of the ionizing radiation, the treated liquid waste intended for discharge is collected in monitoring tanks. Recirculation and discharge pumps are connected to the monitoring tanks to mix the liquid waste or to return it to the storage tanks.

Before discharge from the monitoring tanks, samples are taken for analysis in the laboratory. Based on the results of the analysis the radiation protection supervisor decides whether the discharge may be made. The discharge, as function of the gamma spectrometry (in Angra-1) or the activity concentration (total gamma as equivalent Cs-137) and gamma spectrometry monitoring weekly mixed samples (in Angra-2), is performed in accordance with the technical specification for the plants, based on CNEN and IBAMA regulations and on the environmental legislation.

The released activity is monitored on-line. If the maximum allowable value of activity concentration for undiluted discharge water is exceeded an alarm is triggered and the discharge is automatically interrupted. In NPP Angra 2, the discharge of the liquid wastes to the environment is permitted (KTA 3603 standard) only if the specific activity of 1.85 E+7 Bq/m^3 is not exceeded in a non-analysed mixture prior to dilution using the circulating or service cooling water.

To optimize doses to Public Individuals, CNEN sets an authorized limit of 0.25 mSv/year for each plant.

H.2.1.3 - Solid Waste

To reduce the potential of migration and dispersion of radionuclides and to minimize the dose to the environment, both plants are equipped with Solid Waste Treatment Systems. These systems process the spent resins, the concentrated liquid waste contaminated filters and the solid waste produced in the operation and maintenance of the plants, and confine them in special packages.

In Angra-1, the concentrates, spent resins and contaminated filters from the purification systems are immobilized in cement and conditioned in liners and special 200-liter metallic drums, within the prescribed requirements for transportation and storage. The non-compactable wastes are conditioned in special metallic boxes.

In Angra-2, concentrates and spent resins are immobilized in bitumen and conditioned in special 200-liter metallic drums. The non-compactable wastes are also conditioned into special metallic boxes and contaminated filters are stored inside the plant into 200-liter metallic drums for further conditioning.

In both plants, the compressible solid waste is compacted by a hydraulic press, and conditioned in special 200-liter metallic drums.

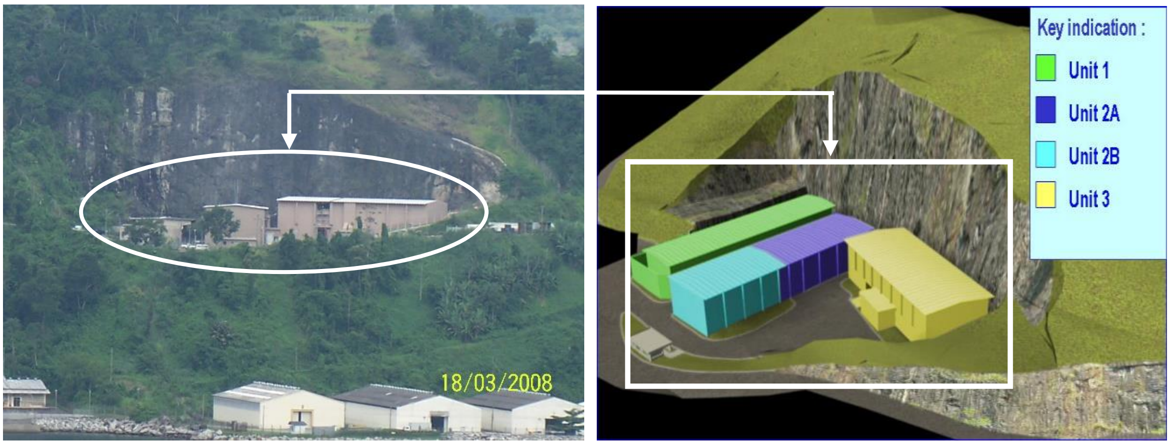
All the waste forms must fulfill the requirements for final disposal established by CNEN regulations.

To minimize the accumulation of solid radioactive waste, the entrance of materials in the controlled area is limited and controlled. Also, all the material collected in the controlled area is monitored and segregated, according to its physical and radiological features. Whenever possible, such material is decontaminated and reused or released as non-radioactive waste.

The solid radioactive waste produced in Angra-1 is stored in an on-site initial storage facility. This facility, denominated Radioactive Waste Management Center (CGR), is composed of three installations, called Storage Facility 1, Storage Facility 2 (A and B), and Storage Facility 3, all them in operation, see Figures H.1.

In Angra-2, except for non-compactable waste, all the produced waste is stored in a compartment inside the plant, called in-plant storage facility (UKA Building) with a total capacity of 1,644 two hundred liters drums. Non-compactable waste is packed in metallic boxes, which are stored in the Radioactive Waste Management Center (CGR).

All packed radioactive waste is monitored to assure that the surface dose rates for transportation do not exceed the established values in regulation CNEN-NE-5.01 [15] and the resulting occupational exposures are in accordance with the values established in regulation CNEN-NN-3.01 [12].



Figures H.1 – On-site initial waste storage facilities – location and schematic

Up to 1998, the radioactive concentrate produced in the evaporator unit and the spent resins of Angra-1 were packed in 200-liter drums. As the mixture was not homogeneous, the immobilization process was considered improper, because the matrix was not in accordance with the established standard of the regulatory body.

The present Solid Waste Processing System for Angra-1, encapsulates the concentrates and spent resins in cement, inside 1 m^3 shielded liners. The present system, besides generating a more homogeneous product, reduces the occupational dose during the operational process, due to improved shielding.

Storage Facility 1 was built in 1981, with a design capacity for 2,432 drums, being 1488 of low level activity and 944 of medium level activity. From 2015 to 2016 were made improvements in its civil structure. This work optimized the conditions of storage of packages in this building. Currently, in this building is possible perform visual inspections on all packaged stored, because inspection lanes were created, which were not previously available. Now, the building is able to store packages equivalents 4,064 drums, being 2,368 of low level activity and 1,696 of medium level activity. At the moment, this building is occupied with 1,716 drums, 128 B-25 boxes and 81 metallic boxes (3 boxes are equivalent 16 drums). Its occupation is reported in equivalent drums, so there are 1,712 drums in low level activity and 1,204 drums in medium level activity.

In 1992, Storage Facility 2A was built with the capacity to store 621 liners. The remote operation capability was improved to minimize occupational doses. In 2011 this building was remodelled to increase its storage capacity for 783 liners. Actually, this building is occupied with 743 liners and 19 VBA's (VBA is a concrete cylinder with 1.3m³ from Angra 1 and these 19 VBA's are equivalent 28 liners).

In 2008, the Storage Facility 2B was built with the capacity to store 2,296 drums and 252 liners. Actually, this building is occupied with 85 liners and 2,296 drums. At that time, was also built the Storage Facility 3, with the capacity to store 5,612 drums and 300 metallic boxes. Nowadays, this building is occupied with 268 metallic boxes and 1,868 drums.

In 2016, the Radiological Monitoring Building was built and Its purpose is to perform gamma spectrometry of all kind of waste package. However, this building isn't in operation because the purchase process of equipaments isn't finished. Eletronuclear/We works/work together with IPEN (Instituto de Pesquisas Energéticas e Nucleares) to develop method for calculating isotopic inventory of waste.

The inventory of waste stored at Angra site (August 2017) is presented on Tables H.1 and H.2.

Table H.1 - Waste Stored at Angra Site - Angra-1

Waste	Packages	Location
Concentrate	3,050	Storage Facility 1/ Storage Facility 2/ Storage Facility 3
Primary Resins	796	Storage Facility 2/ Storage Facility 3
Filters	534	Storage Facility 1/ Storage Facility 2/ Storage Facility 3
*Non-compressible	1004	Storage Facility 1/ Storage Facility 2/ Storage Facility 3/ SG Storage Facility
**Compressible	945 (817 drums + 128 B25 boxes)	Storage Facility 1 / Storage Facility 2 / Storage Facility 3
Secondary Resins	828	Storage Facility 1
TOTAL	7,157	*(Includes 206 Inactive drums)*

* Two Steam Generators and one reactor vessel cover are stored at SG Storage Facility.

** In 2006, the NPP supercompacted 1938 waste drums from Angra-1.The pellets (crashed drums) were placed inside special metallic boxes (B-25) with 2500 liters of capacity.

Table H.2 - Waste Stored at Angra Site - Angra-2

Waste	Quantity (drums)	Location
Concentrate	274	In Plant Storage
Primary Resins	140	In Plant Storage
Filters	16	In Plant Storage
Non-compressible	14	Storage Facility 3 and SG Storage Facility
*Compressible	379	In Plant Storage
TOTAL	823	-

* In 2006, the NPP supercompacted 89 waste drums from Angra-2.The pellets (crashed drums) were placed inside special metallic boxes (B-25) with 2500 liters of capacity.

H.2.2 - INB FACILITIES

The INB units store only low activity nuclear material. The waste produced is minimized due to the high value in the nuclear content of the material processed. The recovery of uranium in all phases of the process is a constant objective not only due to the economic value, but also to avoid the presence of hazardous effluents. The material inventory is presented below, although not all this material is "radioactive waste" in the sense of the Convention.

H.2.2.1 – Nuclear Fuel Factory (FCN)

The low level nuclear waste is packed in 200-liter metal drums. Although 405 drums have been produced so far, there is a plan to reduce the number of drums by crushing and replacing the drums contents. These drums contain several materials (gloves, shoes, tools, filters, etc.) contaminated with up to 4.0% enrichment uranium.

The FCN’s Low-level Waste Storage Facility (DIRBA) was designed in two modules. The Module I has been already built, with an area of 325 m^2, with the maximum design capacity of 444 drums for solid wastes and 120 drums of liquid waste.

H.2.2.2 - Interlagos Processing Plant (USIN) and Botuxim Storage Facility

The area of USIN has about 60,000 m^2. The site located in an urban industrial area was acquired to receive the USAM Facility but unused at that time. In this site there were 3 storage facilities A, B and C. The Storage Facilities B and C have been disassembled in September 2002. Storage Facility A, with 2,060 m^2, has been renovated to receive the waste originated from the USAM decommissioning. This process initiated in 1993.

Although belonging to the same company as USAM, the USIN site was not under regulatory control by CNEN, because the process of rare earth separation that used to take place in USIN did not involve significant amounts of radioactive elements, since they were eliminated in previous stages of the process at USAM.

Between 2008 and 2010 was made an inventory of stocks of materials at the plant. This survey has allowed the number of plastic drums and distribution of material that allowed the correction of some previously released values. At a given moment of the operational period of USIN, however, some leakage of the material stored led to the contamination of the area surrounding Storage Facility A and also to radioactive contamination of groundwater. From 1998 to 2002 and 2010 to 2013, the area was partially decontaminated. In this operation were generated 170 plastic drums and 18 metal drums with soil contaminated. The other 1,717 plastic drums stored in USIN were generated during decontamination of the USAM facilities.

Besides this occurrence, the USIN site has received large amounts of the light fraction of monazite sand, as landfill to the swampy areas around the storage facilities. As a result of these landfills, activity concentrations up to 33,000 Bq of ^{228}Ra per kg of soil could be measured. The decision to clean-up the area in order to release it for unrestricted use has already been taken by CNEN, and the operator has decided to keep that area under regulatory control and to use it as a temporary waste repository for the decommissioning waste coming from USAM.

In addition to the waste storage, Storage Facility A is also used to store radioactive material (Table H.3) that can still be used as a source for nuclear material and other applications, such as the byproducts of the USAM process, mainly a material called Cake II *(Torta II)*, composed basically of thorium hydroxide concentrate. The inventory of Cake II awaits development of improved technology to allow its economical use.

Table H.3 - Types and amounts of material stored in Storage Facility A

Packages (100-liter plastic drums)	**Amount**	**Mass (ton)**
Cake II	3,283	590.94
Moseothorium	760	83,6
Non- Contaminates Trisodium Phosphate	768	92.16
Contaminated Trisodium Phosphate	61	7.28
Radioactive Waste (clothes, equipment, wood soil)	1,769	192.08
Radioactive Waste (soil)	221	29.88
TOTAL	**6,862**	**995,94**
Maritime Containers (30 m³ capacity)		
Contaminated press-filter canvas	3.0	32
Contaminated Wood	1.5	53
Contaminated metal parts	6.0	82
Other materials	2,5	9
TOTAL	**13.0**	**176**
Metal Boxes (1m³ capacity)	**6**	**6**

The area of the Botuxim storage facility has about 284,000 m^2, where there are 7 silos with ca. 3,500 tons of Cake II stored (Table H.4)

Table H.4 - Amounts of Cake II stored in Botuxim.

Concrete silo number	Mass (ton)
Silo 1	321.48
Silo 2	376.93
Silo 3	374.97
Silo 4	504.32
Silo 5	479.33
Silo 6	778.85
Silo 7	664.19
TOTAL	**3,500.07**

H.2.2.3 - Ore Treatment Unit of Poços de Caldas (UTM)

The first uranium mine of Brazil, which was called in the past of Poços de Caldas Industrial Complex (CIPC), has finished operation and is under preparation for decommissioning. As the licensing process took place before the present radiological protection criteria were established in Brazil, there was no previous planning for the decommissioning phase. The main areas that will need attention include the open pit mining area, the waste rock piles and the tailings dam. Up to this moment, the whole area is still under control by the operator. Radiological control is maintained at effluent discharge points, including at the waste dam and at the treatment units for the water drained from the mining area and from the waste rock piles. At UTM, the following materials and/or by-products are considered tailings, radioactive waste, or raw material:

1. Mesothorium, stored in different conditions, namely:
    a. Disposed of in the waste dam during the 1980's: there are around 13,000 fifty-liter drums corresponding to 1,300 tons of this product.
    b. Stored in five (5) silos excavated in a clay bank at the slope of the UTM waste dam: there are 2,700 fifty-liter drums, corresponding to 280 tons of the material. The silos are lined and covered with a three- meter thick layer of clay and soil. This operation was performed in 1987.
    c. Placed in a trench at the slope of the waste dam, in 1984: there are 5,750 fifty-liter drums, corresponding to a total of 600 tons of mesothorium. This trench is covered with a two-meter thick layer of clay and soil.

2. Cake II
    a. Approximately 11,000 tons of Cake II (wet base) are currently stored
    b. in sheds, packed in 200-liter drums (19,400 units) and 100-litre plastic drums (16,250 units). Other 1,734 tons of bulk Cake II, which were placed in four concrete silos, are now being treated.
    c. Additionally, there are 1,600 200-liter drums of Goianite Cake II
    d. resulting from experiments for the extraction of rare earths from Goianite

mineral, which presents a low thorium content; as well as 3,560 200-liter drums of Cake II, corresponding to 534 tons, stored in silos close to the CIPC waste dam.

e. Finally, there are 824 200-liter drums (124 tons) of Inaremo, named after the process used by Nuclemon for extracting rare earths from Goianite. Inaremo is characterized by a very low thorium content, being a neutralized waste.

3. Thorium
    a. Approximately 80 tons of ThO_2, resulting from Cake II processing in two periods: In 1990, 32.9 tons were disposed of in a pond; in 1995/1996, 46.58 tons were stored in 148 concrete containers.

4. Calcium Diuranate (DUCA)
    a. The treatment of Acid Mine Drainage (AMD) is performed by conventional procedures, by the addition of hydrated lime. The slurry resulting from the process, known as DUCA, is pumped into the mine pit. DUCA is a residue containing uranium. This process accumulated approximately 217,000 tons of DUCA into the pit, with estimate of 308 tons of U3O8.
    b. Chemical composition (results expressed as dry basis):
        - Mud pH: > 11;
        - U3O8: 0,2 % a 0,4 %;
        - Total rare earth: 3 % a 7 %;
        - CaO: 16 % a 30 %;
        - SO4: 14 % a 22 %;
        - MnO: 1,5 % a 7,5 %;
        - Al2O3: 5 % a 11 %;

H.2.2.4 - Uranium Concentrate Unit (URA)

The Uranium Concentrate Unit is located at the uraniferous province of Lagoa Real in the Center-South region of the state of Bahia. The ore bodies have average U_3O_8 concentrations of about 0.22%. Mining activities, developed at an open pit cast, ended in 2014 and the underground mode of mining is following nuclear licensing procedures required by CNEN. These activities are expected to continue for over 9 years. Uranium extraction is made by the Heap Leach method. The efficiency of solubilization of this method is estimated to be about 78%. The exhausted ore is disposed of in piles along with the waste rocks from the mining activities. The leachate is captured in holding tanks that are lined with geo-synthetic membranes (HDPE). The liquor is then pumped to the milling unit where uranium is isolated by means of organic solvent extraction and then precipitated as ammonium di-uranate.

The licensing process focused mostly on the aerosol and gamma exposure pathways, because the facility avoids the release of liquid effluents to the environment, since the processed and collected waters are usually pumped back to the process. Thus, no major impacts are expected in the local rivers, which are not perennial. On the other hand, subsequent facts showed that impacts into the aquifers need attention since these water bodies are also the source of water to local communities. Besides the influence of mining activities on groundwater, other pollutant sources have to be assessed like the waste-rock/leached ore piles as well as the leaching tanks. In order to assess any impact into groundwater, a monitoring program is carried out by the mining operator under regulatory surveillance. Groundwater samples are collected monthly from monitoring wells placed close to the area of direct influence of the facility and close to the population groups living at the site surroundings. Runoff samples are also collected close to the main sources to determine the concentrations of dissolved radionuclides, assessing the drainage contribution to groundwater pollution.

Data from environmental monitoring carried out by the mining operator, under regulatory surveillance, are collected from around 64 sampling sites at 27 surrounding communities. There are also 190 sampling sites around the facility (plant, mine, waste rocks and leached ore), and comprise the following media: surface water, rain drainage, groundwater, rainwater, aerosol, radon, air quality, gamma exposure (TLD), sediment, soil, agricultural product and weather data.

The objectives of the monitoring control are: (1) to keep under control the radionuclide fluxes from mining and milling activities to atmosphere and groundwater compartments, according to the release limits prescribed in the nuclear licensing, (2) to assess the potential impacts of the pollutant sources by means of mathematical simulation and (3) to establish the overall environmental management strategy for the uranium production.

H.2.3 - NAVY FACILITIES

As already mentioned in **D.4**, the amount of waste that has been generated by the naval programme so far is very small. The solid waste generated in the controlled areas is stored in standardized two hundred-liter metallic drums, which, after being identified, are transferred to a Radioactive Waste Storage Facility, situated on the site of CEA. Liquid waste is treated in thermo-solar evaporators and the sludge is later classified as solid waste. Handling, storage and accounting of the waste are under responsibility of the Radiation Protection Division.

The aforementioned storage facility is a small buiding measuring 18 m long by 9.2 m wide, with steel frame, concrete brick walls and metallic roof. The facility is provided with natural ventilation, fire protection and physical protection equipment, and a drainage system to avoid flooding.

The initial storage capacity of the facility was 224 two hundred-liter drums. However, in 2012 a study was submitted to CNEN, with a new arrangement of drums, consisting of piles of up to three (3) drums each. This new arrangement will allow the storage capacity to increase up to 336 two hundred-liter drums.

The current waste inventory is presented on the table below.

Table H.5 - Waste Inventory at CEA

Type of Waste	Mass (kg)	Number of Drums
SC	5,361.4	91
SNC	6,416.5	125
TOTAL	**11,777.9**	**216**

SC: Solid combustible Compacted
SNC: Solid non-combustible non-compacted

H.2.4 - CNEN INSTITUTES

H.2.4.1 - IPEN

IPEN has been storing the radioactive waste generated in its own installations since the beginning of operations in 1956.

The Radioactive Waste Department (GRR) is responsible for receiving, treating and temporarily storing radioactive waste generated at IPEN, as well as those generated at many other radioactive facilities all over the country. The main features of the GRR include units for: waste reception and segregation; decontamination; liquid waste immobilization and conditioning; in-drum compaction of compressible solids; spent sealed source and lightning rod disassembly; primary and final waste characterization; storage of untreated and treated wastes. The existing facility, an Integrated Plant for Treatment and Storage of Radioactive Waste, has a total built area of 1,450 m^2 and comprises the following units:

- *Changing rooms and radiation protection control*: To allow controlled access to the working area.
- *Reception and segregation unit:* To receive, classify and distribute the waste to proper treatment. If necessary, waste segregation is carried out.
- *Liquid waste storage and treatment/conditioning unit*: Equipped with suitable containers or devices for operational storage and pre-conditioning of liquids, either for immobilization or for release to the retention tanks for further discharge to the sewage system.
- *Cementation unit:* Cementation was the process chosen for conditioning and encapsulating some kinds of wastes such as liquids, wet solids, including ion-exchange resins and activated carbon generated in the reactor operation, sludge, biological and some non-compressible waste.
- *Compaction unit:* Equipped with a 10-ton hydraulic press. Compressible solids are collected in 60 litter transparent polyethylene bags and pressed into 200 litter metallic drums. The volume reduction factor is about 4-5.
- *Lightning rod dismantling unit:* Provided with a three-cell glove-box, where ^{241}Am sources are removed from the devices and packaged in metallic containers.

- *Disused source encapsulation unit*: Designed to handle source activities up to about 4 TBq ^{60}Co equivalent. Sources will be withdrawn from original shielding or device and encapsulated in a retrievable package for interim storage.
- *Analytical and radiochemical laboratories:* For characterization of primary wastes and waste forms.
- *Storage facility.* For interim storage of drums containing treated waste.

The wastes managed at IPEN are characterized by a wide diversity in nature, forms, radionuclide contents and activities, so that, for some types of waste, specific methods of treatment and conditioning had to be developed.

In general, solid and liquids wastes are treated and packaged in 200 liter steel drums, as follows:

- Compressible solids: segregation at the generator installation, compaction and package.
- Non-compressible solids: dismantling and, if necessary, encapsulation in concrete.
- Wet solids: chemical conditioning and immobilization in cement.
- Liquids: Wastes of short half-lives are discharged to the sewage system as liquid effluents after temporary storage for radioactive decay; releases meet the proper radiation protection standards. Wastes of longer half-life are immobilized in cement matrix.

Lightning rods with ^{241}Am sources were manufactured in Brazil until 1989. In that year, CNEN issued a resolution lifting the authorization for manufacturing of such devices. Since then, radioactive lightning rods are being replaced by regular lightning rods. The radioactive lightning rods removed are delivered to IPEN or to other installations of CNEN. The estimated amount of lightning rods to be collected is about 80,000 pieces. From this amount, IPEN has already collected about 12,000 and dismantled almost all of them. Smoke detectors are also dismantled and about 49,000 units have been treated until now.

Disused sealed sources represent for IPEN and CNEN by far the largest waste problem from non-power applications, specially due to the long lived radionuclides such as ^{226}Ra and ^{241}Am. Sources with low activity or low exposure rate received until 1993 are already conditioned and immobilized in cement as well as the ^{226}Ra needles collected up to that date, meaning in the last case about 1,000 needles or 200 GBq. Currently, this process has been replaced by packing the sources in a retrievable package. The spent sealed sources dismantling and conditioning unit was concluded in 2016 and the start-up tests were carried out successfully. The operation licence was solicited at the end of 2016 and now it is waiting the approval of regulatory body, DRSN/CNEN. In total, GRR has received about 14,800 sealed sources and treated 28% of them.

The facilities for waste management are located inside IPEN, as part of its several nuclear and radioactive installations, properly certified by CNEN.

H.2.4.2 - CDTN

CDTN’s waste treatment and storage facilities, as well as the laboratories are shown on Table H.6. In Figures H.2.a and H.2.b are presented some CDTN facilities used to treat radioactive waste.

Table H.6 - CDTN Waste Treatment Facilities

Facilities	**Characteristics**
Chemical treatment	200 L batch, main components: tanks, filters, pumps, control panel and sample system
Cementation, out-drum mixture	200 L batch, main components: tanks, mixer, pump, automatic weighing system and control panel
Compaction	16 t press
Cutting/shredding	Cutting mill, output 80-130 kg/h
Lightning rod dismantling	Glove box equipped with unbolting system, electrical scissors and other tools
Nuclear gauge dismantling	Hot cell with shielded windows, manipulators, pneumatic system, and control panel
Package testing	Facilities for Type A and Type B package testing
Heater system	Tank with heater device for about 600 L solution
Supporting laboratories	**Main equipment sets**
Chemical treatment	Lab hood with filtration system, pH meters, analytical scale, pumps, jar-test equipment, magnetic stirrers
Cementation	Lab hood, glove box, lab oven and many equipment sets using for physical-chemical and mechanical tests
Thermo differential analysis	Room with the suitable equipment to carry out the analysis.
Storage facility	**Description**
DFONTE - Storage building for treated wastes and disused sources	450 m^2 surface hall with control system for effluents, fence, natural ventilation, appropriate lighting and alarm system
DRNT – Untreated Waste Storage Facility	90 m^2 surface hall with control system for effluents, shelves, appropriate lighting and ventilation.

Besides the radioactive waste generated at its own laboratories, CDTN has received disused sealed sources from other users, like industries, hospitals and universities. These sources include radioactive lightning rods, smoke detectors, nuclear gauges and teletherapy units, which are stored at CDTN's storage facility (DFONTE). The main nuclides are ^{60}Co, ^{137}Cs, ^{226}Ra, ^{241}Am, ^{241}Am-Be,^{85}Kr and ^{90}Sr.

The strategy devised and implemented for the management of radioactive waste at CDTN is based on the standard CNEN-NN-8.01 [25] and takes into account the available infrastructure. The main aspects of the management program are:

- waste generation minimization by an adequate segregation and characterization;
- volume reduction by chemical treatment for the aqueous liquid waste and compaction and cutting for solid waste;
- cementation of sludge arising from the chemical treatment and immobilization of the non-compactable solid waste in cement/bentonite matrix;
- quality control of the final product in order to guarantee safety during storage and to minimize doses to workers and individuals of the public;
- registry of the waste and disused sealed sources inventory using an electronic database.

Segregation is carried out taking into account the physical, chemical and radiological characteristics of the waste. The liquid waste is segregated into aqueous or organic and the solid waste into compactable and non-compactable. Besides, waste containing short-lived radionuclides is segregated from the ones with long-lived radionuclides, the former being stored for decay and then released from radiological control. Each waste package is identified according to the origin and type of waste.

After being monitored, the segregated waste is transferred to the treatment facilities. All relevant data, like origin, composition, volume or weight, chemical contaminants are registered in a specific form – GUIARR.

(a) (b)

Figures H.2 - (a) Package testing (b) Cementation Laboratory

Regarding to sealed source, lightning rod and smoke detector management, the guidelines are:

- To provide suitable conditioning of brachytherapy and teletherapy sources. The later ones are stored in their original shields;
- To dismantle the lightning rods, smoke detectors, and nuclear gauges and to remove the source in order to reduce the stored waste volume. The sources from the gauges are assessed for possible further use.

A glove box for dismantling of the ^{241}Am lightning rods and smoke detectors is operational at CDTN (Figure H.3). A hot cell for dismantling nuclear gauges is in operation at Laboratory for Treatment of Sources. The removed sources are checked for leaks and their activity is determined for possible reuse.

Figure H.3 – Glove box equipped to dismantle lightning rods

Concerning the ^{226}Ra sources, they are conditioned to maintain retrievability. The sources are inserted in leak-proof stainless steel capsules, which are placed in lead shields; once loaded, the shields are put inside the cavity of an internally shielded 200-liter drum.

The waste packages are identified, monitored and stored at DFONTE. The relevant packages data are registered in a specific form - GUIART. The information of both forms - GUIARR and GUIART - is used as input into the Waste Database of CDTN, where complex searches can be performed and all information about the stored waste inventory can be easily retrieved. Another database - named SISFONTE - contains data about the sealed sources from other users received and stored at CDTN. Among other features, this database performs an on-line update of the activity stored.

H.2.4.3 - IEN

IEN stores the radioactive waste generated in its own installations and in other radioactivity users, such as hospitals, industries and research centers. The existing facility for radioactive waste management and treatment in IEN includes a compressive unit for compactable material and a storage facility on an area of 324 m^2. Although it has been planned the construction of a laboratory for liquid waste treatment, its implementation was halted, once it was detected the need to develop further specific skills in the staff to operate this type of facility. Currently, the only treatment implemented is compacting solid waste and natural decay. The compactable material is stored in 200 l drums, the same drums are used to the sealed sources.

All the strategy for the management of radioactive waste at IEN is based on the safety regulation CNEN-NN.8.01 [25] and takes into account the available infrastructure.

There is only a simple waste characterization, TRING, whenever possible, reducing its volume, so it can be packaged in a 200-liter steel drum and storing at the proper unit. Liquid waste is simply identified and stored in a different area while expecting a treatment unit to go into operation.

H.2.4.4 - CRCN-NE

CRCN-NE stores radioactive waste generated by radioactivity users, such as hospitals, industries and research centers. The existing facility for radioactive waste management and treatment includes a compressive unit for compactable materials and a storage facility on an area of 366.5 m^2. It is planned the construction of a laboratory to dismantle the smoke detectors and remove the source, in order to reduce the waste volume stored.

H.2.5 - WASTE REPOSITORY AT ABADIA DE GOIÁS

For the repository of the waste from Goiânia accident, also the 0.3 mSv/y dose constraint defined by the Regulatory Body based on regulation CNEN-NN-3.01 [12] was used during the design of the installation. As the installation contains two buildings, each one related to different activity concentration of ^{137}Cs in the waste, as already described in this report. The design basis for the first repository (Waste Group 1) a dose limit of 0.05 mSv/y has been applied to critical members of the public while a level 0.25 mSv/y was used to the main repository, in agreement with the Technical Instruction CNEN IT-01/91 [16].

H.3 - SITING OF PROPOSED FACILITIES (*Article 13*)

H.3.1 - NUCLEAR POWER PLANTS

The On-Site Storage facility was built at the north side of the Angra site.

The Storage Facility 1 of the on-site storage facility was built in 1981. The Storage Facility 2 is composed by the old Storage Facility 2A constructed in 1992 and a Storage Facility 2B constructed in 2009.

To erect the Storage Facility 2B, IBAMA, the national environmental agency, required an Environmental Impact Study, which was submitted and accepted. The Environmental Operational License was issued in 2007.

Together with the Storage Facility 2B, in 2009, a third storage facility (Storage Facility 3) was constructed.

To improve the waste management facilities, a Monitoring Building is being planned. This building will be constructed between Storage Facilities 1 and 2 and will hold all the equipments and operations related to the new system of waste packages measurement (Gamma Segmented Counter System) for the waste isotopic inventory determination.

This area is part of the south-eastern part of the Brazilian Platform. Studies made in 1982 had demonstrated that there is no sign of failure occurrence or another tectonic activity in the region of Itaorna beach, since the inferior cretacic period.

The storage facility area was constructed on 13,000 m^2 “plateau”, as the result of a rock quarry excavation in the Ponta Fina hill.

Engineering measures were implemented in the vertical rocky slope and top of the hill, based on geological-geotechnical mapping.

In order to improve the safety of the upstream slopes of the storage facilities areas, a contention gabion walls and soil nails with gunite concrete were performed, as well as superficial draining system was implemented.

Given the geologic formation of the region, predominantly crystalline rock, there is little possibility of underground water.

Specifically, the hillside where the storage facility is located was technically certified for stability and safety conditions.

In addition, a Storage Facility for the replaced old steam generators from Angra-1 was constructed close to the site dock and within the site boundary and the replacement was concluded in 2009.

Regarding to the spent fuel storage for Angra-1 and 2, and in the future for Angra-3, complementary dry storage unit is being implemented in order to complement the current on-site storage capacity of the plants. This installation is under Eletronuclear responsibility. The design bases of this solution is a Canister basis Dry Storage System, widely used by American Nuclear Power Station in USA. This complementary storage unit will be located in an area between Angra-2 and 3, and will be a shallow foundation structure on sound rock

H.3.2 - LOW AND INTERMEDIATE LEVEL WASTE REPOSITORY

The present Brazilian nuclear scenario consists of two nuclear power plants (NPPs) in operation – Angra-1 and Angra-2, and one under construction – Angra-3, one nuclear fuel fabrication plant and facilities that use radionuclides in the industry, medicine, R&D activities and agriculture. For the future it is also forecasted the construction of four other NPPs and expansion of the present nuclear fuel cycle installations, in accordance with the Federal Government's plans. The operation of those facilities during this century and their decommissioning shall generate radioactive waste enough for justifying the construction of a national repository for low and intermediate radioactive level waste.

In accordance with Brazilian Law 10308 of 2001, which establishes the responsibilities, and the licensing and funding provisions for waste management and final disposal, DPD/CNEN has the responsibility to provide the country a facility to dispose of all radioactive waste generated in Brazil.

In addition, in the Previous License for the construction of Angra-3 NPP, the Brazilian environmental authority (IBAMA) requested that the licensing application for the low and intermediate level waste Repository must have been carried out before the startup and the operation of Angra-3. Due to political and financial issues the construction was interrupted, and there is a prevision to be restarted in 2018.

In November 2008, CNEN decided to propose a project to implement a repository in Brazil for low and intermediate- level radioactive wastes. In November 2009 is signed the project charter of the Project RBMN aiming at having a licensed and commissioned repository to dispose of those wastes. The waste inventory to be disposed of includes those from the NPPs operation, from nuclear fuel cycle installations, their decommissioning and from the use of radionuclides in medicine, industry and R&D activities. Material classified as NORM is not foreseen to be disposed of in this repository.

The RBMN Project has the objectives to establish, control and execute all the tasks for the implantation of the Brazilian Repository, since its site selection, through the conceptual and basic design until its construction, startup and commissioning. The design concept will be a near-surface multi-barrier repository constructed in compliance with the currently existing waste inventory and the radioactive wastes that will be generated in the future.

The repository project is part of the Brazilian solution for the disposal of radioactive waste generated by the nuclear energy activities in Brazil. Presently the crucial phases for the project success are site selection, public acceptance and environmental and nuclear licensing.

The site selection is currently in the step of candidate sites. Regions of interest have already been identified and the sequential criteria to eliminate the non-acceptable areas were applied, the present remaining areas are being considered as the preliminary candidate sites. However, there is a Governmental recommendation for giving priority to areas from its own property, whenever it is technically possible. A report presenting the site selection process is now being analyzed by the nuclear regulator (DRSN/CNEN). The final decision of the candidate areas depends on the Nuclear Regulatory Body requirements. These areas will be studied and one site will be selected based on the geological survey and on other properties in compliance with the technical criteria, and of course, taking into account the aspects related to public acceptance.

H.4 - DESIGN AND CONSTRUCTION OF FACILITIES (*Article 14*)

Design criteria and conception of the radioactive waste facilities are based on comprehensive survey on the volume and physic-chemical and radiological characteristics of the waste to be received and managed in the life of the facility, and an estimation of the future demand.

H.4.1 - NUCLEAR POWER PLANTS

Angra waste is mixed with cement or bitumen before transfer to the On-site Storage Facility. This operation is performed under requirements for protection of the workers, the public and the environment, according to approved plant procedures.

All packed radioactive waste are monitored to assure that the surface dose rate, for transportation, does not exceed the established values in regulation CNEN-NE-5.0 [15] and the resultant occupational exposure and contamination are in accordance with the values established in regulations CNEN-NN-3.01 [12] and CNEN-NE- 8.01 [25].

The waste is stored according to a previously established layout, to reduce the dose rate in external areas of the building.

The possibility of the environmental contamination in terms of the storage is remote, since all the waste is in the solid form and is conditioned in certified containers. For additional precaution the units of storage are equipped with ventilation systems to assure negative pressures (including high efficiency filtering system) and internal drains directed to sumps subjected to inspections and release control.

The inventory control of the stored waste is made with the aid of validated managing software. The data bank includes information on the physical, chemical, radiological and mechanical features of the packed waste.

Periodic visual inspections are performed to verify possible alterations in the stored packed waste. Moreover, monthly inspections are performed on the general conditions of the building and the installations.

For Storage Facility 2 and Storage Facility 3, the following systems are installed:

- Remote automatic visual inspection equipment;
- On-line external radiation monitoring system;
- Ventilation system to assure negative pressures, including high efficiency filtering system;
- Internal and external drainage systems.

The storage facility for the old steam generators is equipped with on-line radiation monitoring system, ventilation system and drainage systems.

H.4.2 - INB FACILITIES

At INB, specifically at the operational facilities of FCN and URA all waste, after monitoring, go through a segregation process, in order to be separated in drums according to their characteristics. After the selection, the waste is packed up, in identified drums, and they are stored within the facility.

All drums containing radioactive waste are monitored to assure that the surface contamination does not exceed the values established in the regulation CNEN-NE-5.01 [15] and that the resulting occupational exposures are in accordance with the limits established in the regulations CNEN-NN-3.01 [12] and CNEN-NN-8.01 [25].

H.5 - ASSESSMENT OF SAFETY OF FACILITIES (*ARTICLE 15*)

A comprehensive safety assessment is a requirement established by the licensing regulation in Brazil [3].

H.5.1 - NUCLEAR POWER PLANTS

For the Angra-1 and Angra-2 plants, a Final Safety Analysis Report (FSAR) were prepared. For the Angra-3 plant, a Preliminary Safety Analysis Report (PSAR) was also prepared. The FSARs and PSAR followed the requirements of US NRC Regulatory Guide 1.70 - Standard Format and Contents for Safety Analysis Report of LWRs.

Chapter 11 of the FSAR deals with radioactive waste management issue, including waste generation, treatment, in plant storage and the radiation protection aspects.

These reports were reviewed and assessed by CNEN, and extensive use was made of the US NRC - Standard Review Plan (NUREG - 0800).

H.5.1.1 - Onsite Storage Facility

Before the start-up operation of Angra-1 the documentation for the installation of the Storage Facility 1 of the On-Site Storage Facility, establishing the design, security and radiological protection plans, was submitted and approved by CNEN. The Storage Facility 1 was built in 1981. Later, the Storage Facility 2A module was also approved by CNEN and built in 1992.

To erect the Storage Facility 2B, besides the CNEN license, IBAMA, the National Environmental Agency, required an Environmental Impact Study, which was submitted by Eletrobras Eletronuclear (ETN) and evaluated by IBAMA. The Operational Licence for Storage Facility 2 was issued by IBAMA in December 2007 and in January 2009 by CNEN.

The safety and environmental licensing procedures for the construction of the Storage Facility 3 was concluded in the beginning of 2009. This process included:

- A safety evaluation submitted to the Nuclear Regulatory Commission
- An environmental impact study
- An environmental impact report
- A set of Public Hearings for discussions with the Public and local and state Organized Society Members.

H.5.2 - OTHER FACILITIES

H.5.2.1 - Fuel Cycle Facilities

The management of radioactive waste is considered a part of the Safety Analysis Report of all fuel cycle facilities. The information submitted is evaluated by CNEN during the licensing process.

H.5.2.2 - Radioactive Waste Repositories

As mentioned above, the environmental licensing process of any waste repository in Brazil is responsibility of the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA). When radioactive waste is involved, CNEN acts in accordance with IBAMA, assisting this institution in nuclear matters.

In the implementation phase of the National Repository for Radioactive Waste, the Directorate for Radiological Protection and Nuclear Safety (DRSN/CNEN) is in charge to assess all documents related to nuclear safety and also to perform the evaluation of the Safety Analysis Report of the installation.

Some projects were implemented by CNEN in the field of safety assessment of final disposal facilities. The main one was developed under the assistance of the IAEA. This project was aimed to improve the national capability for assessing the safety of waste disposal facilities, and for this purpose, a multidisciplinary expert group was created and was trained in safety assessment methods, including the use of the relevant computer codes as well as laboratory and field measurements techniques.

Besides, in 2002 the International Atomic Energy Agency (IAEA) launched a coordinated research project in the field of safety assessment for near surface radioactive waste disposal facilities (ASAM – Application of Safety Assessment Methodologies for Near Surface Waste Disposal Facilities) with the participation of Brazilian experts. The primary objectives of the project were to investigate the application of methodologies used for post-closure safety assessment, in particular the methodology developed under the IAEA’s ISAM project, to a range of near surface disposal facilities; and to develop practical approaches to assist regulators, operators and other specialists in their review of such safety assessment.

Further, CNEN is participating in the IAEA working group of international experts in radioactive waste management and decommissioning with particular emphasis on strategies, implementation technologies and methodologies called WATEC – International Radioactive Waste Technical Committee. The main functions of WATEC, among others, are to provide advice and guidance, and to marshal support in their countries for implementation of Agency's programmatic activities in the area; to act as a link between the Agency's activities in this area and the scientific communities; to develop and review selected documents for the Nuclear Energy Series; and to provide support to Member States for planning and implementing radioactive waste management and decommissioning activities

The Waste Management Division (DIREJ), under DRSN/CNEN structure, is responsible for the Safety Assessment of waste disposal facilities and, and, as previously mentioned, is composed by a multidisciplinary expert group with 6 PhDs, 6 MSc, 9 graduates and 3 technicians. In this sense, DIREJ has reviewed a number of safety assessment reports originated from nuclear and radioactive facilities across the country. This Division has also developed a publication and training material that covered the principles of safety assessment to regulated agents and research institutions, thus disseminating the safety assessment culture among the operators of nuclear and radioactive facilities, in order to improve the technical quality of the safety assessment reports. DIREJ staff has been continuously trained in several IAEA training courses in related areas.

H.5.2.3 - Safety Assessment of Goiânia Repositories

CNEN conducted three safety assessments of the Goiânia repositories, one in the year 1995, one in the year 2002 and another one in the year 2014, as described below.

- **The First Safety Assessment (1995)**

A robust model or screening model was developed considering that one of the main scenarios for the prediction of the impact of a near surface repository is related with the water pathway. The following scenarios related with the water pathway were considered:

(a) water ingestion;
(b) ingestion of contaminated vegetables due to water irrigation;
(c) ingestion of contaminated animal;
(d) inhalation of contaminated soil due to irrigation;
(e) external irradiation due to contaminated soil.

The dose factor was calculated considering a steady concentration of 1,000 Bq/m^3 in the well water, the scenarios above, resulting in:

- Annual Effective Dose = 4.19×10^{-5} Sv;
- Committed Effective Dose = 2.93×10^{-3} Sv.

Three pathways were also considered for intrusion. The following hypotheses were considered for the geosphere:

- The establishment of an Institutional Control Period;
- The continuous linear degradation of the cap, after construction of the repository allowing a higher infiltration rate each year (after 30 years the cap would completely fail);
- The infiltration rate at the surface of the cap would be only a function of the water balance between water fall and evapotranspiration;
- The unsaturated zone thickness bellow the repository bottom at the beginning of the analysis was neglected;
- The concentration inside the repository in the water phase, each year, was calculated taking into consideration the adsorption coefficient of the waste (k_d) and the available quantity of water, which is a function of the water balance and the permeability of the cap.

Two cases were studied:

- Model 1: Neglecting the permeability of the top of the vault due to the concrete thickness and applying Darcy law on the bottom of the repository to calculate the flow to the water table;
- Model 2: Neglecting the permeability of the top and bottom of the vault and considering that all the water infiltrated each year leaches the waste based on the adsorption coefficient and flows to the aquifer.

A plume model was used in the aquifer.

➢ Reassessment of the Goiânia Repositories (2002)

The source term considered on this model was conservative: an annual leaching fraction of the waste considers that all the water that enters in the repository leaves the disposal and enters the geosphere (neglects cap and the engineered barriers).

The unsaturated zone thickness below the landfill was considered only at the end of the analysis, based on a transit time.

The model adopted for the saturated zone, to be coupled with the source term, takes into consideration the well-known one dimensional transport equation including dispersion, retardation and decay of the contaminant in the aquifer.

The same data for the geosphere and biosphere used in the 1995 safety assessment was used in the 2002 assessment.

For modelling the biosphere, two kinds of scenarios were considered:

(a) Intrusion on the site resulting in: (i) direct inhalation of particulate due to contaminated soil, (ii) deposition on vegetables and ingestion by man; (iii) deposition on vegetables, ingestion by animals, meat consumption by man; (iv) deposition of grass, ingestion by the cow, transfer to milk and ingestion by man;

(v) ingestion of contaminated soil due to resuspension and (vi) external dose due to the radioactive hazardous materials.

(b) A residential scenario, that is, the existence of a house near the site (at the border) using water from a well, resulting in: (i) Irrigation, re-suspension and inhalation; (ii) direct consumption of the well water – ingestion; (iii) irrigation of vegetables and consumption by man; (iv) irrigation of vegetables, consumption by animals, consumption of contaminated meat by man; (v) surface water contact, transfer to fish and to man; (vi) irrigation of vegetables, consumption by animals, transfer to milk and ingestion by man; (vii) irrigation and accidental ingestion of contaminated soil; (viii) irrigation and external exposure in the case of radioactive

It should be pointed out that an agriculture scenario can only occur when the engineering barrier is completely destroyed (the concrete is transformed in sand and mixed with the waste). Many countries establish a period between 300 and 500 years for the complete transformation of the concrete barriers, although cracks and modification on its permeability can occurred before this period of time. The results showed that, after approximately 280 years, the doses related to a probable agriculture scenario would be lower than the established limit for intrusion of 1 mSv/y. It should also be pointed out that on the post drilling scenario analysis a limit of 1 mSv/y is used, resulting in the necessity of establishing an institutional control period of 50 years, confirming the results obtained in 1995.

Based on a discovery scenario, a limit dose for intruder of 5 mSv is applied due to a single acute dose and an institutional control period of 40 years would be necessary (in the case of no waste dilution). Under the assumption of 0.25 dilution factor no institutional control period is necessary in this case.

The safety re-assessment of the Goiânia repositories confirmed the results obtained in 1995, as follows:

- The water pathways related to a possible residential scenario near the site is negligible when considered the retention factor (transit time of ^{137}Cs) of the unsaturated zone (natural barrier). The maximum concentration below the repository, at any time, would be under the maximum allowed value of 25,000 Bq/m^3 – (6.8 x 10^{-7} Ci/m^3), that could result in a dose for an individual of the critical group of 0.25 mSv/y;
- The consumption habits of the individual of the critical group was over estimated when compared to the real consumption habits of the population nearby the site today;
- Three intrusion scenarios were considered and the most critical one would be the agriculture scenario. If this is assumed to happen only after the complete degradation of concrete (300 to 500 years), it would be of no importance, since after 280 years the doses would be lower than the allowed limit of 1 mSv/y. If in the case of Goiânia the concrete transforms into sand before the usual time of 300 to 500 years, an institutional control period of approximately 280 years would be necessary;

- If one neglects this possibility (degradation of concrete in time lower than 300 years) the most important scenario would be the post drilling scenario and an institutional control period of 50 years would be necessary;
- It should also be pointed out that the results of seven years of Environmental Monitoring Program (PMA) at the site proved that it is very unlikely to find in the future concentrations of ^{137}Cs in the aquifer which will be dangerous to the population living near the site (Concentrations lower than the detection limit of 200 Bq/m3 - 5.4 x 10^{-9} Ci/m^3 were obtained until today).

- **The Third Safety Assessment (2014)**

The same assumptions of the second safety assessment were adopted in the third one. The conservative model also neglects the cap and the engineered barriers of the repository and considers the unsaturated zone thickness below the source to calculate a transit time and a decay factor which was employed at the end of the analysis.

The mathematical model for groundwater contamination considers the one-dimensional Advection-Dispersion solute transport equation in semi-infinite medium coupled with a mixing zone just below the unsaturated zone throughout a third type boundary condition, and the equilibrium between solid and liquid phases. An exact solution for the ADE was implemented and all calculations were performed in Mathematica platform.

A Latin Hypercube Sampling (LHS) algorithm was also implemented in Mathematica platform and used to perform an uncertainty analysis on the distribution coefficient, Kd, which has a direct influence on the leaching of Cs-137 from the source-term and on the solute transport into the aquifer. A set of Kd values was generated based on the Cumulative Distribution Function for the log-normal distribution of Kd, recalled from the original work of Godoy and Pereira (1993), which estimated values of Kd from 61 samples of Abadia de Goiás soil, at repository site. The estimated Kd values are within the range from 100 cm^3/g to 2200 cm^3/g.

The same data for the geosphere and biosphere used in the 1995 and 2002 safety assessments were used in the 2014 assessment. However, only the residential scenario was chosen to model biosphere contamination (the same from 2002 assessment). The model considers a house near the border of the repository using water from a well.

The results from 600 simulations are presented on Figure H.4, where the source and aquifer Kd values were pseudo randomly generated by the LHS algorithm. The results correspond to the annual doses at x=3 m from the source. One can observe that the 95th percentile results are below the limit of 0,25 mSv/y (horizontal red line) allowed for this repository, with maximum value obtained at approximately 120 years. The mean is one order of magnitude below this percentile. The maximum predicted annual dose is approximately 1 mSv/y, three orders of magnitude higher than the maximum dose rate calculated using the same Kd values of the other safety assessments. These results do not consider the retardation and decay due to the unsaturated zone. If one considers the solute transit time in the analysis, these results would be multiplied by a factor of 6. x 10^{-5}.

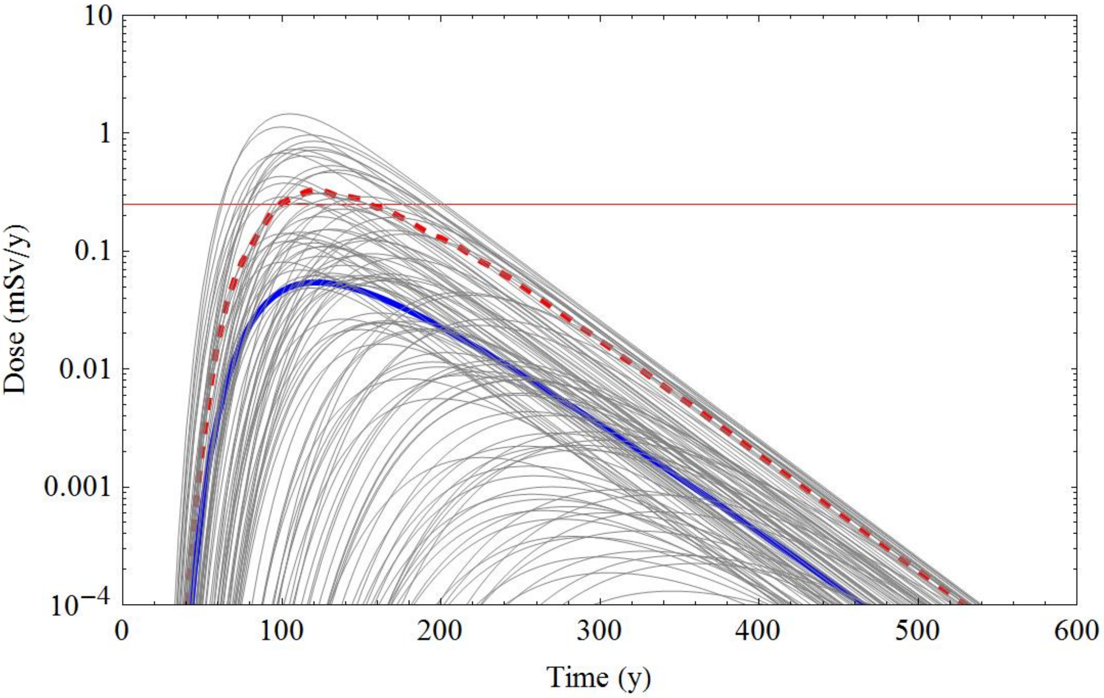


Figure H.4 – Uncertainty analysis on the source and aquifer distribution coefficients: annual doses at x=3 m from the source term.

The results obtained at other positions are of the same magnitude of the respective results calculated in 1995 and 2002, when using the same Kd values. The dose rates calculated at 10 meters from the border are 10-14 times lower than the dose rates at the border of the repository, showing that the groundwater pathway can be neglected in further analysis.

The intrusion scenarios were not considered in this assessment, however they will be included in the next one, to be presented in 2022. The 1995´s and 2002´s intrusion scenarios will be updated based on the international knowledge developed during the last decades. The next assessment will be based on the probably improved local data such as: (i) geosphere information (ii) demographic grown information; and (iii) variation of possible consumption habits by the population, and it will be important to confirm the established institutional control period of 50 years.

H.5.3 - INB FACILITIES

At the FCN facility, the low level nuclear waste is packed in 200-liter metal drums. The FCN's Low-level Waste Storage Facility (DIRBA) was designed in two modules. The Module I has been already built, with an area of 325 m^2, with the maximum design capacity of 444 drums for solid wastes and 120 drums of liquid waste.

At the URA, it was built a unit for the decontamination of materials, coming from the controlled areas. It is a masonry building, with appropriate facilities to perform the activities of monitoring, segregation, washing and decontamination of these materials.

This building is also prepared to held storage of items not decontaminated, which will be cataloged and arranged according to specific procedures. A future expansion of the installation is possible due to how the unit was built. All wastewater is directed to the wastewater treatment system unit.

H.6 - OPERATION OF FACILITIES (*Article 16*)

The responsible for the safety of the radioactive waste facilities is the operator. Information on the conduct of operation is submitted to CNEN in the corresponding Safety Analysis Report, and is reviewed during the licensing process. The operation is subject to CNEN regulatory inspection programs and audits, and periodical reports have to be submitted according to regulation CNEN-NE-1.14 [5] and specific licensing conditions.

H.7 - INSTITUTIONAL CONTROL AFTER CLOSURE (*Article 17*)

H.7.1 - ABADIA DE GOIÁS REPOSITORY

The institutional control defined after the closure is maintained after the site closure to limit radiation dose to population. It involves record keeping, area delineation, land use restrictions, environmental monitoring program (PMA), inspections and any other corrective action that may be required.

In 1988, the IRD/CNEN, through its Department of Environmental Radiological Protection began the implementation of the Environmental Monitoring Program (PMA) around the interim storage facility for the radioactive waste from the decontamination of the areas affected by the radiological accident of Goiânia.

Due to the need of characterizing the area that would site the repository, the results obtained in that Program for the period between 1988 and 1992 were used as a pre-operational Program for the repositories.

IRD/CNEN continued with the environmental monitoring program until 1996, when the responsibility for the program was transferred to the Midwest Regional Center for Nuclear Sciences (CRCN-CO) of the District of Goiânia.

The program includes a TLD net around the site, and analyses of samples of surface and groundwater, soil, sediments, pasture and milk to determine the quantity of ^{137}Cs.

IRD/CNEN implemented a monitoring control program in 1998, including auditing records related to site monitoring and the duplicate sampling program, that includes all environmental media included in the monitoring program performed by CRCN-CO. Results of this program control program attest the good performance of the laboratory in charge of the monitoring program and the integrity of the repository.

Although not required by regulation, the laboratory of CRCN-CO participates from the National Intercomparison Program sponsored by IRD/CNEN. The results are presented regularly at the annual environmental monitoring report and indicate a good performance.

The repository structures are not supposed to have any release of radioactive material. Therefore, no operational level on activity concentration was defined for the installation. Any increase of the background levels shall be considered as a violation of the integrity of the repository and will demand further investigation of the situation.

According to an agreement formalized between CNEN and the state of Goiás, the institutional control, started in 1998, will be maintained over 50 years with the possibility of being extended for another 50 years.

SECTION I - TRANSBOUNDARY MOVEMENT

I.1 - TRANSBOUNDARY MOVEMENT (*Article 27*)

The Brazilian policy on transboundary movements of spent fuel and radioactive waste follows international practices. According to this policy, no radioactive waste shall be imported into the country.

The following section describes a case of shipment of spent nuclear fuel from a research reactor to the original supplier country.

I.1.1 - SHIPMENT OF IPEN SPENT FUEL TO THE ORIGINAL SUPPLIER COUNTRY

After 40 years of the IEA R-1 reactor operation, 127 Spent Fuel Assemblies (SFA's) had been stored at the facility, being 40 in a dry storage and the other 87 in the reactor storage pool. In 1996, CNEN started negotiation with US-DOE to return the SFA's of IEA-R1 to USA. Finally, in 1998, an agreement was achieved between CNEN and US-DOE and in November 1999 the shipment was successfully performed. This section describes the operational and logistic experience of the SFA's transport.

I.1.1.1 - Companies Contracted for the Transport Operation

The contract between CNEN and DOE was signed in 1998. Edlow International Co. and the German Consortium formed by Nuclear Cargo & Services (NCS) and Gesellschaft fur Nuklear-Service (GNS) were hired to perform the transport. Tec Radion Comercial Ltda (TRION) was subcontracted by Edlow to provide the necessary infrastructure for loading, transporting within Brazilian territory, and customs documents.

The German Consortium provided 4 transport casks (two GNS-11 and two GNS-16), one transfer cask, equipment and experts to handling their equipment. IPEN performed the necessaries tasks to fulfill the Brazilian legislation requirements, such as: the export license, a detailed Transport and Security Plan, safeguards documents, as well as operational and radiological protection support for the entire operation.

I.1.1.2 -Transport Equipment Description

The transport casks were designed in a "sandwich" construction. The cylindrical cask consisted of the following components: inner liner with inner liner bottom, lead filling, wall with bottom plate, side wall cover sheet with spacer wire, head ring, primary lid and protective plate. The maximum weight of the cask was 13,230 kg. The capacity of each cask was 33 spent fuel assemblies.

I.1.1.3 - Fuel Cutting Equipment

Before the beginning of the loading operation, 19 control fuel assemblies were cut 1.27 cm from the cut line to the interior fuel plates. The cutting operation of the five control fuel assemblies stored in the dry-storage was performed in the first floor of the reactor building. For cutting the 14 control fuel assemblies stored in the reactor pool, an underwater saw was used. This tool was specially designed and constructed in Brazil under supervision of Edlow/Trion.

I.1.1.4 - Loading and Transportation

On September 16, 1999, four containers, two with the GNS-11 casks and two with equipment, arrived at IPEN. The two GNS-16 casks arrived on October 7. German experts, supported by IPEN technicians and the transportation company staff hired by Edlow/Trion, removed the equipment from the containers and placed it on a truck, which were transported to the reactor building.

On September 21, the rotary lid was positioned on top of the first transport cask to be loaded, and some cold tests, with a dummy element, were performed. A transfer cask, 4-ton weight was used to transfer the assemblies from the wet storage to the transport cask. The SFAs were lifted from the storage racks inside the reactor pool with a special tool and positioned inside a plastic tube located on a metallic platform located at 2 meters from the pool surface. The transfer cask was submerged inside the reactor pool over the assembly to be removed. The assembly was guided to one of the 33 positions of the cask. After the cask loading, a water tank was positioned above the cask and filled with 4,000 liters of water. Finally, the cask was closed and the water was drained from it and from the water tank. This operation was repeated for the 87 assemblies stored in the wet storage. For the other 40 SFAs stored in the dry storage, the transfer cask was not used.

On October 15 the four GNS casks had been loaded with a total of 127 Brazilian spent fuel assemblies. Then, decontamination procedures were performed. On October 20 all the equipment and cask were removed from the reactor building to the containers. The casks were sealed and controlled by safeguards inspectors from ABACC (Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials) supervised by IAEA.

On November 3, the transport operation was initiated after approval from the Brazilian regulatory bodies (Nuclear and Environmental). The licenses were issued by CNEN and IBAMA (Environmental Brazilian Agency), which required documents relative to transport, radiation, physical protection, and an environmental impact evaluation. Also the GNS 11 and GNS 16 certificates issued by American and German authorities had to be revalidated in Brazil. Opposition from environmental organizations, local politicians and harbor union demanded a comprehensive public information work, including debates and press briefing, to overcome this opposition and avoid legal action against the operation.

On November 4 at down, a huge convoy consisting of 5 trucks (one spare) escorted by Federal, State and County Police arrived in the harbour of Santos. It is also worthy to note that the highway and the main avenues and streets in São Paulo and Santos were closed for traffic during the operation. Loading trucks were available at strategic places, to be used in case of need. Loading of the containers in the ship was concluded in 42 min. Before and during all shipment operation, the workers were monitored by the CNEN radiation protection personnel. At 4:50 am, the ship left the harbour escorted by boats of the federal police. At the exit of the harbour, these boats were replaced by a frigate of the Brazilian Navy, which followed the ship until a distance of 200 miles away from the Brazilian coast. At this point the Brazilian responsibilities over the fuel were terminated.

I.1.1.5 - New Shipment of Fuel to USA

On November 2007, 33 spent fuel elements stored in the IEA-R1 reactor pool and containing uranium of US origin were shipped back to Savannah River Laboratory, South Carolina, USA. This operation, which was very similar to the one of 1999, when 127 spent fuel elements were shipped back to the USA, used a different transport cask LWT supplied by American company NAC.

I.1.2 - PACKING AND REPATRIATION OF US-ORIGINATED SOURCES

In addition to the operations carried out in 2007 and 2010, already described in the previous National Reports, a third operation was carried out to remove from the Brazilian territory disused high activity sealed sources.

The repatriation/exportation operation was conducted at IPEN from September 2016 until March 2017 in order to send to USA and Germany disused sealed radioactive sources (DSRS) categories 1 and 2 stored in Brazil. A NECSA team assisted by the IPEN team removed the DSRS from their original shielding using a mobile hot cell and then conditioned them in special transportation packages.

A total of 86 units were handled but the DSRS of 5 units could not be removed because they were stucked to the units' drawers. Thus, 81 units (1,085.2 TBq) were repatriated of which 78 DSRS (947.9 TBq) were removed from their original units. From these 78 DSRS, fifty five US-origin sources (430.2 TBq) were repatriated to USA and 23 Canadian-origin sources (517.7 TBq) were sold to a Germany recycling company for reuse. Two drawers containing 1 source each (130.2 TBq) were transferred directly to the transport package and 1 whole unit (Alcyon) (7.1 TBq) was transferred directly into the transport package and shipped to Germany for recycling. See Figures I.1, I.2, I.3 and I.4.

Figure I.1 – Teletherapy head pre-dismantling

Figure I.2 – Inserting a teletherapy head in the Mobile Hot Cell

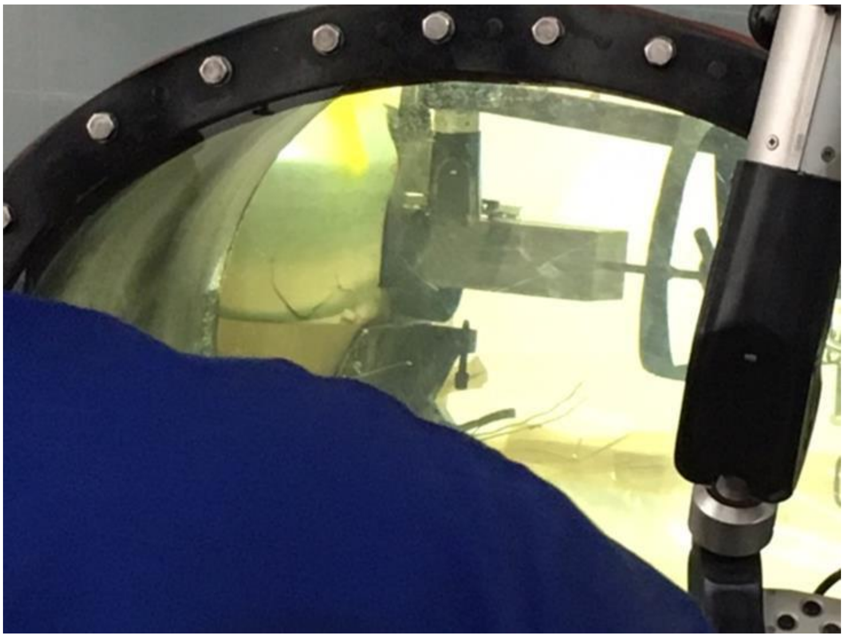


Figure I.3 – Pulling a source drawer from the head

Figure I.4 - Packages ready for shipment

SECTION J – DISUSED SEALED SOURCES

J.1 - DISUSED SEALED SOURCES (*Article 28*)

The Brazilian regulation establishes that disused radioactive sources cannot be stored in radioactive facilities of medicine, industry, research and education, distribution, services or production of radiopharmaceuticals (cyclotrons). CNEN enforces the return of the disused sources to the manufacturer or the transfer of these sources to one of the CNEN's storage facilities, where the sources will be dismounted from its device or shielding for further disposal. To avoid unauthorized removal, these sources are identified and properly stored within controlled areas with restrict personal access. These storage facilities are under a Security Plan and under a periodic inspection program led by Safeguards and Physical Protection Coordination (COSAP) of Directorate for Radiological Protection and Nuclear Safety (DRSN) of CNEN.

All transfer of radioactive sources between radiation facilities has to be authorized by CNEN, and in some cases it is also required the authorization for the transport of the source.

Brazil has implemented several actions for the detection of illicit traffic of radioactive sources. These actions include the training of security forces, customs, and postal company and the use of detectors in the field. At regional level Brazil and the others MERCOSUL (Southern Common Market) and associated member countries, have implemented common policies for prevention, detection and response of the illicit traffic of radioactive sources and nuclear material.

J.1.1 - DISUSED SOURCE STORAGE

The inventory of disused sources stored at CNEN institutes in June 2017 is presented on Table J.1. The occupational rate of the storage facility is also presented.

Table J.1 - Disused sources in storage

Institute	Number of Sources	Total Volume (m^3)	Total Activity (Bq)	Occupation Rate (%)
IPEN	152,530*	100,4	1.28E+14	~25
CDTN	11,864**	52	6.34E+13	~22
IEN	20,085	190	3.24E+14	~51
CRCN-NE	1,068	32	1.76E+14	~21
TOTAL	**185,547**	**374.4**	**6.91E+14**	-

* This includes 137,748 ^{241}Am and ^{226}Ra sources from lightning rods and smoke detectors

**This includes 3,142 and 6,763 sources from lightning rods and smoke detectors, respectively, and also 90 200L-drums with treated wastes

Nuclear medicine installations have usually just weak calibration sources. Disused sources are stored in the installation but the main concerns are towards the quality of those sources still in use.

J.1.2 - PROGRAM FOR COLLECTING OF DISUSED SOURCES AND RADIOACTIVE WASTE

CNEN has the legal obligation to receive and keep in safe storage any kind of radioactive waste, however CNEN has no legal obligation to collect disused sources and radioactive waste.

Nevertheless, after the large radiological accident in Goiânia with a disused ^{137}Cs source in 1987, CNEN contacted all users of radioactive material in the country to participate in the effort to solve the problem of the storage of disused radioactive sources. As consequence, two big campaigns were conducted, one in 1989 for the Northeast and other in 1998 in the South Region to collect disused radioactive sources such as small radium needles, lightning rods, and large sources used in radiotherapy. The sources were later transferred to the storage facilities existing at CNEN institutes, Figure J.1

Currently, CNEN only collects radioactive waste and disused sources in case of a formal request from the owner, after a careful analysis of the request. Normally the majority of requests are related to contaminated material of large volume.

In the last three years, thousands of spent sources were received and stored at CNEN's Institutes, as shown on detail on Tables J.2, J.3, J.4 and J.5.

Figure J.1 - Disused source storage at IPEN

Table J.2 - Number of Received Spent Sources at IPEN - 2014/2017

RAD	Type of Source	Quant	Total Activity (Bq)	Date of Storage
Am-241	Sealed Source	69	3.63E+11	08/2014 to 03/2017
Am-241Be	Sealed Source	3	4.00E+09	12/2014 to 12/2016
Ba-133	Sealed Source	3	1.33E+07	08/2014 to 12/2016
C-14	Sealed Source	1	3.29E+06	04/2015
Cd-109	Sealed Source	1	5.72E+04	08/2016
Cm-244	Sealed Source	1	1.34E+09	11/2014
Co-57	Sealed Source	11	5.96E+07	08/2014 to 12/2016
Co-60	Sealed Source	31	3.07E+14	11/2014 to 10/2016
Cs-137	Sealed Source	209	1.17E+13	07/2014 to 02/2017
Fe-55	Sealed Source	7	2.08E+09	08/2014 to 08/2016
Gd-153	Sealed Source	2	1.45E+05	04/2016
Ge-68	Sealed Source	14	1.13E+07	01/2015 to 12/2016
H-3	Sealed Source	1	6.50E+08	08/2016
Ir-192	Sealed Source	637	2.85E+11	09/2014 to 08/2016
Kr-85	Sealed Source	41	4.87E+11	04/2014 to 09/2016
Ni-63	Sealed Source	69	2.62E+10	11/2014 to 11/2016
Pm-147	Sealed Source	71	1.86E+09	05/2014 to 03/2017
Ra-226	Sealed Source	5	4.45E+07	12/2014 to 02/2016
Se-75	Sealed Source	6	1.56E+10	04/2014 to 11/2016
Sr-90	Sealed Source	15	3.86E+10	09/2014 to 02/2017
Am-241	Lightning rod	516	1.55E+10	04/2014 to 03/2017
Ra-226	Lightning rod	13	4.81E+08	04/2014 to 03/2017
Am-241	Smoke detector	5,756	1.73E+08	04/2014 to 03/2017
	TOTAL	**7,483**	**3.20E+14**	

Table J.3 - Number of Received Spent Sources at IEN – 2014/2017

RAD	Type of source	Quant	Total activity (Bq)	Date of Storage
Am-241	Lightning rod	30	5.5E+9	May/2014 to May/2017
Am-241	Smoke detector	6,167	1.14E+9	May/2014 to May/2017
Am-Be	Sealed source	2	7.4+9	July/2014
Am-241	Sealed source	1	5.79E+11	July/2014
Ba-133	Sealed source	3	9.25E+6	July/2015 to Sept/2016
Co-57	Sealed source	16	1.65E+10	Jan/2015 to July/2016
Co-60	Sealed source	24	5.21E+13	May/2014 to Dec/2016
Cs-137	Sealed source	115	2.12E+12	Mar/2011 to Mar/2014
H-3	Sealed source	6	1.05+10	Jan/2016
Ir-192	Sealed source	9	3.09E+11	Jan/2017
Kr-85	Sealed source	2	7.4E+8	July/2014
Pm-145	Sealed source	1	5.55E+9	July/2014
Ra-226	Sealed source	1	3.33E+7	Dec/2015
Ra-Be	Sealed source	1	1.67E+8	July/2014
Sn-119	Sealed source	92	7.4E+8	June/2015
Sr-90	Sealed source	2	7.4E+8	July/2014 to Dec/2015
	TOTAL	**6,472**	**5.51E+13**	

Table J.4 - Number of Received Spent Sources at CRCN-NE - 2014/2017

RAD	Type of source	Quant	Total activity (Bq)	Date of storage
Am-241	Smoke detector	300	1.11E+7	2014/2017
Am-241	Lightning rods	62	5.36E+8	2014/2017
	TOTAL	**362**	**5.48E+8**	

Table J.5 - Number of Received Spent Sources at CDTN - 2014/2017

RAD	Type of source	Quant	Total activity (Bq)	Date of Storage
Am-241	Alloy Analyzer	1	1.77E+01	07/06/2017
Am-241	Process Analyzer	2	3.21E+03	25/06/2015
Am-241	Process Analyzer	1	1.29E+00	01/12/2014
Am-241	Process Analyzer	3	8.75E+03	16/12/2014
Am-241	Process Analyzer	4	1.03E+04	25/06/2015
Am-241	Process Analyzer	6	3.02E+04	10/10/2016
Am-241	Process Analyzer	3	1.08E+05	17/07/2017
Am-241	Process Analyzer	1	5.38E+03	20/07/2017
Am-241	Density Gauge	9	6.32E+02	12/12/2014
Am-241/Be	Process Analyzer	6	6.49E+04	16/09/2016
Am-241/Be	Process Analyzer	2	2.08E+04	01/11/2016
Am-241/Be	Thickness Gauge	1	1.76E+03	09/08/2017
Am-241/Be	Level Gauge	16	2.84E+05	26/02/2015
Ba-133	Calibration source	1	2.68E+00	28/03/2016
C-14	Chromatography	1	3.70E+00	07/07/2015
Cd-109	Alloy Analyzer	1	8.13E-05	07/06/2017
Cf-252	Process Analyzer	2	4.34E+01	25/09/2014
Cf-252	Process Analyzer	2	2.73E+01	19/11/2014
Cf-252	Process Analyzer	2	3.03E+02	27/03/2017
Co-57	Calibration source	3	2.12E+00	28/03/2016
Co-57	Calibration source	2	1.19E-04	16/09/2016
Co-57	Process Analyzer	2	6.33E+00	20/04/2016
Co-60	Process Analyzer	2	3.23E+03	25/09/2014
Co-60	Process Analyzer	8	2.07E+02	25/06/2015
Co-60	Process Analyzer	19	4.20E+02	16/09/2016
Co-60	Process Analyzer	16	1.76E+02	01/11/2016
Cs-134	Process Analyzer	2	4.04E+01	16/12/2014
Cs-137	Calibration source	1	2.49E+00	28/03/2016
Cs-137	Calibration source	1	2.98E-01	29/08/2016
Cs-137	Calibration source	1	2.12E-02	10/10/2016

Table J.5 - Cont.

RAD	Type of source	Quant	Total activity (Bq)	Date of Storage
Cs-137	Process Analyzer	6	1.29E+04	24/09/2014
Cs-137	Process Analyzer	2	1.20E+04	15/10/2014
Cs-137	Process Analyzer	3	1.76E+04	27/10/2014
Cs-137	Process Analyzer	5	7.51E+03	29/10/2014
Cs-137	Process Analyzer	6	5.72E+04	30/10/2014
Cs-137	Process Analyzer	4	1.33E+04	31/10/2014
Cs-137	Process Analyzer	1	6.98E+02	13/11/2014
Cs-137	Process Analyzer	9	1.24E+04	18/11/2014
Cs-137	Process Analyzer	43	2.20E+05	15/12/2014
Cs-137	Process Analyzer	5	1.45E+05	16/12/2014
Cs-137	Process Analyzer	1	3.75E+04	07/01/2015
Cs-137	Process Analyzer	11	5.84E+04	09/02/2015
Cs-137	Process Analyzer	1	8.16E+02	23/03/2015
Cs-137	Process Analyzer	2	1.95E+03	22/10/2015
Cs-137	Process Analyzer	7	1.13E+03	26/10/2015
Cs-137	Process Analyzer	9	7.78E+03	19/11/2015
Cs-137	Process Analyzer	5	1.14E+04	15/12/2015
Cs-137	Process Analyzer	9	3.86E+04	16/09/2016
Cs-137	Process Analyzer	5	5.44E+02	10/10/2016
Cs-137	Process Analyzer	6	2.80E+04	08/11/2016
Cs-137	Process Analyzer	4	3.59E+04	22/08/2017
Cs-137	Process Analyzer	2	1.12E+04	31/08/2017
Fe-55	Alloy Analyzer	1	1.78E+00	07/06/2017
Fe-55	Process Analyzer	1	1.04E+01	30/10/2014
Ge-68/Ga	Calibration source	3	5.44E-01	02/10/2014
Ge-68/Ga	Calibration source	2	2.76E+00	23/05/2016
Ge-68/Ga	Calibration source	1	1.25E+00	25/05/2016
Ge-68/Ga	Calibration source	6	1.51E+01	19/07/2017
Ge-68/Ga	Calibration source	7	3.14E-01	14/07/2015
Ir-192	Gamagraphy	1	6.10E+01	12/04/2016

Table J.5 - Cont.

RAD	Type of source	Quant	Total activity (Bq)	Date of Storage
Kr-85	Chromatography	1	8.80E+02	07/07/2015
Kr-85	Thickness Gauge	1	7.32E+03	09/03/2016
Kr-85	Thickness Gauge	1	3.44E+03	30/05/2017
Kr-85	Thickness Gauge	1	5.31E+03	22/08/2017
Ni-63	chromatography	1	4.89E+02	02/02/2015
Ni-63	chromatography	1	5.20E+02	07/07/2015
Ni-63	chromatography	2	9.48E+02	06/12/2016
Pm-147	Thickness Gauge	1	3.38E+03	28/08/2015
Pu-238	Process Analyzer	3	3.04E+03	29/10/2014
Ra-226	Unknown	1	1.11E-05	04/10/2016
Se-75	Gamagraphy	2	6.32E+06	21/03/2016
Th-232	Level Gauge	1	1.00E-05	03/11/2015
	TOTAL	**305**	**7.62E+06**	

SECTION K - PLANNED ACTIVITIES TO IMPROVE SAFETY

Safety culture requires a questioning attitude and a search for excellence. Therefore, notwithstanding the good safety record, nuclear operators and regulators in Brazil are constantly working on safety improvements.

In the area of legislation, at present a bill of law is under discussion establishing administrative and monetary penalties to all nuclear facilities and services in cases of non-compliance. This is expected to strengthen the enforcement powers of CNEN.

K.1 - IMPROVEMENTS IN THE NUCLEAR POWER PLANTS

K.1.1 - STEAM GENERATORS

The replacement of the two steam generators of Angra-1, in the beginning of 2009, has improved the plant safety margins and, as a byproduct, has provided a revised safety analysis, with newer methods and codes.

K.1.2 - ISOTOPIC INVENTORY

An Isotopic Waste Characterization Program is underway in order to determine the isotopic inventory, aiming the final disposal.

K.1.3 - FUKUSHIMA RESPONSE PLAN

The Fukushima Response Plan, implemented by Eletronuclear (ETN) for incorporation of the lessons learned from the accident that happened in Japan, comprises:

a. The revaluation of the threats and risks related to the possibility of occurrence of natural disasters in the CNAAA (Almirante Álvaro Alberto Nuclear Power Station) area;
b. Improvements in the structures, systems and equipment that are part of CNAAA, with the purpose of increasing the design safety margins against the possibility of occurrence of such events;
c. Improvements in the infrastructure of CNAAA for the management of emergency situations.

The Plan was implemented at the end of 2011 and revised in August 2012 for incorporation of the results of the stress test assessments for units 1 and 2 of CNAAA, carried out in accordance with the same specifications adopted for the safety reassessment of the plants in operation in Europe.

The reassessment reports have been submitted to and analysed by the National Commission for Nuclear Energy (CNEN) and the *Foro Iberoamericano de Organismos*

Reguladores, Radiológicos y Nucleares (FORO) and the results were compared with those of similar plants abroad.

The reports were considered consistent as regards the reassessment and the results showed that the plants have a high level of safety for withstanding the threat represented by the possibility of natural disasters.

Earthquakes, landslides, flooding due to heavy rains, sea movements and tornadoes were taken into consideration in the reassessment of the threat and risks of natural disasters.

For these studies, Eletronuclear's technical staff worked with the most renowned Brazilian experts of the major research centers and universities of Brazil and with foreign advisors who are directly involved in the safety reassessment of nuclear power plants abroad.

In case of earthquakes, the evaluations carried out by using as a basis the characteristics of CNAAA's site have confirmed that the region is not subject to the risk of high-intensity earthquakes. As a part of the said studies, on-site inspections were performed in Angra-1 and Angra-2 facilities, concluding that both plants can safely withstand earthquakes with intensities much higher than those of the earthquakes that have been already recorded in Brazil.

The risk of landslides at CNAAA's surroundings have been revaluated and the conclusion is that, even under extreme scenarios, the facilities of the plants would not be hit, assuring the capacity for safe shutdown of the reactors. Nevertheless, some specific measures for reinforcement of the retaining walls and expansion of the slope monitoring have been determined and their implementation is already being arranged.

The risks associated with flooding at CNAAA, as a consequence of heavy rains, have been revaluated, using up-to-date data about precipitation in the region as well as modern calculation methods, and the conclusion is that the barriers against flooding of the safety buildings are suitable, even when considering rainfalls with much higher intensities than those already observed not only in the region but also in the entire state of Rio de Janeiro.

The studies reassessing the threat of CNAAA being hit by waves with higher magnitudes, as a result of natural events, is concluded. These studies consider the occurrence of high-magnitude oceanic waves at the entrance to Ilha Grande Bay or the occurrence of a hurricane inside the aforementioned bay. In the current status, the studies indicate insignificant impacts on CNAAA, which may lead only to measures of reinforcement of the protection jetty (still being designed).

The measures of protection against tornadoes are concluded. These specific measures apply to particular equipment located at the external areas of the plants.

The improvements in structures, systems and equipment for increasing the safety margins against natural disasters, as established in the scope of the stress tests, are already being implemented.

An important part of these improvements is the planned use of mobile equipment such as portable compressors and mobile diesel generators, so as to assure the cooling of the reactors if the safety equipment of CNAAA is hit, owing to the consequences of a natural disaster.

Such equipment has been already purchased. Almost all parts of the equipment have been already delivered and, over this year, all equipment will be available at CNAAA. The design modifications to allow the quick connection of the equipment in case of emergency are being made.

Some other safety systems have been added to the, such as the hydrogen catalytic recombiners in Angra-1 and Angra-2, which protect the reactor containment in case of severe accidents, assuring the containment of radioactive materials inside the reactor building.

These measures also include the construction of a new water reservoir for emergency situations, which is in the design phase, able to assure the availability of water to cool the reactor, even if CNAAA is hit by a natural disaster that affects the other existing reservoirs.

With regard to the improvement in the infrastructure for coping with emergencies, Eletronuclear (ETN) has been supporting the implementation of new options for personnel and equipment movement in the Emergency Plan, including the creation of footpaths for movement by land on parts of the road that may be hit by landslides and the expansion of the moorings at CNAAA's surroundings for movement by sea.

The improvements in the Emergency Centers have been already evaluated and they are currently in the design phase.

The already made or committed investments of Eletronuclear for the Fukushima Response Plan amount to more than R$ 50 million and approximately R$ 100 million are estimated to be invested over the next years.

The works that have been carried out by Eletronuclear for application of the lessons learned from the accident in the NPPs of Fukushima are being evaluated by inspection programs conducted by international organizations, such as the International Atomic Energy Agency (IAEA) and the World Association of Nuclear Operators (WANO), which have been attesting the adequacy of the Plan and of the measures that are being taken.

K.1.4 - THE BRAZILIAN MULTIPURPOSE RESEARCH REACTOR – *The RMB Project*

The project is ongoing. Upon completion of its conceptual project, the site for the Multipurpose Research Reactor (RMB) was chosen and the environmental impact assessments were already conducted. CNEN and IBAMA have issued the Local Approval in 2015. The RMB will be a new Nuclear Research and Production Centre that will be built in a Sorocaba city, about 100 kilometers from Sao Paulo city, in the southeast part of Brazil.

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 underway, benefiting of the cooperation with Argentina.

This reactor will enable the production of radioisotopes for application in medicine, industry and environment; irradiation testing of advanced nuclear fuels; irradiation and materials testing and, if possible, to conduct fundamental scientific research with a beam of neutrons in various fields of knowledge.

K.2 - IMPROVEMENTS IN THE RADIOACTIVE WASTE AREA

K.2.1 – THE BRAZILIAN NATIONAL REPOSITORY (THE *RBMN* PROJECT)

Site selection process aiming at the construction of the Brazilian Repository for the low and intermediate level radioactive waste is currently in its final step. Regions of interest have already been identified and the sequential criteria to eliminate the non-acceptable areas were applied, the present remaining areas are being considered as the candidate sites, and a report presenting the site selection process is currently under analysis by the nuclear regulatory body (DRSN/CNEN).

Once the final candidate sites are chosen, the next step will be start the public acceptance program, where the stakeholders should be identified in the selected areas. However, there is a request from the Federal Government for giving priority to areas from its own property. As consequence, since this Governmental request can be technically supported, it should be the final criterion to be applied in the site selection process.

In order to have an international technical support and socio-political consultancy, DPD/CNEN signed with ANDRA, the French Agency for the Radioactive Waste Management, a consultancy contract to assist in the conceptual, basic and executive designs. The preliminary conceptual design is already performed, and it can be adapted to the future selected site, without major difficulties.

Currently, the RBMN project is certainly the main challenge. The Project involves several specialties in different professional fields. In each one of them CNEN and other Brazilian institutions have different degrees of accomplishment. A coordinated effort is being carried out to make possible to have the repository still operational in the first years of the next decade.

K.2.2 – THE BRAZILIAN NUCLEAR REGULATORY AGENCY

As mentioned in item **E.3**, the Brazilian Government, through CNEN, has assured the independency of regulatory activities in the nuclear area. In the case of regulation activities applied to ETN (the organization concerned with the promotion and utilization of nuclear energy for electricity generation) the independence can be seen from a governmental structure point of view. While CNEN is under the Ministry for Science, Technology Innovations and Communications (MCTIC), ETN is under the Ministry for Mines and Energy

(MME). Within the framework of CNEN, the Directorate of Radiation Protection and Nuclear Safety (DRSN) is in charge of CNEN's regulatory body functions and does not operate any nuclear or radioactive installation. As can be noted in Figure E.2, this allows effective separation from the production and promotion activities performed by the Directorate for Research and Development (DPD), whose institutes and centres are considered by DRSN as any other licensee, subjected to the same rules and regulations.

Although it has been assured a functional independency between nuclear regulatory activities and the others as promoting and research and development activities, the Federal Government took the political decision to create an administratively and legally independent Brazilian Regulatory Nuclear Agency. In this sense, CNEN prepared a draft legislation for the creation of the nuclear regulatory agency based on the existing structure of the Directorate of Radiation Protection and Nuclear Safety (DRSN). The new agency shall be created by a federal law and the proposal was submitted to the concerned Ministries before being sent to the National Congress for public discussion and approval.

Nevertheless, due to political changes in Brazil in 2015, there were some changes in high level governmental and organizational positions as a whole. This fact led the new top managers to ask back the draft legislation for a revaluation. In this context, CNEN is proposing the creation of an inter-ministerial group for discussion and review of the current Brazilian Nuclear Program, including a discussion of the most appropriate model for a Brazilian Nuclear Regulatory Agency. Therefore, this subject is still pending.

K.2.3 – REVISION AND EMISSION BY CNEN OF SAFETY REGULATIONS

Regarding the last Brazil Repost 2014, besides the regulations CNEN-NN-8.02 - Licensing of storage and disposal facilities for low- and intermediate-level radioactive waste and CNEN-NN-8.01 - Radioactive Waste Management for Low- and Intermediate-Level Waste [25], CNEN has recently issued the new regulation NN-9.02 - Financial Management for Decommissioning of Nuclear Power Plants [30] (October 2016), that established the basic requirements for the management of financial resources, complementary to those established in article 15 of the CNEN-NN-9.01, including the management of radioactive waste generated during decommissioning. Furthermore, in May 2016 CNEN issued the regulation CNEN-NN-7.01 "Certification of the Qualification of Radiation Protection Supervisors" in replacement to the old Certification guide CNEN- NE-3.03, which was revoked.

CNEN regulation NN-6.09 [23] on acceptance criteria for final disposal of low- and Intermediate-level radioactive waste was revised and is now under public consultation. The regulations CNEN-NN-1.10 [32] from 1980 on safety of waste dam systems containing radionuclides and CNEN-NN-3.01 [12] on radiation protection directives began their revision process in May 2016 and April 2015, respectively. Concerning this last one, the review process will be based on the new IAEA BSS, the General Safety Requirements Part-3, "Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards", of July 2014.

K.3 - PLANS FOR DECOMMISSIONING USIN

The decommissioning of the plant is described in Section **F.6.3.3** and is scheduled to be executed in three phases: (*i*) to decontaminate the area without buildings and store contaminants segregated in the warehouse, (*ii*) to transfer the radioactive waste stored in the shed, including the radioactive waste generated in the decontamination of the land, to an interim storage facility or a final disposal facility; and (*iii*) to decontaminate and demolish the shed, clean up the soil in the area of the shed and transfer the radioactive waste generated in the decontamination of the shed for an intermediate storage facility or to the national repository.

INB decided that the area will be decontaminated for unrestricted use. The Decontamination Plan was approved by CNEN and by the IBAMA. From the total area of 60,000 m^2, the amount of 18,000 m^2 was decontaminated and released by CNEN for unrestricted use. The decontamination work is being performed in the free area (not built) around of the shed A, but depends on weather conditions.

K.4 - FINAL REMARKS

Brazil has demonstrated that the Brazilian nuclear power programme and the related nuclear installations have met the objectives of the Convention.

Based on the safety performance of nuclear installations in Brazil, and considering the information provided in this National Report, the Brazilian nuclear organizations consider that their nuclear programs have:

- achieved and maintained a high level of safety in the area of spent fuel and waste management on its nuclear and radiological installations;
- established and maintained effective defenses against potential radiological hazards in order to protect individuals, the society and the environment from harmful effects of ionizing radiation;
- prevented accidents with radiological consequences and are prepared to mitigate such consequences should they occur;
- assured a self-sustainable development and the adoption of good practices on radioactive waste and spent fuel management.

Therefore, Brazil considers that its nuclear programme has met and continues to meet the objectives of the Join Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

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[29] Decommissioning of Nuclear Power Plants - CNEN-NN-9.01 - November 2012.

[30] Financial Management for Decommissioning of Nuclear Power Plants – CNEN-NN-9.02 – October 2016.

[31] INTERNATIONAL ATOMIC ENERGY AGENCY, Standard Format and Content for Safety Related Decommissioning Documents, Safety Report Series No. 45, IAEA, Vienna (2005).

[32] Safety of Waste Dam Systems Containing Radionuclides - CNEN-NN-1.10 – November 1980.

SECTION L - ANNEXES

L.1 - ANNEX 1 - Present Inventory

The following table presents the inventory of radioactive waste in Brazil as of the end of March 2008.

Source/ Type	Present Situation	Inventory as of August 2017	Treatment	Interim Storage	Final Disposal (proposal)
ANGRA-1 NPP					
Spent Fuel	Storage inside reactor pool (Spent fuel pool)	969 fuel assemblies	Waiting for decision concerning reprocessing. Under Brazilian regulation is not considered waste.	Inside reactor pool	Deep geological disposal
Filters	Stored in 200 L drums at plant site	534 packages / 111.1 m^3 / 4,65E+13 Bq	Cementation and encapsulation in steel drums	At plant site	Brazilian repository
Evaporator concentrates	Stored in 200 L drums and 1,000 L liners at plant site	3,050 packages / 1,075 m^3 / 8,23+12Bq	Cementation and encapsulation in steel drums/shielded liners	At plant site	Brazilian repository
Non-compressibles	Stored in 200 L drums and 1,000 L metallic boxes at plant site	1,004 packages / 729,9 m^3 / 1.58E+13 Bq	Cementation and encapsulation in steel drums/metallic boxes	At plant site	Brazilian repository
Resins	Stored in 200 L drums and 1,000 L liners at plant site	1,624 packages / 546,1 m^3 / 4,60E+15 Bq	Cementation and encapsulation in steel drums/shielded liners	At plant site	Brazilian repository
Compressibles	Stored in 200 L drums at plant site and compacted drums stored in 2,500 L metallic boxes (B-25) at plant site	817 drums / 169,9 m^3 and 128 metalic boxes (B-25) 320 m^3 / 2.95E+12 Bq	Compaction and encapsulation in steel drums	At plant site	Brazilian repository

Source/ Type	**Present Situation**	**Inventory as of August 2017**	**Treatment**	**Interim Storage**	**Final Disposal (proposal)**
ANGRA-2 NPP					
Spent fuel	Storage inside reactor pool (Spent fuel pool)	704 fuel assemblies	Waiting for decision concerning reprocessing (under Brazilian regulation is not considered waste)	Inside reactor pool	Deep geological disposal
Filters	Stored in 200 L drums at plant site	16 drums / 3.2 m^3	Betuminization and encapsulation in steel drums	At plant site	Brazilian repository
Evaporator concentrates	Stored in 200 L drums at plant site	274 drums / 54,8 m^3 / 3.69E+10 Bq	Betuminization and encapsulation in steel drums	At plant site	Brazilian repository
Non-Compressibles	Stored in 1,000 L metallic boxes at plant site	14 packages / 17.5 m^3 / 1.54E+11 Bq	Cementation and encapsulation in metallic boxes	At plant site	Brazilian repository
Resins	Stored in 200 L drums at plant site	140 drums / 28.0 m^3 / 1.12E+13 Bq	Betuminization and encapsulation in steel drums	At plant site	Brazilian repository
Compressibles	Stored in 200 L drums at plant site	379 drums / 75.8 m^3 / 5.92E+11 Bq	Compaction and encapsulation in steel drums	At plant site	Brazilian repository

Source/ Type	Present Situation	Inventory as of August 2017	Treatment	Interim Storage	Final Disposal (proposal)
RADIONUCLIDE APPLICATIONS IN MEDICINE, INDUSTRY AND RESEARCH					
Waste generated by radioactive installations and research institutes (including those belonging to CNEN and lightning rods)	Stored in the institutes of CNEN: IPEN(SP), CDTN(MG), IEN(RJ) and CRCN-NE (PE)	IPEN: 546m^3/ 1.30E+14Bq CDTN: 87m^3 / 6.4 E+13Bq IEN: 190m^3 / 6.4E+13Bq CRCN-NE: 32m^3/ 1.76E+14Bq	According to type of waste	Institutes of CNEN	Brazilian Repository and/or waiting a final decision on borehole disposal (BOSS)
FUEL CYCLE INSTALLATIONS					
Operation of the rare-earth production line of Usina de Santo Amaro (Santo Amaro Mill - USAM) – Uranium and Thorium concentrates (Cake II)	Stored in shed and trenches	11,334 tons / 7,250 m^3 119,288 GBq (3,224 Ci) (Low level waste)	-	Ore Treatment Unit (UTM)	Ore Treatment Unit (UTM)
Ore Treatment Unit (UTM) – Mesothorium	Talings dam	1,500 ton (Low level waste)	-	Ore Treatment Unit (UTM)	Ore Treatment Unit (UTM)
Ore Treatment Unit (UTM) – Mesothorium	Trenches	880 tons (Low level waste)	-	Ore Treatment Unit (UTM)	Ore Treatment Unit (UTM)
Ore Treatment Unit (UTM) – Waste Generated in the Process	Tailings dam	2,111,920 tons (Low level waste)	-	Ore Treatment Unit (UTM)	Ore Treatment Unit (UTM)

Source/ Type	Present Situation	Inventory as of August 2017	Treatment	Interim Storage	Final Disposal (proposal)
Ore Treatment Unit (UTM) – Calcium Diuranate (DUCA)	Tailings dam and Mine Pit	120,000 tons (197 tons of U_3O_8)	-	Ore Treatment Unit (UTM)	Ore Treatment Unit (UTM)
Ore Treatment Unit (UTM) – Contaminated Filters and Other Materials	Isolated areas on the site	Approximately 50 tons (Low level waste)	-	Ore Treatment Unit (UTM)	Ore Treatment Unit (UTM)
Ore Treatment Unit (UTM) – Thorium (ThO_2)	Pond and 148 concrete containers	159 tons (Low level waste)	-	Ore Treatment Unit (UTM)	Ore Treatment Unit (UTM)
Nuclear Fuel Factory (FCN) - filters of the ventilation system, filters of the air conditioned system, and filters of portable dust vacuum cleaners)	Stored in 200-liter drums, temporarily in the Low-Level Waste Storage Facility (DIRBA)	101 drums / 6,408 kg 20.2 m^3 (Low-level solid waste)	-	Nuclear Fuel Factory (FCN)	-
Nuclear Fuel Factory (FCN) - non compactable waste (metal pieces, wood, glass, plastic pieces, and others)	Stored in 200-liter drums, temporarily in DIRBA	84 drums / 5,906 kg 16.8 m^3 (Low-level solid waste)	-	Nuclear Fuel Factory (FCN)	-
Nuclear Fuel Factory (FCN) - compactable solids (plastic sheets, gloves, clothes, and others)	Stored in 200-liter drums, temporarily in DIRBA	158 drums / 13,195 kg 31.6 m^3 (Low level solid waste)	-	Nuclear Fuel Factory (FCN)	-
Nuclear Fuel Factory (FCN) - refractory material (bricks)	Stored in 200-liter drums, temporarily in DIRBA	40 drums / 6,077 kg 8 m^3 (Low level solid waste)	-	Nuclear Fuel Factory (FCN)	-

Source/ Type	**Present Situation**	**Inventory as of August 2017**	**Treatment**	**Interim Storage**	**Final Disposal (proposal)**
Nuclear Fuel Factory (FCN) - dried lime cake	Stored in 200-liter drums, temporarily in DIRBA	14 drums / 2,384 kg / 2.8 m^3 (Low level solid waste)	-	Nuclear Fuel Factory (FCN)	-
Nuclear Fuel Factory (FCN) – contaminated oil	Stored in 200-liter drums, temporarily in DIRBA	3 drums / 111 kg / 0.6 m^3 (Low level solid waste)	-	Nuclear Fuel Factory (FCN)	-
Nuclear Fuel Factory (FCN) - pieces of molybdenum	Stored in 200-liter drums, temporarily in DIRBA	2 drums / 113 kg /0.4 m^3 (Low level solid waste)	-	Nuclear Fuel Factory (FCN)	-
Uranium Concentrate Unit (URA) – waste rock	Unpackaged solid	16,723,126 tons	-	Uranium Concentrate Unit (URA)	Uranium Concentrate Unit (URA)
Uranium Concentrate Unit (URA) - leached ore	Unpackaged solid	1,985.190 tons	-	Uranium Concentrate Unit (URA)	Uranium Concentrate Unit (URA)
Uranium Concentrate Unit (URA) - pulp wastewater treaty	Solid dense impermeable basin	184,346 tons	-	Uranium Concentrate Unit (URA)	Uranium Concentrate Unit (URA)
Uranium Concentrate Unit (URA) - waste treatment emulsion	Stored in 200-liter drums at isolated areas plant site	14,035 Kg	-	Uranium Concentrate Unit (URA)	-
Uranium Concentrate Unit (URA) - small materials from several sources (wood, glass, metal pieces, plastic pieces, sheets, gloves, clothes and others)	Stored in 200-liter drums at isolated areas on the site	Approximately 150 drums 30 m^3	-	Uranium Concentrate Unit (URA)	-

Source/ Type	Present Situation	Inventory as of August 2017	Treatment	Interim Storage	Final Disposal (proposal)
Uranium Concentrate Unit (URA) - scrap metals (parts of crushing, mixer, hydrocyclones, metal pipes and others equipment)	Unpackaged solid	16,950 kg	-	Uranium Concentrate Unit (URA)	-
Uranium Concentrate Unit (URA) - mixer	Unpackaged solid	5,000 kg	-	Uranium Concentrate Unit (URA)	-
Uranium Concentrate Unit (URA) – wool coating reactor	Stored in drums at plant site	7 drums / 1.4 m^3	-	Uranium Concentrate Unit (URA)	-
Uranium Concentrate Unit (URA) - waste paper, wood, rubber, text materials and others	Solid stored in 200-liter drums	1,032 kg	-	Uranium Concentrate Unit (URA)	-
Uranium Concentrate Unit (URA) - waste valves, rollers and others	Stored in 200-liter drums at isolated areas on the site	1,352 kg	-	Uranium Concentrate Unit (URA)	-
Uranium Concentrate Unit (URA) - waste equipment, pieces of equipment and others	stored on wooden pallets at isolated areas on the site	310 kg	-	Uranium Concentrate Unit (URA)	

Source/ Type	Present Situation	Inventory as of August 2017	Treatment	Interim Storage	Final Disposal (proposal)
MONAZITE SAND PROCESSING INSTALLATIONS					
Operation of the rare-earth production line of Usina de Santo Amaro (Santo Amaro Mill - USAM) - Uranium and Thorium concentrates (Cake II)	Stored in plastic drums	590,94 ton / 328 m^3 / 5,069 GBq (137Ci)	-	Interlagos Processing Plant (USIN)	-
Operation of the rare-earth production line of Santo Amaro Processing Plant (USAM) - Mesothorium	Stored in plastic drums	83,6 ton / 38 m^3 / 222 GBq (6 Ci)	-	Interlagos Processing Plant (USIN)	-
Operation of the rare-earth production line of Santo Amaro Processing Plant (USAM) - Other contaminated material	Stored in plastic drums, maritime containers and metal boxes	405,72 tons / 599 m^3	-	Interlagos Processing Plant (USIN)	-
Operation of the USIN descontamination - Other contaminated material	Stored in metal drums	7,43 tons / 6 m^3	-	Interlagos Processing Plant (USIN)	-
Operation of the rare-earth production line of Santo Amaro Processing Plant (USAM) - Uranium and Thorium concentrates	Stored in concrete silos	3,500.07 ton / 1,943 m^3 / 32,856 GBq (888Ci)	-	Botuxim Deposity (Itu/São Paulo)	-

Source/ Type	Present Situation	Inventory as of August 2017	Treatment	Interim Storage	Final Disposal (proposal)
RADIOLOGICAL ACCIDENT IN GOIÂNIA					
Low level wasts (^{137}Cs) below exemption level	Final disposal concluded	1,525 m^3 / 1 Ci	Encapsulation in steel and concrete drums	Open air at Abadia de Goiás	Great Capacity Conteiner (CGP)
Low level waste (^{137}Cs) above exemption level	Final disposal concluded	1,975 m^3 / 750 Ci	Encapsulation in steel and concrete drums	Open air at Abadia de Goiás	Goiânia Repository

L.2 - ANNEX 2 – List of Relevant Conventions, Laws and Regulations

L.2.1 - 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.

Join Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Ratification: 14/11/2005.

Convention n. 115 of the International Labor Organization. Signature: 7/04/1964.

L.2.2 - RELEVANT NATIONAL LAWS

Decree 40110 of 1956.10.10 - Creates the National Commission for Nuclear Energy - CNEN.

Law 4118/62 of 1962.07.27 - Establishes the Nuclear Energy National Policy and reorganizes CNEN.

Law 6189/74 of 1974.12.16 - Creates Nuclebras as a company responsible for nuclear fuel cycle facilities, equipment manufacturing, nuclear power plant construction, and research and development activities.

Law 6453 of 1977.10.17 - Defines the civil liability for nuclear damages and criminal responsibilities for actions related to nuclear activities

Decree 1809 of 1980.10.07 - Establishes the System for Protection of the Brazilian Nuclear Programme (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 7735 of 1989.02.23 - Creates the Brazilian Institute for Environment and Renewable Natural Resources - IBAMA

Law 7781/89 of 1989.06.27 - Reorganizes the nuclear sectors.

Decree 99274 of 1990.06.06 - Regulates application of Law 6938, establishing the environmental licensing process in 3 steps: pre-license, installation license and operation license.

Decree 2210 of 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 Programme (COPRON).

Law 9605 of 1998.02.12 - Defines environmental crimes and establishes a system of enforcement and punishment.

Decree 3719 of 1999.09.21 - Regulates the Law 9605 and establishes the penalties for environmental crimes.

Law 9765 of 1998.12.17 - Establishes tax and fees for licensing, control and regulatory inspection of nuclear and radioactive materials and installations.

Decree 3833 of 2001.06.05 - Establishes the new structure and staff of the Brazilian Institute for the Environment (IBAMA).

Law 10308 of 2001.11.20 – Establishes rules for the site selection, construction, operation, licensing and control, financing, civil liability and guarantees related to the storage and dispose of radioactive waste.

Supplementary Law 140 of 2011.12.08 - Set standards relating to sections III, VI and VII of the sole paragraph of art. 23 of the Constitution, for the cooperation between the Union, the states, the Federal District and the municipalities in administrative proceedings arising from the exercise of common responsibility for the protection of outstanding natural landscapes, the protection of the environment, the control of pollution in any of its forms, and the preservation of forests, fauna and flora.

L.2.3 - CNEN REGULATIONS

NE-1.04 - Licenciamento de Instalações Nucleares - Resol. CNEN 11/84 - ***(Licensing of nuclear facilities).***

NN-1.14 - Relatórios de operação de usinas nucleoelétricas - ***(Nuclear power plant operation reports).***

NE-1.16 - Garantia da qualidade para a segurança de usinas nucleoelétricas e outras instalações - Resol. 15/99 - ***(Quality assurance and safety in nuclear power plants and other facilities).***

NE-1.17 - Qualificação de pessoal e certificação para ensaios não destrutivos em itens de instalações nucleares - ***(Personnel qualification and certification for non-destructive testing in nuclear power plants components).***

NE-1.18 - Conservação preventiva em usinas nucleoelétricas - ***(Nuclear power plant preventive maintenance).***

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 programs for coolant loss accident analysis in pressurized water reactors).***

NE-1.20 - Aceitação de sistemas de resfriamento de emergência do núcleo de reatores a água leve - ***(Acceptance criteria for emergency core cooling system of light water reactors).***

NE-1.21 - Manutenção de usinas nucleoelétricas - ***(Maintenance of nuclear power plants).***

NE-1.22 - Programas de meteorologia de apoio de usinas nucleoelétricas - ***(Meteorological programme for nuclear power plant support).***

NE-1.25 - Inspeção em serviço de usinas nucleoelétricas - ***(In service inspection of nuclear power plants).***

NE-1.26 - Segurança na operação de usinas nucleoelétricas - ***(Operational safety of nuclear power plants).***

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 organizations in nuclear power plants and other installations)***

NN-1.01 - Licenciamento de operadores de reatores nucleares - Resol. CNEN 12/79 - ***(Licensing of nuclear reactor operators).***

NN-1.06 - Requisitos de saúde para operadores de reatores nucleares - Resol. CNEN 03/80 - ***(Health requirements for nuclear reactor operators).***

NN-1.12 - Qualificação de órgãos de supervisão técnica independente em instalações nucleares - Resol. CNEN 16/85 - Revisada em 21/09/1999 ***- (Qualification of independent technical supervisory organizations for nuclear installations).***

NN-1.15 - Supervisão técnica independente em atividades de garantia da qualidade em usinas nucleoelétricas - ***(Independent technical supervision in quality assurance activities in nuclear power plants).***

NE-2.01 - Proteção física de unidades operacionais da área nuclear - Resol. CNEN 07/81 – revised by Resol. 06/96 ***(Physical Protection in operating units in nuclear area).***

NN-2.02 – Controle de materiais nucleares - Resol. CNEN 11/99 ***(Nuclear material control).***

NE-2.03 - Proteção contra incêndio em usinas nucleoelétricas - Resol. CNEN 08/88 - ***(Fire protection in nuclear power plants).***

NN-3.01 - Diretrizes básicas de proteção radiológica - Resol. CNEN 48/2005 - ***(Radiation protection directives) January 2005.***

NE 3.02 - Serviços de proteção radiológica - ***(Radiation protection services) August 1988.***

NE 3.03 - Certificação da qualificação de supervisores de radioproteção - Resol. CNEN 09/88 – Revised in 01/09/95, Modified in 16/10/97 and 21/09/99 - ***(Certification of the qualification of radiation protection supervisors) September 1999. (Revoked).***

NN 7.01 - Certificação da qualificação de supervisores de radioproteção ***(Certification of the qualification of radiation protection supervisors)*** - ***Published in May 2016 in replacement to NE 3.03 -*** Resol. CNEN 194/16 –

NE 5.01 - Transportes de materiais radioativos - Resol. CNEN 13/88 - ***(Transport of radioactive materials) August 1988.***

NE 5.02 - Transporte, recebimento, armazenamento e manuseio de elementos combustíveis de usinas nucleoelétricas - ***(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 - ***(Transport, receipt, storage and handling of materials in nuclear power plants) February 1989.***

NE 6.02 - Licenciamento de instalações radiativas ***– (Licensing of radioactive installations). Revised and published in April 2014*** - Resol. CNEN 166/14.

NE 6.05 - Gerência de rejeitos radioativos em instalações radiativas - ***(Radioactive waste management in radioactive facilities) December 1985 (Revoked).***

NN 8.01 - Gerência de rejeitos radioativos de baixo e médio níveis de radiação - ***(Radioactive waste management for low- and intermediate-level waste). Published in April 2014 in replacement to NE 6.05*** - Resol. CNEN 167/14.

NE 6.06 - Seleção e escolha de locais para depósitos de rejeitos radioativos - ***(Site Selection for radioactive waste storage and disposal facilities).- December 1989.***

NN 6.09 - Critérios de aceitação para deposição de rejeitos radioativos de baixo e médio níveis de radiação - ***(Acceptance criteria for disposal of low and intermediate level radioactive wastes). – Setember 2002 (Currently under review).***

NN 8.02 – Licenciamento de depósitos de rejeitos radioativos de baixo e médio níveis de radiação ***(Licensing of storage and disposal facilities for low- and intermediate-level***

radioactive waste). - ***April 2014 -*** Resol. CNEN 167/14 ***(New).***

NN-9.01 – Descomissionamento de Usinas Nucleoelétrica ***(Decommissioning of Nuclear Power Plants). November 2012 -*** Resol. CNEN 133/12 ***(New).***

L.2.4 - CONAMA 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 companies, 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 companies) -*** (19.12.1997).

IBAMA Normative Instruction n º 184/08 – ***(Establishes within this Agency, the procedures for federal environmental permits)*** - (17.07.2008).

L.2.5 - SIPRON REGULATIONS

NG-01 - Norma Geral para o funcionamento da Comissão de Coordenação da Proteção do Programa Nuclear Brasileiro (COPRON) - ***(General norm for the Coodination Commission for the Protection of the Brazilian Nuclear Programme).*** Port. SAE Nr. 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 Nr.01 of 13.06.1996.

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 Nr. 01 of 19.07.1996.

NG-04 - Norma Geral para situações de emergência nas unidades de transporte - ***(General norm for emergency situations in the transport units).*** Resol. SAE/COPRON Nr. 01 of 19.07.1996

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 campaings about emergency situations).*** Port. SAE Nr. 150 of 11.12.1992.

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 Nr. 27 of 27.03.1997.

NG-07 - Norma Geral para planejamento das comunicações do SIPRON ***(General norm for SIPRON communication planning).*** Port. SAE Nr. 37 of 22.04.1997.

NG-08 – Norma Geral para o planejamento e a execução da proteção ao conhecimento sigiloso ***(General norm for planning and execution of classified knowledge protection****).* Port. SAE Nr. 145 of 7.12.1998.

NI-01 – Norma Interna que dispõe sobre instalação e funcionamento do Centro para Gerenciamento de Emergência Nuclear ***(Internal norm on the installation and operation of the national Center for Nuclear Emergency Management).*** Port. SAE Nr.001 of 21.05.1997.

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. nº 8 – 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 Committee for the Safey and Support Areas of the System for Protection of the Brazilian Nuclear Program)***. Port. nº 31 GSIPR, of 26.03.2012.

L.3 - ANNEX 3 - LIST OF ABBREVIATIONS

ABACC	*Agência Brasileiro-Argentina de Contabilidade e Controle de Materiais Nucleares* (Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials)
ABIN	*Agência Brasileira de Inteligência* (Brazilian Inteligence Agency)
ALARA	As Low As Reasonable Achievable
AOI	*Autorização para Operação Inicial* (Authorization for Initial Operation)
AOP	*Autorização para Operação Permanente* (Authorization for Permanent Operation)
BSS	Basic Safety Standards (of IAEA)
CAPES	*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (Brazilian Coordination for Improvement of High Level Education Personnel)
CCCEN	*Centro de Coordenação e Controle de uma Situação de Emergência Nuclear* (Center for Coordination and Control of a Nuclear Emergency Situation)
CDTN	*Centro de Desenvolvimento de Tecnologia Nuclear* (Nuclear Technology Development Center)
CEA	*Centro Experimental Aramar* (Aramar Experimental Center)
CENA	*Centro de Energia Nuclear na Agricultura da Universidade de São Paulo* (University of São Paulo's Center of Nuclear Energy for Agriculture)
CESTGEN	*Centro Estadual para Gerenciamento de uma Situação de Emergência Nuclear* (State Center for Management of a Nuclear Emergency)
CETESB	*Companhia de Tecnologia de Saneamento Ambiental* (São Paulo State Institute for Environment)
CICP	*Complexo Industrial de Poços de Caldas* (Poços de Caldas Industrial Complex)
CIEN	*Centro de Informações de Emergência Nuclear* (Center for Information in Nuclear Emergency)
CGR	*Centro de Gerenciamento de Rejeitos* (Radioactive Waste Management Center)
CGRC	*Coordenação Geral de Reatores e Ciclo do Combustível* (General Coordination for Reactors and Fuel Cycle)
CNAAA	*Central Nuclear Almirante Álvaro Alberto* (Admiral Álvaro Alberto Nuclear Power Station)
CNAGEN	*Centro Nacional para Gerenciamento de uma Situação de Emergência Nuclear* (National Center for the Management of Nuclear Emergency Situation)
CNEN	*Comissão Nacional de Energia Nuclear* (National Commission for Nuclear Energy)
CNPq	*Conselho Nacional de Desenvolvimento Científico e Tecnológico* (National Council for Scientific and Tecnological Development)
COGEPE	*Coordenação Geral do Plano de Emergência* (General Coordinator for Emergency Plan)
COEND	*Coordenação de Geração de Energia Elétrica, Nuclear e Oleodutos* (Coordination for Electrical Power, Nuclear Energy and Pipelines)
CONAMA	*Conselho Nacional do Meio Ambiente* (*National Council for the Environment*)
COPREN/RES	*Comitê* de *Planejamento* de Resposta a *Emergência Nuclear no Município de Resende* (Emergency Response Planning Committee in Resende)
COPRON	*Comissão de Coordenação da Proteção ao Programa Nuclear Brasileiro* (Coordination Commission for the Protection of the Brazilian Nuclear Program)

DIREJ	*Divisão de Rejeitos Radioativos* (Radioactive Waste Division)
CRCN-CO	*Centro Regional de Ciências Nucleares do Centro Oeste* (Midwest Regional Center for Nuclear Sciences)
CRCN-NE	*Centro Regional de Ciências Nucleares do Nordeste* (*Northeast Regional Center for Nuclear Sciences*)
CTMSP	*Centro Tecnológico da Marinha em São Paulo* (Navy Technology Center in São Paulo)
DILIC	*Diretoria de Licenciamento Ambiental* (Directorship of Environmental Licensing)
DIRBA	*Depósito Inicial de Rejeitos de Baixa Atividade* (Low-level Waste Storage Facility)
DPD	*Diretoria de Pesquisa e Desenvolvimento* (Directorate for Research and Development)
DRSN	*Diretoria de Radioproteção e Segurança Nuclear* (Directorate for Radiological Protection and Nuclear Safety)
EAR	*Estudo de Análise de Risco* (Risk Assessment)
EBRR	*Empresa Brasileira de Gerenciamento de Rejeitos Radioativos* (Brazilian Company for Radioactive Waste Management)
EIA	*Estudo de Impacto Ambiental* (Environmental Impact Study)
EPE	*Empresa de Pesquisa Energética* (Brazil´s Energy Research Company)
ETN	*Eletrobrás Termonuclear S.A. - Eletronuclear* (the nuclear power plants operator company)
FAPEMIG	*Minas Gerais State Foundation for Research Support* (Fundação de Amparo à Pesquisa do Estado de Minas Gerais)
FCN	*Fábrica de Combustível Nuclear* (Nuclear Fuel Factory)
FEEMA	*Fundação Estadual de Engenharia do Meio Ambiente* (Rio de Janeiro State Foundation for Environmental Engeneering)
FINEP	*Financiadora de Estudos e Projetos* (Research and Projects Financing)
FSAR	Final Safety Analysis Report
GSI/PR	*Gabinete de Segurança Institucional da Presidência da República* (Institutional Security Cabinet of the Presidency of the Republic)
IAEA	International Atomic Energy Agency
IBAMA	*Instituto Brasileiro do Meio Ambiente e Recursos Renováveis* (Brazilian Institute for Environment and Renewable Natural Resources)
IBGE	*Instituto Brasileiro de Geografia e Estatística* (Brazilian Institute of Geography and Statistics)
ICRP	International Commission on Radiological Protection
IEN	*Instituto de Engenharia Nuclear* (Nuclear Engineering Institute)
INB	*Indústrias Nucleares do Brasil* (Brazil Nuclear Industries)
INEA	*Instituto Estadual do Ambiente* (Rio de Janeiro State Institute for Environment)
IPEN	*Instituto de Pesquisas Energéticas e Nucleares* (Nuclear and Energy Research Institute)
IRD	*Instituto de Radioproteção e Dosimetria* (Radiation Protection and Dosimetry Institute)
LAPOC	*Laboratório de Poços de Caldas* (Poços de Caldas Laboratory)
LI	*Licença de Instalação* (Installation License)

LO	*Licença de Operação* (Operation License)
LP	*Licença Prévia* (Prior License)
MCTIC	*Ministério da Ciência, Tecnologia, Innovations and Communications* (Ministry for Science, Technology, Innovations and Communications)
MERCOSUL	*Mercado Comum do Sul* (Southern Common Market)
MMA	*Ministério do Meio-Ambiente* (Ministry for Environment)
MME	*Ministério de Minas e Energia* (Ministry for Mines and Energy)
NORM	*Ocorrência natural de material Radioativo* (natural occurring radioactive material)
NUCLEP	*Nuclebras Equipamentos Pesados* (Nuclebras Heavy Equipment Industry)
OSTI	*Organismo de Supervisão Técnica Independente* (Independent Technical Supervision Organization)
PCA	*Plano de Controle Ambiental* (Environmental Control Plan)
PNAN	*Programa Nacional de Atividade Nucleares* (National Nuclear Activities Programme)
PNMA	*Política Nacional de Meio Ambiente (National Policy for the Environment)*
PMA	*Programa de Monitoração Ambiental (Environmental Monitoring Program)*
PPA	*Plano Plurianual* (Pluriannual Plan)
PRAD	*Plano de Recuperação de Áreas Degradadas* (Degraded Areas Reclamation Plan)
PSAR	Preliminary Safety Analysis Report
PTCN/MCT	*Programa Técnico-Científico Nuclear do Ministério de Ciência e Tecnologia* (Nuclear Scientific and Technical Program of the Ministry for Science and Technology)
RBMN	*Projeto Repositório para Rejeitos de Baixo e Médio Níveis de Radiação* (Low and Intermediate Level Waste Repository Project)
RIMA	*Relatório de Impacto Ambiental* (Environmental Impact Report)
RL	*Relatório do Local* (Report of the Site)
RR	Research Reactor
SEPRE	*Secretaria Especial de Políticas Regionais* (Special Secretary for Regional Policies)
SAE	*Secretaria de Assuntos Estratégicos* (Secretariat for Strategic Affairs)
SFA	Spent Fuel Assembly
SISNAMA	*Sistema Nacional de Meio Ambiente* (National System for the Environment)
SIPRON	*Sistema de Proteção do Programa Nuclear* (System for the Protection of the Nuclear Program)
SPE/MME	*Secretaria de Planejamento e Desenvolvimento Energético do Ministério de Minas e Energia* (Secretariat for Energy Planning and Development of the Ministry for Mines and Energy)
SSSTS	*Serviço de Saúde e Segurança do Trabalho* (Secretariat for Worker’s Safety and Health)
TAC	*Termo de Ajuste de Conduta* (Conduct Adjustment Term)
TSO	Technical Support Organization
UMP	*Unidade de Minerais Pesados - Buena* (Heavy Minerals Processing Unit – located in Buena)
URA	Unidade de Concentrado de Urânio de Caetité (*Uranium Concentrate Unit Of Caetité*)

USAM	*Usina de Santo Amaro* (Santo Amaro Processing Plant)
USIN	*Usina de Interlagos* (Interlagos Processing Plant)
USNRC	United States Nuclear Regulatory Commission
UTM	*Unidade de Tratamento de Minérios* de Poços de caldas (Ore Treatment Unit of Poços de Caldas)
WMB	Waste Monitoring Building

This report was prepared by a task force composed of representatives of the following organizations:

Comissão Nacional de Energia Nuclear (CNEN)
Centro Tecnológico da Marinha em São Paulo (CTMSP)
Eletrobrás Termonuclear - Eletronuclear S.A. (ETN)
Gabinete de Segurança Institucional da Presidência da República (GSI/PR)
Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA)
Indústrias Nucleares do Brasil S.A. (INB)
Ministério da Ciência, Tecnologia, Inovações e Comunicações (MCTIC)
Ministério de Relações Exteriores (MRE)

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CNEN
Comissão Nacional
de Energia Nuclear

INB
INDÚSTRIAS NUCLEARES DO BRASIL

Eletrobras
Eletronuclear

IBAMA
MMA

CTMSP

SIPRON

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CIÊNCIA, TECNOLOGIA,
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MINISTÉRIO DE
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GABINETE DE
SEGURANÇA INSTITUCIONAL

ORDEM E PROGRESSO
BRASIL
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