Federative Republic of Brazil

IAEA
International Atomic Energy Agency

COUNTRY PROGRAMME FRAMEWORK

2020-2024

On behalf of the Government

HE Mr Marcel Fortuna Biato
Resident Representative
Permanent Mission of the Federative Republic of Brazil to the IAEA

VIENNA, 10/12/19
Place and date

On behalf of the International Atomic Energy Agency

Mr Dazhu Yang
Deputy Director General
Head of the Department of Technical Cooperation

Vienna, Dec. 10, 2019
Place and date

Table of Abbreviations

ABFM – Brazilian Association of Medical Physics
AgNSNQ – Naval Agency for Nuclear Safety and Quality
ANA – National Water Organization
ANVISA – National Health Surveillance Agency
ARCAL – Regional Cooperation *Agreement* for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean
BNF –Biological Nitrogen Fixation
CBR – Brazilian College of Radiology
CENA – Agriculture Nuclear Energy Center
CENASF – Nuclear Security Support Center
CNEN – National Nuclear Energy Commission
CTMSP – Brazilian Navy Centre of Technology of São Paulo
ECCC – Emergency Command and Control Center
ELETRONUCLEAR – Nuclear Electricity Enterprise
EMBRAPA – Brazilian Enterprise for Agriculture Research
EPE – Energy Planning Enterprise
GNIP – Global Network of Isotopes in Precipitation
HNMD –Marcílio Dias Naval Hospital
IBAMA – Institute for the Environment and Renewable Natural Resources
IAEA – International Atomic Energy Agency
IEAPM - Institute Admiral Paulo Moreira
INB – Brazilian Nuclear Industry
IPEN – Institute for Energy and Nuclear Research
PAHO – Pan American Health Organization
PPA – Brazilian pluriannual development plan
SBPR – Brazilian Society of Radiation Protection
SBMN – Brazilian Society for Nuclear Medicine
SBRT – Brazilian Radiotherapy Society
SDG – Sustainable Development Goals
SIPRON – Protection System to the Brazilian Nuclear Program
TSO – Technical and Scientific Support Organisation
UNFCCC – United Nations Framework Convention on Climate Change
WHO – World Health Organization

Glossary

TERMS	MEANINGS
NORM	Natural Occurrence of Radioactive Materials
Yellow Cake	benefited uranium concentrate
NM	Nuclear Medicine
NS	Nuclear Security
SMART	Specific, Measurable, Achievable, Relevant and Time-bound
PET	Positron Emission Tomography
Theranostic	Therapy and diagnostic
SIT	Sterile Insect Technique
Biodiesel	Diesel oil produced from vegetables.
EB	Electron beam
Nucleonic Instruments	Instruments incorporating a radioactive source
URA	Uranium Concentrate Unit
RBMN	Repository of Low and Medium Level Waste
GHG	Greenhouse gas
TEC-DOC	Technical Document published by IAEA
CT	Computerized Tomography
NPP	Nuclear Power Plant

Executive Summary

The purpose of the Country Programme Framework (CPF) is to serve as a medium-term planning tool to define the areas within Brazil's national development priorities, in which technical cooperation with the International Atomic Energy Agency (IAEA) is considered of strategic relevance to contribute to the achievement of such priorities. This agreement between Brazil and the IAEA outlines the mainstream of national development plans and the proposed areas of technical cooperation, as well as an estimate of the cost and funding sources.

This document is also a comprehensive revision of the CPF signed in 2012 and covers the period 2020 - 2024. Its validity can be extended upon mutual agreement between Brazil and the Agency. The National Liaison Officer (NLO) has been appointed by the national authorities as the CPF National Coordinator and falls within the structure of the National Commission of Nuclear Energy (CNEN).

The CPF was consolidated based on experts' vision of the science and technology development trends, the Brazilian Nuclear Policy decree published at the end of 2018, and the National Development Plan formulated during 2019. In this sense the CPF encompasses technical, policy and development visions.

The proposed technical cooperation programme will focus on enhancing the control of Dengue, Chincungunya and Zika outbreaks in humans; strengthening nuclear medicine and radiotherapy for cancer control, improving capacities to reduce the burden of malnutrition particularly in infants; contribute to enhance food safety and strengthen small farm yield; strengthening national capacities to sustainably manage terrestrial, coastal and marine ecosystems and improving energy planning capacities and industrial processes in the country. In addition, it will contribute to strengthening nuclear and radiation safety and security in Brazil for the application of nuclear technology safely and securely in line with international best practices. The planned outcomes will address to the attainment of Sustainable Development Goals (SDGs) 2, 3, 7, 9, 14 and 15.

1. Introduction

The Country Programme Framework contained in this document is a strategic programming tool and serves as a frame of reference for the proposed technical cooperation activities in Brazil during the period 2020-2023.

The CPF was consolidated based on experts' visions of the science and technology development trends, the Brazilian Nuclear Policy decree published at the end of 2018, and the National Development Plan formulated in 2019. In this sense the CPF encompasses technical, policy and development visions. The proposed technical cooperation programme will focus on the thematic areas of health, environment, energy and industry, in addition to strengthening nuclear and radiation safety and security in Brazil for the application of nuclear technology safely and securely in line with international best practices.

The CPF development process was led by the National Liaison Officer from the National Commission of Nuclear Energy (CNEN) who has been appointed by the national authorities as the CPF National Coordinator for Brazil, and the Programme Management Officer in charge of Brazil at the International Atomic Energy Agency (IAEA). The CPF has been developed in close consultation and involvement of CTMSP, CNEN and its institutes, EMBRAPA, CENA, ELETRONUCLEAR, INB, Institute of Physics/Fluminense Federal University, Radiology institute/Faculty of Medicine/University of Sao Paulo, Clinic Hospital/Federal University of Pernambuco and Escola Superior de Ciencias da Santa Casa de Misericordia/Vitoria.

The National Nuclear Energy Commission (CNEN) is the main scientific, technological and innovative organization in the nuclear sector of Brazil. Its scope covers most aspects of nuclear applications from safety, security and radiation protection to basic research and innovation in nuclear energy and applications, providing services to the society, such as production of primary radioisotopes and radiopharmaceuticals, services using nuclear analytical techniques and irradiation of materials. In addition, CNEN, through its different institutes, has an extensive academic and training programme. In such context, and in collaboration with the CNEN's technical departments, and other national institutions an extensive consultation process with representatives from health, nutrition, agriculture, environment, energy and water management sectors was carried out in order to identify Brazil's needs and priorities for cooperation.

2. Situation Analysis

During the past decades, IAEA support through the technical cooperation programme contributed the building and enhancing human resource and technical capabilities to apply nuclear technology in a broad range of areas to contribute to development priorities and needs in a sustainable manner. Key areas of technical cooperation between Brazil and the IAEA included agriculture, environment, industry, nuclear medicine and radiopharmaceutical production, radiotherapy and dosimetry, as well as nuclear and radiation safety and security.

The IAEA inter alia provided support to the establishment of a medfly, fruit fly parasitoids and codling moth rearing facility with the aim to improve the quality of fruit grown in Brazil and the decommissioning of the Poços de Caldas Uranium Mining and Milling Production facility

The CPF was consolidated based on experts' vision of the science and technology development trends, the Brazilian Nuclear Policy decree published at the end of 2018, and the National Development Plan formulated during 2019 and builds upon achievements of past TC programme activities in Brazil. In this sense, the CPF encompasses technical, policy and development visions.

The proposed technical cooperation programme under the CPF will contribute to the attainment of the Decree 9.600, dated December 5, 2018 outlined the Brazilian Nuclear Policy. It states the general objectives of ensuring the peaceful and safe use of nuclear energy, development of nuclear science and technology, in the fields of medicine, industry, agriculture, environment and power generation, and it also contains provisions for equipment, components and supplies for the nuclear and high technology industries.

The decree set the main challenges for the Brazilian nuclear sector as:

a) seek the autonomy and sustainability of Brazil in the production of nuclear power;

b) have self-sufficiency in the stages of the fuel cycle with the possibility of exporting surplus;

c) expand the supply of technological products and services in the nuclear area (health, environment, agriculture and industry); and

d) the separation of the regulation function (regulatory activity) from the promotion, research, development, service and production functions, both carried out by CNEN.

At the national development plan (PPA 2020-2023) these policy issues are framed at the table 1:

TABLE 1: PPA 2020 – 2023 Actions and results framework

Problem to be addressed	Actions	Expected result
Critical reduction in the specialized technical staff in the nuclear area and insufficient human resources	• Specialized training for the nuclear sector • Use of talent data bank	Provision of professionals to meet the needs of the nuclear sector

	for reallocation of human resources	
Insufficiency and inadequacy of regulatory instruments for specific nuclear technologies and inadequate regulatory framework	• Review and consolidation of regulatory frameworks related to nuclear technology strategies • Nuclear safety and control of nuclear material	Regulatory frameworks appropriate to the needs of the use of nuclear technologies
Insufficiency of coordination actions of the Protection System to the Brazilian Nuclear Program (Sipron)	Protection System of the Brazilian nuclear program strengthened.	Improved coordination capacity of Sipron
Insufficient knowledge of the nuclear resources in the national territory and discontinuation of mapping	• Prospective geological survey of nuclear minerals, including the reuse of nuclear ores as by-products • Extension of the geophysical survey in specific areas	Improvement in the knowledge of the potential of nuclear minerals in Brazil
External dependence of radioactive raw material	Implementation of the Brazilian multipurpose reactor	Self-sufficiency of products for nuclear medicine
Insufficient nuclear medicine services to attend the population and delay in introducing new diagnostic and therapeutic procedures in nuclear medicine	• Expansion of nuclear medicine services in the country • Increase supply of radiopharmaceuticals • Support for national production of new radiopharmaceuticals • Training of nuclear medicine professionals • Participation on research projects with new diagnostic and therapeutic RPs	Increased use of nuclear medicine services by the population and incorporation of new diagnostic and therapeutic procedures
Insufficient research infrastructure for the development of strategic technology in the nuclear area.	• Research and development in nuclear science and technology and applications • Implementation of the nuclear fusion laboratory Implementation of the food irradiator	Expansion of infrastructure to meet demands in a sustainable way
Insufficient production infrastructure to meet the demands of the nuclear area	• Expansion of manufacturing of fuel elements • Implementation nuclear reactor for electric power generation for remote locations • Provision of technological services • Storage of radioactive waste • Expansion of the uranium concentrate unit in Caetité • Implementation of the nuclear fusion laboratory • Manufacturing of heavy equipment for the nuclear	Expansion of infrastructure to meet demands in a sustainable way

	industry • Expansion of the Uranium Concentrate Unit (URA) • Implementation of the Repository of Low and Medium Level Waste – RBMN • Increase enrichment capability • Implementation of the industrial conversion facility	
Vulnerability of the electric power production chain	• Definition of a nuclear power generation program • Inter-ministerial working group and stakeholder's engagement in the nuclear sector	Strengthening the productive chain
Ignorance of the benefits of the nuclear sector by society and low level of knowledge of nuclear activity	Scientific dissemination and awareness of society on the benefits of nuclear energy applications	Improved society's perception of the nuclear sector

2.1 Radiation and Nuclear Safety and Security

Nuclear techniques and ionizing radiation sources are widely used in Brazil. The national strategy for ionizing radiation safety and nuclear safety is to ensure the adequate use of radiation sources and nuclear materials and to prevent the harmful effects of ionizing radiation, protecting the people (including patients, workers and members of the public) and the environment. Nuclear security is a very important aspect in the licensing process of nuclear and radiation facilities in Brazil. The nuclear security system aims to prevent nuclear material or other radioactive material from being possessed in an unauthorized manner, and that nuclear and radiological facilities are sabotaged.

Brazil has a well-developed regulatory infrastructure in the area of ionizing radiation protection, nuclear safety and security, establishing the requirements of radiation protection and the safety of radiation sources, mostly based on IAEA Safety Standards: radiation protection, radiation safety, nuclear safety and security are in general competences of the National Nuclear Energy Commission (CNEN), whereas diagnostic radiology practices are regulated by the National Health Surveillance Agency (ANVISA) of the Ministry of Health.

CNEN is responsible for the regulation, licensing and surveillance of nuclear and radiation installations, encompassing nuclear power plants, research reactors, nuclear fuel cycle facilities, industrial, medical, and research facilities, mining and processing of NORM, waste management and disposal facilities, and of the transport of nuclear and other radioactive materials. The government has established and maintains an appropriate governmental, legal and regulatory framework for radiation and nuclear safety and security, with responsibilities clearly allocated. CNEN also participates in the development of public policies and other activities in the nuclear field.

One of the areas of concern in the sector is that most of the experienced staff was trained in more depth during the 1980's and very few professionals were hired in the subsequent decades. As a consequence, the sector currently faces a progressive process of retirement of these professionals: currently more than two thirds of the regulatory body employees are eligible for retirement. A similar situation occurs in the other institutions in the field. Thus, there is the pressing need of intergenerational knowledge management and transfer among the professionals in the sector and of hiring and training new professionals. As an element of the national policy and strategy for safety, professional training to maintain a sufficient number of suitably qualified and experienced staff must be made available.

New nuclear power plants (NPPs) are expected to be included in the new edition of the ten-year energy plan and it is important for Brazil to improve human resources capacity in the nuclear power production fields. In this sense, it is equally important to build capacity and deliver a study (report) on the analysis of the nuclear fuel cycle, modelling the entire fuel cycle, including the life extension of the current NPPs and the construction of a Dry Storage Unit for spent fuel.

Life extension of nuclear installations and ageing management of system, structures and components important to safety are important technical cooperation subjects to Brazil, and IAEA training and assistance is expected to be requested both to the regulator and to the operator.

The optimization process of occupational radiation protection in medical and industrial practices needs improvement. Regarding the diagnostic radiology area, another area of improvement is justification of X-ray exams, particularly pediatric computed tomography examination, since the same exposure parameters are still often applied to infants as for adults. Another area for improvement is regarding the monitoring services, which can often only provide the monitoring data from external gamma and X-ray exposure, and are unable to provide adequate monitoring of beta and neutron radiation, dose to lens/hands and internal exposure.

The variety and complexity of nuclear installations is relatively large for the scale of the country's nuclear programme, yielding a complex management of the nuclear and radiation safety of these installations. These facilities include: nuclear power plants; research reactors; facilities for uranium mining and processing into "yellow cake" (ADU), conversion from U_3O_8 to UF_6, enrichment of UF_6 (isotope U^{235}), conversion from UF_6 to UO_2 powder, pelletizing of UO_2 powder, and nuclear fuel assembly.

Another concern is that many of the safety regulations were originally developed in the 1980's and subsequently revised. However, this revision process did not cope with the increase in number and complexity of nuclear and radiation facilities, associated to the adoption of new technologies and safety standards. Thus, well-documented regulatory guides and procedures need to be developed and some safety regulations need to be developed or revised. The same can be said about nuclear security regulations.

Following the Brazilian Government guidelines (National Development Plan - PPA 2020-2023, and Complementary Law 140 of 8th Dec. 2011), Brazil is actively pursuing to foster the development of networks and partnerships among national institutions related to safety issues in radiation and nuclear installations, such as: (i) the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA); (ii) environmental regulatory bodies of each of the states and municipalities neighboring nuclear facilities; (iii) Technical Support Organizations (TSOs), such as universities and the research and development institutes of CNEN; (iv) professional organizations, such as CBR, ABFM and SBPR. These partnerships sometimes are not systematic and lack formal grounds, such as memoranda of understanding among these institutions. With regards to other regulatory bodies, partnerships need to involve the establishment of common grounds for licensing facilities, improving the technical competence, and reducing legal competence gaps and overlaps through the establishment of memoranda of understanding and regulatory acts. The partnerships with the TSOs needs to be targeted towards enhancing the quality of their technical assistance for the regulatory body, to be achieved through capacity building of the TSOs in regulatory issues, acquisition of equipment and software, and also through the establishment of formal memoranda of understanding that define the roles and responsibilities of the TSOs in assisting the regulatory process.

Some studies were performed under the ARCAL projects to assess radiation protection procedures in conventional radiology examinations of adult and pediatric patients, mammography, computer-aided tomography and cardiac interventional radiology. Motivated by the results of these projects, the Brazilian College of Radiology (CBR) recently implemented a Radiation Protection Commission aiming to support radiologists in the optimization of images and radiation protection of patients. Besides, the Brazilian Society of Radiation Protection (SBPR) and the Brazilian Association of Medical Physics (ABFM) are organizing meetings to discuss the radiation safety procedures in the country. Universities and research centers from the different regions of the country are also developing activities to implement the radiation protection procedures according the IAEA Basic Safety Standards.

Regarding nuclear security, the Nuclear Security Support Center – CENASF from CNEN has carried out extensive cooperation with international partners, such as the IAEA, the US Department of Energy – DoE and the US Department of State – DoS, organizing and structuring training events (courses, workshops) for professionals from various Brazilian and Latin America institutions involved in Nuclear Security, including Intelligence and Law Enforcement Agencies, Armed Forces, nuclear power plants, research institutes and radiation facilities. These events raise awareness and capacity of staff from these institutions to act on strategic planning, to establish measures and procedures of prevention, detection and response to nuclear security events. This way, CENASF contributes to the implementation of a Nuclear Security Culture and to the improvement of NS in Brazil and in Latin America, disseminating the knowledge in this area.

In addition, the nuclear sector is a public sensitive issue and Brazilian Government is in an effort to increase transparency and accountability. In this sense, Brazil has identified the need to enhance public information and engagement in the nuclear and radiation safety issues through public participatory means across the regulatory process.

Motivated to change this scenario, Brazil has identified the need to improve the regulatory body infrastructure, hire new employees, and proceed with the knowledge transfer from senior experts to new staff. Due to the increase in scope and diversity of the Brazilian nuclear programme the Government took the political decision to separate the regulatory functions from the research and development functions of CNEN, thus raising the status of the nuclear and radiation safety to a new level within the government. At the wake of the naval nuclear propulsion project a new organization was created: the Naval Agency for Nuclear Safety and Quality (AgNSNQ) which manages its own Emergency Command and Control Center (ECCC).

Brazil actively participates in a number of IAEA efforts aiming to improve the regulatory body infrastructure, including by actively participating in safety committees and IAEA safety related missions, and sending its staff to training courses, workshops and meetings. Regarding nuclear security, Brazil expects to increase the capacity of operation of CENASF by increasing the number and capacity of its human resources and acquiring its own equipment, which would result in a larger logistic autonomy and efficiency.

The IAEA technical cooperation in this area, including developing networks of knowledge, transferring technology, and promoting education and training of professionals on radiation and nuclear safety and security, will complement the country's efforts in leading the strengthening of the Brazilian nuclear and radiation safety and security systems to ensure the safe and secure operation of the nation's nuclear and radiation facilities, and the radiation protection of patients, workers, the public and the environment.

The *planned outcome* of the proposed technical cooperation programme in the thematic area of nuclear and radiation safety and security is thus:

- Strengthened national radiation and nuclear safety and security infrastructure and capacities in line with best international practices in all relevant safety and security issues to protect people and the environment from ionizing radiation.

The planned outcome will contribute to the attainment of SDG 3.

2.2 Food and agriculture

Thanks to the technological development of agriculture, Brazil has passed in less than 40 years from a situation of large food importer to exporter. It should be noted that the problem of hunger, associated with extreme poverty has decreased significantly in the last decade to the current levels of around 6% of the population, is in the LA average, but it is still worrying to have about 12 million inhabitants starving. As mentioned above, hunger in Brazil is not associated with the low availability of food, but with poverty itself, which limits the population's attainment of food. It can be said that Brazilian agricultural development has been and continues to be aimed at directly meeting objective 2 of the UN SDG, which basically seeks to eliminate hunger through sustainable agricultural development.

For Brazil to achieve high agricultural development took about 40 years and was mainly due to the advances in the technological development of soil management and its fertility, in the genetic improvement of plants and animals, in the control of pests and diseases, and improving agricultural irrigation and mechanization. In all the technologies developed, except in the last two, the nuclear techniques were, directly and / or indirectly, very important for its development as to evaluate the efficiency in the field. In the case of soil fertility management, the use of the techniques of 32P, 33P, 15N, 13C, 34S, among others, has been used to optimize the management of synthetic fertilizers and biological nitrogen fixation (BNF), in the farming. Since Nitrogen is the most influent nutrient in Brazilian agricultural production the use of 15N techniques, made possible to determine that BNF is the main source of N for Brazilian agriculture, accounting for more than 75% of total nutrient demand in Brazilian agriculture.

Vulnerabilities and uncertainties are increasing and in the near future it will not be enough to produce larger volumes, it will be imperative to produce with higher quality, reducing costs, minimizing risks and conserving natural resources.

On the other hand, in recent decades there has been concern about the environmental impact of Brazilian agriculture, important advances have been obtained with the application of the nuclear technique of ^{13}C, a stable isotope that distinguishes in the soil the original carbon and the new carbon derived of agriculture, and allows to determine with certainty if a system is promoting the C sequestration in the soil. In livestock farming, ^{13}C and ^{15}N techniques, among others, also play an important role in research aimed at sustainable meat production.

It can be said that nuclear techniques are increasingly applied in Brazilian agricultural sector, and much has contributed to the specialization of human resources by CENA and IPEN, with the direct support of the IAEA. It should also highlight the support received from the IAEA through various programs, especially ARCAL. In Brazil, apart from CENA and IPEN, the Ministry of Agriculture network of applied agriculture research coordinated by Embrapa, is increasingly using nuclear techniques in improving quality, productivity and environmental sustainability of the Brazilian food production. It is believed that nuclear techniques could be of greater use in technological advancement if they are more widespread, showing the benefits to the end users, to local researchers directly involved in the development of new agricultural technologies. To this end, it could help the establishment of multidisciplinary and multi-institutional research networks, including laboratory analysis services, among others.

The *planned outcome* of the proposed technical cooperation in the thematic area of food and agriculture is thus:

- Increased food chain production value.

The planned outcome will contribute to the attainment of SDG 2.

2.3 Health and nutrition

2.3.1. NUCLEAR MEDICINE

2.3.1.1 – Services and HR

The technological base in Brazil has 427 nuclear medicine (NM) facilities authorized by CNEN across the country, with only 20% of the procedures performed in the public system.

Regarding Human Resources, formal medical training is well established in Brazil and Diagnostic Imaging (DI) training is reportedly part of the mandatory curriculum in 80% of the curricula. The training and education situation of medical physicists is more deficient. There are 13 Brazilian Institutions with graduate programs in Physics with specialization in Medical Physics or related fields while 140 programs are available for MSc and 116 for PhD degrees. In addition, there are "residency programs" and "Professional Development Programs", which offer almost 40 training slots per year in RT, NM, Radiopharmacy and RD.

The educational programs and technological equipment are also unevenly distributed with larger concentration in the Southeast of Brazil. There are currently two categories of certifications for Medical Physicists in Brazil: (1) Radiation Protection Supervisor - RPS, issued by the CNEN, and (2) Specialist Certificate, issued by the Brazilian Association of Medical Physics (ABFM). Currently, in Brazil there are 739 certified RPSs (295 in NM and 444 in RT). However, when looking at the distribution of these professionals around the country, we find an enormous disparity. Although almost 30% of the population lives in the Northeast of Brazil, there are only 83 certified RPS for RT (18%) and 48 for NM (16%). There is a training gap for the nuclear physicians in new technologies like anatomical imaging (CT and RM), new quantifications technologies, and brain imaging. This clearly indicates an urgent need for investment in educational structures and health systems in order to decentralize the programs, providing better access to medical physics and physician education and professional distribution across the country. Currently, there is no established medical physics and physician residency program in the Northeast of Brazil.

The national development program and the investments made in nuclear sciences by the Brazilian government, together with IAEA and its associated members, might help the national development in diagnostic imaging. This will contribute to prepare new professionals and create a sustainable capability to serve as a reference for other professionals to improve their knowledge.

The IAEA projects also contributed to filling some of the gaps of nuclear medicine methods and professional capabilities in the Northeast of Brazil, especially by training human resources for education, research and technological innovation in the Brazilian productive sector. This technology monitors and manages all vital variables in nuclear medicine processes to standardize procedures, to reduce radiation exposure, to keep quality and, to optimize costs.

2.3.1.2 - Radiopharmacy

Radiopharmaceuticals (RPs) are the driving force for nuclear medicine practice and are extensively produced and used worldwide for the diagnosis and therapy of human non-communicable diseases. Brazil has been active in the production and quality control of RPs for decades and with the introduction of new generations of RPs such as new positron emission tomography RPs (F-18 RPs beyond F-18 FDG, Ga-68 RPs etc.) as well as theranostic agents, a new horizon to achieve for the country has been opened.

Based on country plan on the introduction and installation of new multi-purpose reactor, production and application of reactor-based radioisotopes and RPs for theranostic applications (such as N.C.A. Lu-177, Sn-117m, and others) as well as seed sources, is foreseen. It is understood that the country will continue to plan and produce Mo-99 and I-131 as major RPs for the Brazilian population using the reactor. From medical accelerator side, cyclotrons with solid/liquid targets will open the way for production and application of many new cutting-edge PET radioisotopes (Ga-68, Zr-89, Cu-64, etc.) for development of new RPs.

2.3.2 RADIOTHERAPY

Radiotherapy is one of the cornerstones of cancer treatment. With the aging of population, cancer will be a major cause of morbidity and mortality. The technological development allowed more precise treatments with improvements in patient's outcomes with less morbidity. Brazil has about half of the required number of machines for radiotherapy, according to the WHO recommendations. This insufficient number is the cause of an estimated 5000 deaths in 2016. Additionally, among the existing equipment, only about 13% are able to deliver high technology/quality treatments. Implementation of technology requires clinical and economical investments in order to deliver results.

An important action of the Brazilian Ministry of Health in 2012, called the "80 solutions", has taken place and is slowly being implemented. Today, 8 (10%) of these machines are operational. Human resources are essential for the success of any project. Development, training and retention of the related staff is a key feature in this context. Organized partnerships with national and international associations can help in the achievement of these goals and strengthen the resources capacity. Also, national reference institutions personnel can either be trained as well as multiply the qualification and promote permanent education in high technology radiotherapy such as Volumetric Arc Therapy (VMAT), Stereotactic Ablative Radiotherapy (SABR), Image-Guided Radiotherapy (IGRT), and functional imaging-based treatments. Shorter treatments, with higher precision and less morbidity are possible to be delivered with these technologies. Thus, more patients will be able to be treated, with potentially long-term survivorship and better quality of life.

IAEA support is sought to strengthen human resource capacity of related staff in national reference institutions in high technology radiotheraphy.

2.3.3. – SIT FOR VECTOR CONTROL

Since the declaration by WHO of Public Health Emergency of International Importance (ESPII) due to triple epidemic, dengue, chikungunya and zika fever transmitted by the *Aedes aegypti* mosquito, Brazil has been working on the development of SIT as a method of vector control, aiming to reduce *Ae. aegypti* and to minimize, or disrupt, arbovirus transmission.

Effective control the vector is essential to block transmission of the disease. New technologies seek to be in line with these factors so that they can be competitive and efficiently attractive to the market. The use of the Sterile Insect Technique (SIT) involves the mass rearing of insects, where the females are eliminated from the process, then the males are sterilized and released, aiming the population reduction of the target species. The technique has been considered as an efficient tool in the control of several insect pests around the world and stands out for its ability to integrate with other existing tools and become an important component of Integrated Vector Management.

IAEA support through the TC programme is thus sought to establish a strategy for the integrated management of Vector *Aedes* with the use of the Sterile Insect Technique.

2.3.4. NUTRITION

In May 2017, Brazil became the first country to enter into SMART commitments (specific, measurable, achievable, relevant and time-bound) as part of the UN Decade of Action for Nutrition (2020-2024). Supported by PAHO and WHO for its implementation. In this context, the three goals to be achieved by 2019 are: 1) halt the growth of obesity in the adult population; 2) reduce the regular consumption of sugary drinks by at least 30% in the adult population; 3) to increase by at least 17.8% the percentage of adults who consume fruits and vegetables regularly. The commitments also include the implementation of public policies that result in health promotion and disease prevention, encouragement of healthy eating and lifestyle, and control of childhood obesity.

These goals will be achieved through the National Food and Nutrition Policy that integrates the National Health Policy and also the Food and Nutrition Security Policy, regulating the universal human right to adequate food. The values pursuit by the government in the issue of food and nutrition are, among others, sovereignty, democracy, social justice, sustainability, cultural diversity and national identity, social participation and accountability. The principles that guide these actions are: a) stimulating intersectorial actions with a view to universal access to food; (b) ensuring the safety and quality of food and the provision of services in this context; c) monitoring the food and nutritional situation; d) promotion of healthy eating practices and lifestyle; e) prevention and control of nutritional disorders and diseases associated with food and nutrition; f) promoting the development of research lines; g) development and training of human resources.

In this way, these policies are aligned to meet the Sustainable Development Goal 2, which provides for "ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture" and goal 3 "to ensure a healthy and promote well-being for all, at all ages ".

2.3.5 - Acute Radiation Syndrome

Regarding the treatment for injured and contaminated people from nuclear and radiological accidents, the Naval Hospital Marcílio Dias (HNMD) is a reference in Latin America in Nuclear Medicine. The HNMD is capable of providing high quality intensive and multidisciplinary care to treat serious casualties, especially those with Acute Radiation Syndrome, which require care similar to those of an immunocompromised patient. The Biomedical Research Institute (IPB) of HNMD conducts a research to treat radio-induced wounds, which are produced by linear electron accelerator in the posterior left hind paw of rats. These radio-induced wounds are treated in 3 different separated groups with the purpose of analyzing and comparing the healing process. These activities require a highly qualified and updated staff, specialized equipment, periodically reviewed and aligned with international recommendations and new technologies requirements.

It is very important to have professional training under the TC programme, in order to improve the qualification of the staff.

Considering all the human health sub-sectors, the *planned outcomes* of the proposed technical cooperation programme in this thematic area are thus:

- Strengthened national capacities to expand high-quality nuclear medicine and radiotherapy.
- Informed decision making for improved nutrition interventions particularly for infants.
- Enhanced national capacity to control Dengue, Chincungunya and Zika outbreaks in human populations.
- Training staff to improve the skills to treat acute radiation syndrome
- Strengthen Acute Radiation Syndrome treatment capacity

The planned outcomes will contribute to the attainment of SDGs 2 and 3.

2.4 Water and the environment

2.4.1 ENVIRONMENT

Many of the challenges threatening the conservation and sustainability of terrestrial, coastal and marine ecosystems are caused or exacerbated by effects of anthropogenic activities and a changing climate. Complex synergies between process and multiple abiotic/biotic stressors (such as increased temperatures, CO2 concentrations, suspended matter, microbial and chemical pollutions, radioactive contaminants, sewage, oil spills, eutrophication) contribute to the spread of the land degradation, biodiversity loss, deterioration of the water quality and ecosystem health. Therefore, the key strategy goals that can provide a substantive and measurable contribution to the Brazilian development framework and the 2030 Agenda are:

- To protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss;
- To protect and restore terrestrial and water-related ecosystems, including mountains, forests, drylands, wetlands, rivers, aquifers and lakes;
- To introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on terrestrial and aquatic ecosystems and control or eradicate the priority species;
- To improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials in the terrestrial and aquatic environments;
- Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity;
- To strengthen resilience and adaptive capacity to climate-related hazards and natural disasters;
- To integrate climate change measures into national policies, strategies and planning;

- To conserve and sustainably use the oceans, seas and marine resources for sustainable development;
- To monitor, minimize and address the impacts of ocean acidification, deoxygenation, fluxes of nuclear and non-nuclear pollutants, plastic debris, toxic harmful algal blooms, food web dynamics, and land-sea interactions;
- Effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans;

IAEA TC can contribute towards addressing water and environmental issues by encouraging the use of science-based tools. However, within the context of anthropogenic- and climate change-impacts, it is important not only to continue to refine existing methods but also to develop new techniques best suited to current and future regimes.

IAEA TC support is sought to enhance national capacities in the application of nuclear technology to monitor, conserve, recover and sustainably manage terrestrial, coastal and marine ecosystems impacted by multiple abiotic and biotic stressors.

2.4.2 WATER

The national water policy was issued in 1997 and in 2000, the national water organization (Agência Nacional de Águas – ANA) was created to implement the policy. ANA has four main roles: implementation of the policy, regulation, monitoring and planning.

It is well known that Brazil has abundant water resources. However, these natural systems are under pressure due to the loopholes on water management policies and environmental control. In recent years Brazil had a sequence of mine tailing dams breach disasters with severe environmental and human consequences. As a result of these disasters, some of the most important river systems in the country were affected with long term consequences that have not been clearly defined. Furthermore, several other iron mine tailings dams are currently in danger of also collapsing. In this context, the nuclear techniques involving stable and radioisotopes can be a valuable asset for helping to identify the real danger of collapse of these dams and for evaluating the environmental impacts of the already affected rivers.

Regarding tailings dams that contain radioactive material, besides assurance of their geotechnical stability, emergency preparedness and planning, as well as prospective radiological environmental impact assessment in the case of dam collapse, are also areas that could benefit from technical cooperation and regulatory information exchange. Tailings dam safety is an emerging problem across the country and is an important area to be developed over the coming years. With the proper support from TC activities, research institutes and universities are fully capable of carrying out these studies.

Recently, Brazil has increased the efforts to improve governance of the water resources, mainly with the concern of the development of tools for integrated water management. The country can benefit from technical support and training for applying nuclear and tracer techniques for understanding and estimating the interaction between ground and surface water. A main issue for Brazil is the quality of water, both in large population centers and in areas with intensive agriculture practice. Environmental isotope techniques may contribute for better assessment and mapping of water sources and evaluating their recharge rates, thus fostering improved irrigation practices and sustainable management of water resources.

Accordingly, the country must dominate the advances in the applications of both radioactive and stable natural isotopes as tracers of environmental processes in the hydrosphere. Among them is the use of the 3H-3He technique and of the noble gases for dating groundwater; especially 39Ar (the 102 – 103a gap), 81Kr/Kr ratio, 4He by alpha decay of 238U and 232Th for very old waters. On the other hand, 14C still remains an unyielding obstacle for dating (103 – 5 x 103 a) groundwater in a country with such vast extent, supportive climate, and whose economy is so dependent on food production. Novel accelerator mass spectrometers have been developed and made marketable; it is about time Brazil should have one.

Another important field of study is related to the use of nuclear techniques are the assessment of local water cycle and climate changes. These studies require mapping and monitoring the water isotopes in precipitation along the country. After a gap of 20 years, new Global Network of Isotopes in Precipitation (GNIP) stations are starting operation. The new TC activities can support the continuity of the new GNIP stations and enhance different forms of using the available data to strengthen the water resources knowledge. It can also support national research institutes and universities to improve or implement new techniques, such as different tracers, that could produce better results given the geographic and hydrological reality of the country.

Since 1996, Brazil has a Monitoring programme of Radionuclides along the Brazilian Coast, initiated by Brazilian Navy Centre of Technology (CTMSP), and now, performed by Sea Research Institute Admiral Paulo Moreira (IEAPM). The aims of this project are: to register and to keep a database of concentrations of artificial nuclides, as Cesium 137 and Strontium 90, in seawater, sediment and fish; and also, to model the dispersion of radionuclides caused by ocean currents. One of the important points of this programme is the construction of the Laboratory of Radionuclides at IEAPM, which is essential for analyzing the samples collected. This lab will put IEAPM as an international reference centre for radionuclides analyses. The IAEA TCP could help providing transfer of technology and knowledge to the technical staff of the institute and others stakeholders in applying new technologies and methods to collect and analyze the data.

The *planned outcome* of the proposed technical cooperation programme in the thematic area of environment is thus:

- Enhanced capacities of the Brazilian environmental authorities to monitor, conserve, recover and sustainably manage terrestrial, coastal and marine ecosystems impacted by multiple abiotic/biotic stressors.
- Improved applications of both radioactive and stable natural isotopes as tracers of environmental processes in the hydrosphere

The planned outcome will contribute to the attainment of SDGs 14 and 15.

2.5 Energy and industry

2.5.1 ENERGY

Brazil is committed to Energy SDG 7 that is to "Ensure access to affordable, reliable, sustainable and modern energy for all". Brazil's Intended Nationally Determined Contributions (INDC)[1] has a

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[1] Under U.N. Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in Paris in December 2015 INDCs are the primary means for governments to communicate internationally the steps they will take to address climate change in their own countries. INDCs reflect each country's ambition for reducing emissions, taking into account its domestic circumstances and capabilities. as

broad scope including mitigation, adaptation and means of implementation, consistent with the contributions' purpose to achieve the ultimate objective of the e United Nations Framework Convention on Climate Change (UNFCCC), pursuant to decision 1/CP.20, paragraph 9 (Lima Call for Climate Action). Brazil's NDC applies to the economy as a whole and it is based on flexible ways to achieve the 2025 and 2030 objectives. In this context, Brazil intends to adopt additional measures for the energy sector, which are consistent with the temperature target of 2°. Brazil intends to commit to reduce greenhouse gas emissions by 37% below 2005 levels in 2025. Subsequent indicative contribution is to reduce greenhouse gas emissions by 43% below 2005 levels in 2030. The following measures are planned to be concludes until 2025:

- Maintenance of the participation of anhydrous ethanol in gasoline (27%);
- Increase share of biodiesel in diesel oil, from 7% to 11% till 2026;
- Increase participation of the rail modal in the cargo activity matrix;
- Greater efficiency in the use of sugarcane bagasse coming from the sugar and alcohol sector for electric generation;
- Use of auctions as a tool to induce the penetration of renewable sources;
- The availability of thermoelectric plants of natural gas is a valuable instrument to enable greater insertion of renewables in the matrix.

Regarding the electricity efficiency, the Brazilian NDC intends to achieve 10% of efficiency gains in the use of electric energy in 2030, that is, conserved energy equivalent to the generation of 25,500 MW hydroelectric.

According to Empresa de Pesquisa Energética of the Brazilian Energy and Mining Ministry the internal energy supply scenario in 2022 should be:

Energy Matrix - Ktep	2017	2022
Non-renewable	**226,808**	**169,134**
Oil	166,276	107,547
Natural Gas	37,938	37,244
Coal	16,570	18,443
Uranium	4,193	3,918
Others non-renewable	1,831	1,982
Renewable	**126,685**	**154,685**
Hydropower and Electricity	35,023	45,333
Wood	23,424	23,731
Sugar Cane	51,116	61,476
Others	17,122	24,145

Source: EPE - PDE2027

Regarding Nuclear Power, the Government recently shifted the industrial facilities that was controlled by the Ministry of Science and Technology to the Ministry of Energy and Mining.

Brazil has two Nuclear Power Plants in operation, and a third in construction. Angra 1 is a 640 MW Westinghouse design PWR, whereas Angra 2 is a 1350 MW Siemens-KWU design. Work in the third unit, also s KWU 1350 MW, has been slowed down due to financial and contractual issues, and the Owner-Operator Eletronuclear is working towards a resumption of the civil works in 2021, which shall bring the start of commercial operation (COD) to 2026. Eletronuclear is also working in another two major endeavours, which is the 20 years life extension of Angra I and a Dry Storage Unit for spent fuel.

countries formally join the Paris Agreement and look forward to implementation of these climate actions – the "intended" is dropped and an INDC is converted into a Nationally Determined Contribution (NDC).

New NPPs are expected to be included at new editions of the ten-year energy plan and the 2050 plan. In this regard, Eletronuclear has been working in identifying suitable sites for the future units.

Regarding Nuclear Fuel Cycle in Brazil, Industrias Nucleares do Brasil (INB) is working on the installation of the conversion facility. With that, Brazil will complete all the steps of fuel supply, from uranium mining and milling to the fuel assembly fabrication, including in between the processes of isotopic enrichment, reconversion of UF6 to UO2 powder and pelletizing. Concerning the mineral resources, Brazil has, today, one uranium production facility, currently with an exhausted open pit mine, and nearby a second mine at the final stage of commissioning. In a different site there is a former uranium production installation, being decommissioned, with opportunities to benefit from environmental remediation knowledge, tools and technology. Also, there is an expansion plan to implement the first uranium underground mine in Brazil.

IAEA support through the TC programme is sought to improve national capacities in energy planning to support studies that consider the expansion of the Brazilian nuclear power programme.

2.5.2 INDUSTRY

Industrial applications of nuclear science and technology can be divided in Radiation Technology, which consist on treatment of goods using irradiation device, and Radioisotope technology which consist on the use of sealed sources and radiotracers. All these applications are available in Brazil.

Regarding the irradiation devices the existing equipment available in Brazil consists of eleven industrial electron beam accelerators with energy from 110 keV to 10 MeV and four Gamma Irradiators with activity from 50 kCi to 5 MCi (Cobalt-60).

For electron beam (EB), there is a growing application in all energy ranges:

a) low-energy (from150 keV to 300 keV) for packaging (bottle and multilayer films) sterilization and for curing of inks, coating and adhesives for the elimination of volatile organic compounds (environmentally friendly), and in energy savings and efficiency.
b) high and mid-energy from 300 keV to 5 MeV), for food irradiation, sterilization of disposable medical, pharmaceutical and cosmetic devices, crosslinking of wire and electric cables, multilayer packaging films, heat shrinkable tubes and films, tires and components, composite and nanocomposite materials, biodegradable composites based on bio-renewable resources, carbon and silicon carbide fibres modification, lignocellulosic and natural polymers irradiation, semiconductor modification, gemstone enhancement, grafting, electrocatalysts nanoparticles production, solid residues remediation, wastewater and flue gas treatments.
c) medium and high energy (from 5 MeV to 10 MeV) with regard to window life time, power supply and cathode.

To enlarge the national capacity to treat industrial effluents using EB, the mobile unit with electron accelerator will demonstrate the efficiency of this technology on site to solve industrial effluent problems in Brazil and provide an effective facility between a laboratory-scale plant to a large-scale plant with the objective to demonstrate the efficacy and transfer the technology.

The future of the EB for environmental and other applications such as flue gas treatment from petrochemical complexes, incinerators and mines requires further technical developments to make the radiation technology competitive.

For Gamma irradiators treatment of cultural heritage artefacts and radio sterilization of medical products are areas with increasing demand. The Government is also studying to open the market for food irradiation. With the advent of very high-current, mid and high-energy accelerators, X-radiation can be used as an alternative to the use of radioactive isotopes in such areas as medical device sterilization and food treatment.

Current applications of radioisotopes in industry are:

a) Process diagnostics - The use of sealed sources of radiation and radioactive tracers in troubleshooting and process optimization.

Applications in refining and petrochemical processing are currently greater than in all the other industries combined, where the main motivator is economic benefit. Radioisotopes are also widely used in oil field studies, where they are applied to tracing:

- Measuring preferential flow trends within an oil or gas reservoir
- Measuring the first breakthrough of injected water or gas
- Detecting fault block communication
- Measuring interlayer connectivity within a reservoir

Radiotracer techniques are used regularly to study the behaviour of wastewater treatment plants. The main motivator is benefit improvements in health and social hygiene and in environmental conservation, particularly in developing countries.

b) Nucleonic Instruments - Instruments incorporating a radioactive source and used for analysis, measurement and control on industrial plants.

A total of eleven private companies and governmental institution apply radioisotopes techniques in Brazil.

The trends for future radiotracer applications are:

- Application of small size neutron generators
- Development and application of nanoparticle tracers
- Radiotracer and Nuclear Control System (NCS) methods for the mineral industry
- Tracer technology for sediment transport
- Development of radiotracer generators including gaseous tracers
- Tomography methods including multi-energy CT
- Multimodality (hybrid) instrumentation
- Modelling of processes including data from nuclear methods
- Nuclear methods in the petroleum industry

Evaluation and application of high efficiency/high resolution detectors for nuclear radiation IAEA TC support is sought to strengthen the institutional capacities of selected laboratories in the nuclear area to improve their infrastructure and knowledge to offer customized solutions.

The *planned outcomes* of the proposed technical cooperation programme in the thematic area of energy and industry are thus:

- Enhanced national capacities in energy planning taking into consideration the planned expansion of the Brazilian nuclear power programme.
- Improved industrial processes in Brazil.

The planned outcomes will contribute to the attainment of SDGs 7 and 9.

3. Programme Plan

3.1 Radiation and Nuclear Safety and Security

Planned Outcome: Strengthened national radiation and nuclear safety and security infrastructure and capacities in line with best international practices in all relevant safety and security issues to protect people and the environment from ionizing radiation.

Indicative Outputs:

1. National radiation protection in worker, medical and public exposures are improved
   The IAEA technical cooperation on radiation protection in worker, medical and public exposures will allow Brazil to employ the best available international practices in order to prevent or reduce the harmful effects of ionizing radiation.

   Specific cooperation outputs include: (i) protection against radon in working areas; (ii) radiation protection in NORM and mining facilities; (iii) interventionist radiology; (iv) compilation of good practices and quality assurance related to radiation protection; (v) improvement and accreditation of radionuclide analytical techniques; (vi) reduction of potential conventional internal and external hazards in radiation and nuclear installations; (vii) improvement of national SSDL infrastructure; (viii) radiation safety of medical workers, patients, and accompanying persons; (ix) radiation safety in decommissioning of radiation and nuclear facilities; (x) radiological environmental impact assessment and reduction;

2. Regulatory body infrastructure is improved with general and specific regulations, guides, procedures, code of practices, tech specs and inspection protocols being developed or updated according to the IAEA Safety Standards.
   The IAEA technical cooperation will support Brazil in: (i) reviewing and developing new regulations, guides and procedures in line with the IAEA Safety Standards; (ii) updating procedures on how to conduct regulatory activities, such as documents assessment, regulatory inspections and reporting, and enforcement; (iii) improving the regulatory body management infrastructure by conducting external appraisals and improving the knowledge management.

3. Radiation safety of the waste management is improved.
   Potential outputs resulting from IAEA technical cooperation include: (i) radiation safety in predisposal management of radioactive waste; (ii) radiation safety of radioactive waste final disposal; (iii) safety of very low level radioactive waste; (iv) safety of NORM mining tailings dams.

4. Radiation safety of existing exposures is improved (such as for radon, and nuclear and NORM legacy sites).
   The IAEA technical cooperation can provide support for Brazil to improve the: (i) protection against radon in dwellings; (ii) radiation safety of existing exposures in nuclear and NORM legacy sites;

5. National emergency preparedness and response is improved.
   The IAEA technical cooperation can support Brazil to: (i) improve national capability on radiological risk assessment for small and large facilities; (ii) improve national capability of

emergency response in radiation and nuclear facilities, and in unregulated uses of ionizing radiation.

6. National infrastructure for education and training of human resources on nuclear and radiation safety and security is updated according to the current technology and a knowledge management system is established.
   The IAEA technical cooperation can provide support for Brazil to: (i) improve human resource capacity on radiation and nuclear safety; (ii) strengthen national requirements on education, training, competence and qualification for the different categories of personnel to be trained in radiation and nuclear safety; (iii) develop national education and training programmes on radiation and nuclear safety; (iv) develop national training centers on radiation safety; (v) develop and establish a national knowledge management system on radiation and nuclear safety.

7. National transport safety and security infrastructure is improved.
   The IAEA technical cooperation can provide support for Brazil to develop an integrated infrastructure for the safe transport of radioactive materials, involving Brazilian regulatory bodies.

8. Equipment and software related to safety and security is up to date.
   The IAEA technical cooperation can support Brazil to update laboratory equipment and procedures on radiation and nuclear safety and security.

9. Improved network among relevant national and international institutions related to the nuclear and radiation safety and security.
   Brazil is actively pursuing to foster the development of networks and partnerships with other national institutions related to safety issues in radiation and nuclear installations. The IAEA technical cooperation in this area, including developing networks of knowledge, transferring technology, and promoting education and training of professionals on radiation and nuclear safety and security, will complement the country's efforts in leading the strengthening of the Brazilian nuclear and radiation safety system to ensure the safe and secure operation of the nation's nuclear and radiation facilities, and the radiation protection of patients, workers, the public and the environment.

10. Information related to nuclear and radiation safety is adequately available to the public
    The nuclear sector is a public sensitive issue and Brazilian Government is in an effort to increase transparency and accountability. In this sense, Brazil has identified the need to enhance public information and engagement in the nuclear and radiation safety issues through public participatory means across the regulatory process. The IAEA cooperation could contribute for making tools available for the improvement of nuclear information and involvement of the Brazilian society.

3.2 Food and agriculture

Planned outcome: Increase food chain production value with sustainable technology

Indicative outputs:

- Increased resilience of crops to climate stress
- Reduction of GHG and sustainable use of the natural resources and biodiversity
- Integration agriculture-livestock-biomes

- Pest and disease control
- Enhanced animal genetics
- Development of new bioproducts: cosmetics, biopharmaceuticals, bioplastic, biofertilizer, biofuel and bio enzymes,
- Increased value in the production chain

3.3 Health and nutrition

Planned outcomes: Strengthened national capacities to expand high-quality nuclear medicine and radiotherapy; informed decision making for improved nutrition interventions particularly for infants; enhanced national capacity to control Dengue, Chincungunya and Zika outbreaks in human populations; strengthen Acute Radiation Syndrome treatment capacity

3.3.1 NUCLEAR MEDICINE

Indicative outputs:

- Increased use and introduction of new diagnostic and therapeutic nuclear medicine procedures in healthcare:

  The IAEA technical cooperation can provide support to: (i) ensure a safe and secure introduction of new diagnostic and therapeutic nuclear medicine procedures to attend and benefit the population; (ii) assure adoption of good practices and stimulate independent quality audits of nuclear medicine practices; (iii) stimulate expansion of nuclear medicine services in the country.

- Reliability and expansion of supplies needed for nuclear medicine practice:

  The IAEA technical cooperation can provide support to a reliable radionuclide and radiopharmaceuticals supply in Brazil: (i) encouraging the implementation of the Brazilian multipurpose reactor, a factor that will bring self-sufficiency on radionuclides production; (ii) stimulate reliable production and supply of radiopharmaceuticals.

- National development of new radiopharmaceuticals:

  The IAEA technical cooperation can provide support to: (i) introduce new diagnostic and therapeutic radiopharmaceuticals in Brazil; (ii) bring inputs and specificities from international experiences on the production of short-lived and therapeutic compounds to the Brazilian regulatory bodies, in accordance with IAEA manuals and TEC-DOCs; (iii) production of non-18F cyclotron radionuclides, non-FDG PET tracers, and new therapeutic radiopharmaceuticals.

- Research projects with new diagnostic and therapy radiopharmaceuticals:

  The IAEA technical cooperation can provide support for Brazil to: (i) develop projects with new diagnostic and therapeutic radiopharmaceuticals; (ii) encourage partnership of academic and research institutions with international institutions in the medical field, developing networks and looking for validation of new clinical procedures in Brazil; (iii) promote education and training of professionals on new diagnostic and therapeutic procedures.

- Improvement of training human resources on nuclear medicine:

  The IAEA technical cooperation can provide support for Brazil to: (i) improve training of nuclear medicine physicians on anatomical imaging (CT and RM), new quantifications technologies, and brain imaging; (ii) improve training of multidisciplinary personnel (biomedical/technologists, medical physicists, pharmacists) in nuclear medicine; (iii) strengthen national requirements on education, training, competence and qualification for the different categories to be trained in nuclear medicine.

3.3.2 RADIOTHERAPY

Indicative outputs:

- Availability and use of new radiotherapy technology are improved:

  Even with the government initiatives to improve the availability of linear accelerators, there is still insufficient radiotherapy equipment in the country. In addition, even the new machines are not used in their full technological capacity, which may be related to the lack of personnel training, specific machine limitations, among other reasons. The IAEA technical cooperation may help in the management and support of the already existing and the new facilities to improve the proper and rational use of the equipment, and with the implementation of new technology in different centers.

- The capacity of the related personnel to manage more advanced radiotherapy technologies, and better use of the available tools are improved:

  A personnel training program is a key feature in the development in this area. Different levels of complexity may be targeted in these trainings, with both, education of the National professionals, as well as the sharing of this training with local and regional personnel. The IAEA technical cooperation can provide support on the development of national training centers and a national training and education program in radiotherapy. Well trained and prepared professionals will help to improve the delivery of radiation treatments, with better patients' outcomes with less morbidity.

- Quality and safety of radiotherapy improved:

  Access to radiotherapy in the country is slowly increasing as well as high technology equipment. Radiation safety is warranted to the proper delivery of radiotherapy, maximizing clinical benefits, while reducing potential side effects. The IAEA technical cooperation will support Brazil in the update of safety regulation and quality control protocols, as well as in the development of appropriate guidelines and procedures related to the new technology. The safety and quality of treatments will be more assured.

- Radiotherapy clinical research improved:

  Brazil is a strategic country in Latin America. Collaboration and experience exchange are fundamental for the development of radiotherapy in this geographic area. Epidemiologic specificities can be addressed properly, and research and clinical collaboration developed unbiased of international standards. The support of IAEA technical cooperation can help the exchange of radiotherapy high technology knowledge among Latin American countries with focus in the application of more effective techniques for better patient care.

- Common knowledge about radiotherapy improved:

  Radiotherapy is a consolidated cancer treatment with reliable results both in radical and palliative scenarios. However, there is a cultural barrier regarding the use of radiation in many areas, even among health professionals. The IAEA technical collaboration support could help in the development of a national radiotherapy awareness program regarding information of benefits of the use of radiation in the health scenario.

3.3.3 SIT FOR VECTOR CONTROL

Indicative Outputs:

- Optimize the methodologies for mass rearing, packaging and releasing insects produced to promote the reduction of operational costs and to guarantee the quality of the final product: sterile male.

- Evaluate new strains of *Ae. aegypti* as: their survival, dispersion, ability to induce sterility in the wild population, among others, aiming to define the potential of use

3.3.4 NUTRITION

Indicative Outputs:

- IAEA support is sought to set up a database on body composition and anemia in infants that will be available to health authorities and to develop a nutrition policy.

3.3.5 ACUTE RADIATION SYNDROME

Indicative Outputs:

- Trained staff in Acute Radiation Syndrome treatment

3.4 Water and the environment

Planned Outcome: Enhanced institutional capacities of the Brazilian environmental and water authorities to monitor, conserve, recover and sustainably manage terrestrial, coastal and marine ecosystems impacted by multiple abiotic/biotic stressors.

Indicative Outputs:

- Analytical capabilities and scientist expertise to identify the triggers of climate change, land degradation, desertification, biodiversity loss, deterioration of the fresh and marine water quality and ecosystem health are strengthened.
- Occurrence rate, impact and effect of multiple environmental stressors in the region are established.
- Guidelines for monitoring and management of multiple environmental stressors established and provided.
- National system framework of early warning, monitoring, and response are established and strengthened.
- Plan for dissemination of results defined and established.
- Application of isotope techniques to assess and map water sources and evaluating their recharge rates, and safety of tailings dams.

3.5 Energy and industry

Planned outcomes: enhanced national capacities in energy planning taking into consideration the planned expansion of the Brazilian nuclear power programme; improved industrial processes in Brazil.

3.5.1 ENERGY PLANNING

Indicative Outputs:

- Study conducted with the analysis of the nuclear fuel cycle, from the modelling of the entire fuel chain, including the life extension of Angra 1 and Angra 2 nuclear power plants.
- Professionals trained to carry out nuclear fuel cycle analysis studies from the modelling of the entire fuel chain, including the current nuclear power plants life extension.
- Study with the analysis of the contribution of nuclear energy (electricity generation) to the achievement of SDGs and NDCs.
- Professionals trained to conduct studies of analysis of the contribution of nuclear energy (electricity generation) to the achievement of SDGs and NDCs.

Technical and economic feasibility study for the implementation of a spent nuclear fuel (dry or wet) deposit.

3.5.2 INDUSTRY

Indicative Outputs:

- Diagnostics of industrial process performed
- Developing of nanoparticles radiotracers
- Clean technologies adopted

3. Results framework and plan of action

Results framework

	Outcome	Indicator	Means of Verification
Radiation and Nuclear Safety and Security	Outcome statement(s)	Relevant indicator(s)	Where/How the information for this indicator may be sourced
	Strengthened national radiation and nuclear safety and security infrastructure and capacities in line with best international practices in all relevant safety and security issues to protect people and the environment from ionizing radiation.	(i) compilation of good practices and quality assurance related to radiation protection disseminated; (ii) updated regulations for research reactors and fuel cycle facilities in line with the IAEA Safety Standards; (iii) education and training programmes for professionals on radiation and nuclear safety and security	1. Lists of the best practices identified and implemented (validated by experts) 2. Regulation approved by the CNEN's Board 3. Training programme approved by the competent authority

Indicative Outputs

1) National radiation protection in medical, worker and public exposures improved.
2) Regulatory body infrastructure improved and general and specific regulations, guides, procedures, code of practices, tech specs and inspection protocols developed or updated according to the IAEA Safety Standards.
3) Radiation safety of the waste management improved.
4) Radiation safety of existing exposures improved (such as for radon, and nuclear and NORM legacy sites).
5) National emergency preparedness and response improved.
6) National infrastructure for education and training of human resources on nuclear and radiation safety and security updated according to the current technology and a knowledge management system established.
7) National transport safety and security infrastructure improved.
8) Equipment and software related to safety and security up to date.
9) Network among relevant national and international institutions related to the nuclear and radiation safety and security improved.
10) Information related to nuclear and radiation safety adequately available to the public

Food and Agriculture

Outcome statement	Relevant indicators	Where/How the information for this indicator may be sourced
Increase food chain production value with sustainable technology	Nuclear technologies applied to the production chain	Food and Agriculture Ministry annual technical reports

Indicative Outputs

1) Increased resilience of crops to climate stress
2) Reduction of GHG and sustainable use of the natural resources and biodiversity
3) Integration agriculture-livestock-biomes
4) Pest and disease control
5) Enhanced animal genetics
6) Development of new bioproducts: cosmetics, biopharmaceuticals, bioplastic, biofertilizer, biofuel and bio enzymes,
7) Increased value in the production chain

Health and Nutrition	Outcome statements:	Relevant indicator(s)	Where/How the information for this indicator may be sourced
	Strengthened national capacities in nuclear medicine and radiotherapy and reduced morbidity and mortality of cancer in Brazil.	New NM procedures and RT techniques implemented	Reports from the Ministry of Healthy
	Informed decision making for improved nutrition interventions particularly for infants.	Nutrition policy developed based on scientific data	Reports from the specialized hospitals
	Enhanced national capacity to control Dengue, Chincungunya and Zika outbreaks in human populations.	National statistics on arbovirus	Reports from the Ministry of Healthy
	Strengthened Acute Radiation Syndrome treatment capacity	Training programme implemented	Reports from the specialized hospitals

Indicative Outputs

1) Sterile Insect Technique (SIT) integrated into the Management of Vector Aedes.
2) New radiopharmaceuticals tested and licensed by health authorities.
3) New NM procedures covered by private and public healthcare systems
4) Theranostics procedures established.
5) Advanced RT treatment implemented.
6) Proton therapy feasibility performed.
7) Data base on body composition and anaemia on infants available to the health authorities.
8) Trained staff in Acute Radiation Syndrome treatment

	Outcome statement	Relevant indicator(s)	Where/How the information for this indicator may be sourced
Water and the Environment	Enhanced institutional capacities of the Brazilian environmental and water authorities to monitor, conserve, recover and sustainably manage terrestrial, coastal and marine ecosystems impacted by multiple abiotic/biotic stressors.	Nuclear and isotope techniques to be applied by the end of 2024; Triggers of environmental change identified by the end of 2024;	Guideline documents provided, networks strengthened, and websites established and filled with project results by the end of 2024
	Indicative Outputs 1) Analytical capabilities and scientist expertise to identify the triggers of climate change, land degradation, desertification, biodiversity loss, deterioration of the fresh and marine water quality and ecosystem health strengthened. 2) Occurrence rate, impact and effect of multiple environmental stressors in the region established. 3) Guidelines for monitoring and management of multiple environmental stressors established and provided. 4) National system framework of early warning, monitoring, and response established and strengthened. 5) Environmental radioactivity monitoring established. 6) Plan for dissemination of results defined and established. 7) Application of isotope techniques to assess and map water sources and evaluating their recharge rates, and safety of tailings dams.		
Energy and Industry	Outcome statements	Relevant indicator(s)	Where/How
	Enhanced national capacities in energy planning taking into consideration the planned expansion of the Brazilian nuclear power programme;	By 2024 the Angra-1 plant's life span extended. By 2024 a study with nuclear fuel cycle analysis published. By 2024 a study analysing the contribution of nuclear energy (electricity generation) to the achievement of SDGs and NDCs published.	Reports and publications from CNEN. Reports and publications from Ministry of Mines and Energy
	Improved industrial processes in Brazil	Industrial process improved	Technical reports from CNEN

Indicative Outputs

A. Energy:

1) Study conducted with the analysis of the nuclear fuel cycle, from the modelling of the entire fuel chain, including the life extension of Angra 1 and Angra 2 nuclear power plants.
2) Professionals trained to carry out nuclear fuel cycle analysis studies from the modelling of the entire fuel chain, including the current nuclear power plants life extension.
3) Study with the analysis of the contribution of nuclear energy (electricity generation) to the achievement of SDGs and NDCs.
4) Professionals trained to conduct studies of analysis of the contribution of nuclear energy (electricity generation) to the achievement of SDGs and NDCs.
5) Technical and economic feasibility study for the implementation of a spent nuclear fuel (dry or wet) deposit.

B. Industry:

1) Diagnostics of industrial process performed
2) Developing of nanoparticles radiotracers
3) Clean technologies adopted

Plan of action[2]

	Indicative Output	Approximate costing in €	Resources currently available in €	Difference (€A – €B)	Relevant national counterpart/institution	Indicative timeframe
Radiation and Nuclear safety and security	1) National radiation protection in medical, worker and public exposures are improved 2) Regulatory body infrastructure is improved and general and specific regulations, guides, procedures, code of practices, tech specs and inspection protocols are developed or updated according to the IAEA Safety Standards 3) Radiation safety of the waste management is improved 4) Radiation safety of existing exposures is improved (such as for radon, and nuclear and NORM legacy sites) 5) National emergency preparedness and response is improved	5,000,000	3,000,000	2,000,000	Ministry of Science and Technology Ministry of Mining and Energy Ministry of Healthy	5 years

[2]The above stated figures are indicative. Signing of the CPF by the Agency does not commit to funding of the CPF implementation.

	6) National infrastructure for education and training of human resources on nuclear and radiation safety and security is updated according to the current technology and a knowledge management system is established 7) National transport safety and security infrastructure is improved 8) Equipment and software related to safety and security is up to date 9) Improved network among relevant national and international institutions related to the nuclear and radiation safety and security 10) Information related to nuclear and radiation safety is adequately available to the public					

Food and Agriculture	1) Increased resilience of crops to climate stress 2) Reduction of GHG and sustainable use of the natural resources and biodiversity 3) Integration agriculture-livestock-biomes 4) Pest and disease control 5) Enhanced animal genetics 6) Development of new bioproducts: cosmetics, biopharmaceuticals, bioplastic, biofertilizer, biofuel and bio enzymes, 7) Increased value in the production chain	3,500,000	3,000,000	500,000	Ministry of Agriculture CENA	4 years

Health and Nutrition	1) Sterile Insect Technique (SIT) integrated into the Management of Vector Aedes. 2) New radiopharmaceuticals tested and licensed by health authorities. 3) New NM procedures covered by private and public healthcare systems 4) Theranostics procedures established. 5) Advanced RT treatment implemented. 6) Proton therapy feasibility performed. 7) Data base on body composition and anaemia on infants available to the health authorities. 8) Trained staff in Acute Radiation Syndrome treatment	6,000,000	3,000,000	3,000,000	Ministry of Health	5 years

Water and the Environment	1) Analytical capabilities and scientist expertise to identify the triggers of climate change, land degradation, desertification, biodiversity loss, deterioration of the fresh and marine water quality and ecosystem health strengthened. 2) Occurrence rate, impact and effect of multiple environmental stressors in the region established. 3) Guidelines for monitoring and management of multiple environmental stressors established and provided. 4) National system framework of early warning, monitoring, and response established and strengthened. 5) Environmental radioactivity monitoring established. 6) Plan for dissemination of results defined and established. 7) Application of isotope techniques to assess and map water sources and evaluating their recharge rates, and safety of tailings dams.	5,000,000	2,000,000	3,000,000	Ministry of Environment, Ministry of Defence	5 years

Energy and Industry	A. Energy: 1) Study conducted with the analysis of the nuclear fuel cycle, from the modelling of the entire fuel chain, including the life extension of Angra 1 and Angra 2 nuclear power plants. 2) Professionals trained to carry out nuclear fuel cycle analysis studies from the modelling of the entire fuel chain, including the current nuclear power plants life extension. 3) Study with the analysis of the contribution of nuclear energy (electricity generation) to the achievement of SDGs and NDCs. 4) Professionals trained to conduct studies of analysis of the contribution of nuclear energy (electricity generation) to the achievement of SDGs and NDCs. 5) Technical and economic feasibility study for the implementation of a spent nuclear fuel (dry or wet) deposit. B. Industry: 1) Diagnostics of industrial process performed 2) Developing of nanoparticles radiotracers 3) Clean technologies adopted	3,000,000	1,500,000	1,500,000	Ministry of Energy and Mining Ministry of Economy Ministry of Science and Technology	5 years

Total estimated overall cost for CPF *22,500,000*	*Total estimated available resources for CPF* *12,500,000*	*Total difference in resources for CPF* ***(€C)*** ***10,000,000***

Estimated government costs sharing, if additional to (€B) *Estimated government in-kind contribution, if additional to (€B)*	*N/A* *N/A*

Total Additional Resources Needed– *this takes €C and subtracts any additional government contributions*	*€ 10,000,000*

4. Programme implementation and support

4.1 CPF coordination and review

The development and application of nuclear energy for peaceful purposes is a fundamental principle in Brazilian policy, which is enshrined in its Constitution. Brazil is well aware of the benefits of international technical cooperation and the synergies fostered by it, for which the Agency's Technical Cooperation Programme (IAEA-TCP) is of strategic importance.

The National Liaison Office of the Brazilian Nuclear Energy Commission coordinated the elaboration of the present CPF and will continue its responsibility during the implementation and revision. Any revision before the end of the CPF signed period must be limited to specific field of activity.

For the preparation of the CPF an extensive consultation process was undertaken by the CNEN/NLO. The document could not be produced without the invaluable cooperation of CTMSP, CNEN and its institutes, EMBRAPA, CENA, ELETRONUCLEAR, INB, Institute of Physics/Fluminense Federal University, Radiology institute/Faculty of Medicine/University of Sao Paulo, Clinic Hospital/Federal University of Pernambuco and Escola Superior de Ciencias da Santa Casa de Misericordia/Vitoria. Beside the institutions, many experts in each field provided invaluable contribution to prepare the CPF.

The CNEN/NLO started to work in the CPF in 2018. Initially to create awareness regarding the relevancy of the process to shape the future cooperation and, after the inauguration of the new government and the issuance of the national Nuclear Energy Policy Decree, inputs were collected from the institutions and experts in all fields.

The CPF coordinator would like to express the appreciation and gratitude of the effort made by all the CPF contributors, and for their patience and dedication.

As the Government National Development plan is being formulated during 2019, so the CPF priorities were taken shape.

To review the CPF, either the NLO or the Agency can start the process, by requesting it in written. Ideally, the revision process can be done before the beginning of any given TC cycle. So that priorities can be up dated as needed and the new programme cycle could reflect updated priorities.

At the same way, if national development priorities don't change in any significant way that could impact the performance of the Technical Cooperation Programme, after the date of the validity of the signed CPF, Brazil and the Agency could mutually agree to extend the validity of the CPF to a maximum of two years.

The UNDAF document of Brazil is approved for 2017/2021. So that, the first milestone to assess the necessity or not to review the CPF is 2022.

4.2 Partner coordination

Brazil is a founding member of the United Nations (UN) and participates in all of its specialized agencies. As a member of the UN, Brazil adopted the 2030 Agenda for Sustainable Development with the Sustainable Development Goals (SDGs) at its core.

Although the IAEA has not co-signed the UNSDPF 2017-2021, the proposed technical cooperation programme under the current CPF could contribute to the following outcomes:

Annex 1: Partnership Framework

Thematic Area	Outcome in National Plan or Sector Strategy	CPF Outcomes	Links with SDGs	Links with Outcomes of United Nations Sustainable Development Partnership Framework Brazil 2017-2021	Relevant Partners
Radiation and Nuclear Safety and Security	Regulatory frameworks appropriate to the needs of the use of nuclear technologies	Strengthened national radiation and nuclear safety and security infrastructure and capacities in line with best international practices in all relevant safety and security issues to protect people and the environment from ionizing radiation.	Goal 3: Ensure healthy lives and promote well-being for all at all ages	N/A	DRS/CNEN LCR/UERJ IRD DEN/UFPe AgNSNQ
Food and Agriculture	Expansion of infrastructure to meet demands in a sustainable way	Increased food chain production value with sustainable technology	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Outcome 1: Strengthened social development throughout the country, with poverty reduction through access to quality public goods and services, particularly in the areas of education, health, welfare, food and nutritional security and decent work, equitably and with emphasis on gender, racial, ethnic and	IPEN EMBRAPA CENA PANAFTOSA MAPA MOSCAMED International: UNDP FAO Interamerican Development Bank

Thematic Area	Outcome in National Plan or Sector Strategy	CPF Outcomes	Links with SDGs	Links with Outcomes of United Nations Sustainable Development Partnership Framework Brazil 2017-2021	Relevant Partners
				generational equality. Outcome 4: Inclusive and environmentally sustainable economic growth, with productive diversification, industrial strengthening, resilient infrastructures, increased productivity and innovation, transparency, social participation and enhancement of micro and small enterprises.	
Health and Nutrition	Self-sufficiency of products for nuclear medicine Increased use of nuclear medicine services by the population and incorporation of new diagnostic and therapeutic procedures Expansion of infrastructure to meet demands in a sustainable way	Strengthened national capacities in nuclear medicine and radiotherapy and reduced morbidity and mortality of cancer in Brazil. Informed decision making for improved nutrition interventions particularly for infants. Enhanced national capacity to control Dengue, Chincungunya	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture Goal 3: Ensure healthy lives and promote well-being for all at all ages	Outcome 1: Strengthened social development throughout the country, with poverty reduction through access to quality public goods and services, particularly in the areas of education, health, welfare, food and nutritional security and decent work, equitably and with emphasis on gender, racial, ethnic and generational equality.	INRAD/HC/FMUSP Hospital de Cancer de Barretos INCA MOSCAMED IPEN SBRT SBMN Ministério da Saúde Hospital Naval Marcilio Dias CRCN-NE CDTN IEN Hospital A. C. Camargo

Thematic Area	Outcome in National Plan or Sector Strategy	CPF Outcomes	Links with SDGs	Links with Outcomes of United Nations Sustainable Development Partnership Framework Brazil 2017-2021	Relevant Partners
		and Zika outbreaks in human populations. Strengthened Acute Radiation Syndrome treatment capacity			International: UNDP PAHO/WHO UNICEF UICC
Water and the Environment	Expansion of infrastructure to meet demands in a sustainable way	Enhanced institutional capacities of the Brazilian environmental and water authorities to monitor, conserve, recover and sustainably manage terrestrial, coastal and marine ecosystems impacted by multiple abiotic/biotic stressors	Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification	Outcome 3: Strengthened institutional capacity to promote public policies for the sustainable management of natural resources and ecosystem services, and combating climate change and its adverse effects, and ensure the coherence and implementation of these policies.	LARA/IF/UFF Marinha do Brasil IEAPM IPEN CDTN IRD IEN Ministério do Meio Ambiente ANA International: UNDP UNEP GIZ World Bank International Fund for Agricultural Development

Thematic Area	Outcome in National Plan or Sector Strategy	CPF Outcomes	Links with SDGs	Links with Outcomes of United Nations Sustainable Development Partnership Framework Brazil 2017-2021	Relevant Partners
Energy and Industry	Expansion of infrastructure to meet demands in a sustainable way Strengthening the productive chain	Enhanced national capacities in energy planning taking into consideration the planned expansion of the Brazilian nuclear power programme. Improved industrial processes in Brazil.	Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Outcome 4: Inclusive and environmentally sustainable economic growth, with productive diversification, industrial strengthening, resilient infrastructures, increased productivity and innovation, transparency, social participation and enhancement of micro and small enterprises.	IPEN ELETRONUCLEAR INB NUCLEP IEN CDTN ABENDI CTMSP AMAZUL IEN International: UNDP UNIDO IRENA Brazilian Development Bank Interamerican Development Bank

Annex 2: List of participating institutions

Agência Naval de Segurança Nuclear e Qualidade (AgNSNQ)
Naval Agency for Nuclear Safety and Quality (AgNSNQ)
Praça Barão de Ladário, Rua da Ponte S/N Ed. 23, Centro, Rio de Janeiro - RJ 20091-000
POC: Auro Correia Pontedeiro
Phone: +55 21 2197-7413
E-mail: auro.correia@marinha.mil.br

Centro Tecnológico da Marinha em São Paulo (CTMSP)
Navy Technological Center in São Paulo (CTMSP)
Av. Prof. Lineu Prestes, 2468 - Vila Universitaria, São Paulo - SP, 05508-000
POC: Marcelo Raposo Ribeiro
Phone: +55 11 3817-7152 or 7762
Email: marcelo.raposo@marinha.mil.br

Instituto de Estudos do Mar Almirante Paulo Moreira (IEAPM)
Sea Research Institute Admiral Paulo Moreira (IEAPM)
Rua Kioto, 253, Praia dos Anjos - Arraial do Cabo - Rio de Janeiro - RJ - CEP 28.930-000
POC: Dr. Luiz Ricardo Gaelzer
Phone: +55 22 2622-9060
E-mail: ricardo.gaelzer@marinha.mil.br

Instituto de Pesquisas Biomédicas (IPB) do Hospital Naval Marcílio Dias (HNMD)
Biomedical Research Institute (IPB) of Marcilio Dias Naval Hospital (HNMD)
R. César Zama, 185 - Lins de Vasconcelos, Rio de Janeiro - RJ, 20725-090
POC: Marcelo Leal Gregório
Phone: +55 21 2599-5452
E-mail: leal.gregorio@marinha.mil.br

Instituto de Pesquisas da Marinha (IPqM)
Navy Research Institute (IPqM)
Rua Ipiru, nº 02. Cacuia, Ilha do Governador - Rio de Janeiro - RJ - CEP 21931-095
Phone: +55 21 2126-7432
E-mail: ipqm-rp@marinha.mil.br

Radioecology Laboratory (LARE)
Estrada Sorocaba – Iperó, Km 12,5 - Iperó – SP, CEP 18560-000
POC: Rosane Correa Fagundes
Phone: +55 15 3229-8119
Email: rosane.fagundes@marinha.mil.br
Secretaria da Comissão interministerial para os recursos do Mar (SECIRM)
Secretary of the Interministerial Commission for Resources of the Sea (SECIRM)
Esplanada dos Ministérios Bloco N - Anexo B - 3º andar, Brasília – DF, CEP:70055-900

Phone: +55 61 3429-1313
Email: secirm.secom@marinha.mil.br
EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária

Biofábrica Moscamed Brasil
Av. C1, 992 - Quadra D 13, Lote 15, Distrito Industrial do São Francisco, Juazeiro - BA - Brasil - CEP 48.908-000
Telefone e Fax: (74) 3612.5399
E-mail: biofabrica@moscamed.org.br

Associação Brasileira de Ensaios Não Destrutivos e Inspeção (ABENDI)
Sede: Avenida Onze de Junho, 1317
Vila Clementino
CEP: 04041-054 - São Paulo - SP
Phone: (11) 5586-3199
Fax: (11) 5581-1164
Email: abendi@abendi.org.br
Site: http://www.abende.org.br/

Centro de Desenvolvimento da Tecnologia Nuclear (CDTN)
Av. Presidente Antônio Carlos, 6627 - Campus UFMG - Pampulha
Belo Horizonte - MG - Brasil
CEP 31270-901
Phone: (31) 3069-3241
Fax.: (31) 3069-3321
http://www.cdtn.br

Centro de Energia Nuclear na Agricultura (CENA)
Av. Centenário, 303
CEP: 13400-970
Piracicaba, São Paulo - SP
Email: diretoria@cena.usp.br
Phone: 0055 19 3429 4600
http://www.cena.usp.br/labs/labfertsol.htm
Email: osny@cena.usp.br
Phone: 0055 19 3429 4713

Comissão Nacional de Energia Nuclear (CNEN)
Rua General Severiano, 90
Botafogo
22290-901 RIO DE JANEIRO, RJ
Email: inter@cnen.gov.br
Fax: 0055 21 21732123
Phone: 0055 21 21732120

Laboratório de Poços de Caldas - LAPOC
Rodovia Poços de Caldas, km 13 - Andradas
Poços de Caldas - MG - Brasil
CEP 37701-970
Phone: (35) 2107-3500
Fax: (35) 3722-3622
Web: http://www.cnen.gov.br/lapoc

Centro Regional de Ciências Nucleares do Centro-Oeste - CRCN-CO
BR 060, km 174,5
Abadia de Goiás - GO - Brasil

CEP 75345-000
Phone: (62) 3604-6000 3604-6001 3604-6002
Fax: (62) 3604-6020 / 3604-6010
http://www.crcn-co.cnen.gov.br

Centro Regional de Ciências Nucleares do Nordeste - CRCN-NE
Av. Prof. Luiz Freire, 200
Cidade Universitária - Recife - PE - Brasil
CEP 50740-540
Phone: (81) 3797-8000
Fax: (81) 3797-8072

Companhia de Tecnologia de Saneamento Ambiental (CETESB)
Avenida Professor Frederico Hermann Júnior, 345
CEP: 05489-900 SÃO PAULO
Fax: 0055 11 3133 3402
Phone: 0055 11 3133 3000
Web: http://www.cetesb.sp.gov.br/

ELETRONUCLEAR - Eletrobrás Termonuclear S.A.
Rua da Candelária 65
CEP: 20091-906 RIO DE JANEIRO
Fax: 0055 21 2588-7200
Phone: 0055 21 2588-7000
Web: http://www.eletronuclear.gov.br/

Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA)
EMBRAPA Sede
Parque Estação Biológica – PqEB s/nº
Brasília, DF – Brasil – CEP 70770-901
Phone: (61) 3448-4433 – Fax: (61) 3347-1041

EMBRAPA (CNPAb) Agrobiologia
Rodovia BR-465 (Antiga Rodovia Rio-São Paulo), km 7
Caixa Postal 74.505, 23890-000 - Seropédica, RJ
Phone: (21) 2682-1500 - Fax: (21) 2682-1230
Web: http://www.cnpab.embrapa.br

Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA)
Rodovia BR-163, km 253,6
Caixa Postal 661, 79804-970 - Dourados, MS
Phone: (67) 3416-9700 - Fax: (67) 3416-9721
Internet: http://www.cpao.embrapa.br
Centro Nacional de Pesquisas de Gado de Corte
Rodovia BR-262, km 4
Caixa Postal 154, 79002-970 - Campo Grande, MS
Phone: (67) 3368-2000 - Fax: (67) 3368-2150
Web: http://www.cnpgc.embrapa.br

Empresa de Pesquisa Energética - EPE
Avenida Rio Branco, 1 – 11º Andar

Centro, Rio de Janeiro/RJ
CEP 20.090-003 RIO DE JANEIRO
Web: http://www.epe.gov.br
Escritório-sede
SAUN – Quadra 1 – Bloco B – Sala 100-A
Brasília – DF
CEP: 70.041-903
Phone: (61) 3312-6750

FMUSP - Hospital das Clinicas
Av. Dr. Enéas de Carvalho Aguiar, 255
Cerqueira César
05403-000
São Paulo -
Web: http://www.hcnet.usp.br

Instituto de Radiologia
Av. Dr. Enéas de Carvalho Aguiar, 255 3o Andar 05403-001
05403-000 SÃO PAULO, S.P.
Email: biblioteca.inrad@hcnet.usp.br
Fax: 0055 11 3069 7553
Phone: 0055 11 05403 001
Web: http://www.hcnet.usp.br/inrad/index.htm

Fundação "Antonio Prudente" - Hospital "A.C. Camargo"
Prof. Antonio Prudente 211
01509-010 SÃO PAULO, S.P.
Phone (11) 2189-5000
Web: http://www.hcanc.org.br/

Fundação Pio XII - Hospital do Câncer de Barretos
Avenida Antenor Duarte Villela, 1331 – Barretos São Paulo, SP
Phone: (17) 3321-6600
Email: diretoria@hcancerbarretos.com.br

Fundação Oswaldo Cruz (FIOCRUZ) CAMPUS Sede:
Av. Brasil, 4365 - Manguinhos, Rio de Janeiro
CEP: 21040-360
Phone: (0xx21) 2598-4242
Web: http://www.fiocruz.br

Hospital Israelita Albert Einstein
Avenida Albert Einstein 627/701
05651-901 SÃO PAULO, S.P.
Email: atendimentocomercial@einstein.br
Phone: 0055 11 2151-1233
Web: http://www.einstein.br

Indústrias Nucleares do Brasil S.A
Headquarter – Central Administration / RJ
INB Rio

Av. João Cabral de Mello Neto, 400 – 101 a 304
Barra da Tijuca
22775-057 – Rio de Janeiro – RJ – Brasil
Phone: 55-21-3797-1600
Fax: 55-21-2537-9391
Email: inbrio@inb.gov.br

Instituto de Eletrotécnica e Energia
Avenida Professor Luciano Gualberto, 1289 - Cidade Universitária
CEP 05508-010 - Butantã - São Paulo SP
Fax: (11) 3812-3352
(11) 3091-2500
Email: diretoria@iee.usp.br
Web: http://www.iee.usp.br

Instituto de Engenharia Nuclear (IEN)
Rua Hélio de Almeida, 75
Cidade Universitária - Ilha do Fundão
Rio de Janeiro - RJ - Brasil
CEP 21945-970
Phone: (021) 2209-8065
Fax: (021) 2590-2692
Web: http://www.ien.gov.br

Instituto de Geociências (IGC)
Department of Economic Geology and Hydrology
Rua do Lago 562
05508-080 SÃO PAULO – SP
Phone: (11)3091-3957
(11) 3091-4274
(11) 3031-2847
Email: igc@usp.br
Web: http://www.igc.usp.br

Instituto de Medicina Nuclear e Endocrinologia de Brasília
Cintilografia
SHLS 716 conj. L, Centro Clínico Sul Torre II sala T223
Phone: (61) 3245-1802
Ecografia, Densitometria e Endocrinologia
SHLS 716 conj. L, Centro Clínico Sul Torre I salas T121/124
(61) 3245-2102
PET-CT e Tomografia
SHLS 716 conj. L, Centro Clínico Sul Praça da Saúde sala W162
(61) 3202-1702
Web: http://www.imeb.com.br

Instituto de Pesquisas Energéticas e Nucleares (IPEN)
Av. Prof. Lineu Prestes, 2242 - Cidade Universitária - Butantã
São Paulo - SP
CEP 05508-000
Phone: (011) 3133-9100

Fax: (011) 3133-9018
Web: http://www.ipen.br

Instituto de Radiologia Serviço de Medicina Nuclear
Rua Dr. Ovídio Pires de Campos
s/n Cerqueira César
CEP05403-010 SÃO PAULO
Phone: 3069-8052 / 3069-8053

Instituto de Radioproteção e Dosimetria
Av. Salvador Allende s/nº - Jacarepaguá
Rio de Janeiro - RJ
CEP 22780-160
Phone: (021) 2173-2701
Fax: (021) 2173-2928
Web: http://www.ird.gov.br

Instituto do Coração – INCOR - HCFMUSP
Rua Dr Enéas de Carvalho Aguiar, 44
CEP: 05403-900 SÃO PAULO - SP
Email: incor@uol.com.br / Jose.soares@incor.usp.br
Fax: 0055 11 3082-2354
Phone: 0055 11 3069 5000
Web: http://www.incor.usp.br/

Instituto Nacional do Câncer (INCA)
Pr Cruz Vermelha 23 - Centro
CEP: 20230-130 RIO DE JANEIRO, RJ
Phone: 0055 21 25066000
Web: http://www.inca.gov.br/

Programa de Qualidade em Radioterapia (PQRT)
Rua do Rezende, 128/322, Centro - CEP 20231-092
Rio de Janeiro - RJ
Phone: (55)(21) 3970-7812 / 7830 / 7824
Fax: (55)(21) 3970-7829
Web: http://www.inca.gov.br/pqrt/

Instituto Nacional de Pesquisas Espaciais (INPE)
Centro de Tecnologias Espaciais
Laboratório Associado de Plasma (LAP)
Av. dos Astronautas, 1758 - Jardim da Granja
12227-010 São José dos Campos, SP
Phone: + 55 (12) 3945 6695, +55 (12) 3945 6698 (secretaria)
Fax: + 55 (12) 3945 6710
Email: virginia@plasma.inpe.br

Irmandade de Santa Casa de Misericórdia de Porto Alegre
Hospital Santa Rita
Pc D Feliciano, 135 - Centro, Porto Alegre - RS,
Phone: (51) 3214-8400

Web: http://www.santacasa.org.br/santa-rita

Microbióticos Laboratório
Avenida Santa Isabel, 2120
Campinas
Caixa Postal 6175
13084-471 CAMPINAS, S.P.
Email: microbioticos@microbioticos.com
Fax: 0055 19 3289 9380
Phone: 0055 19 3289 9690
Web: http://www.microbioticos.com

Pontifícia Universidade Católica
Rua Marquês de São Vicente, 225
22452-900 RIO DE JANEIRO
Fax: 0055 21 22744197
Phone: 0055 21 25299922
Web: http://www.puc-rio.br

PUC - Rio
Depto de Quimica
Rua Marquês de São Vicente, 225, Sala 772-A
Prêdio Cardial Leme, Bloco Leopoldo Hainberger S.J.
Gávea - Rio de Janeiro, RJ - Brasil - 22453-900 Cx. Postal: 38097
Phone: (21)3527-1332 Fax.: (21) 3527-1637
Web: http://www.qui.puc-rio.br/

Laboratório de Resíduos
Avenida Santa Isabel 2120
Campinas
Caixa Postal 6175
13084-471 CAMPINAS, S.P.
Fax: 0055 19 2899690
Phone: 0055 19 2899690

Secretaria de Agricultura e Abastecimento
Instituto Biológico de São Paulo
Avenida Conselheiro Rodrigues Alvez, 1252
CEP: 04014-002 SÃO PAULO, S.P
Email: luchini@biologico.sp.gov.br
Phone: 0055 11 50871756
Web: www.biologico.sp.gov.br

Sociedade Brasileira de Patologia Clínica
Rua Dois de Dezembro, 78, sala 909
Flamengo
22220-040 RIO DE JANEIRO
Phone: 0055 21 2205 3386
Web: http://www.sbpc.org.br/

Tricom Tecnologia e Serviços de Manutenção Industrial

Av. Conselheiro Rodrigues Alves, 58 - Centro Piquete - SP
CEP: 12.620-000
Phone: +55 12 3156-4764, +55 12 3156-3311
Email: tricom@tricomtecnologia.com.br

UBEA - PUCRS - Pontifícia Universidade Católica
Campus Universitário Central
Av. Ipiranga, 6681 - Partenon - Porto Alegre/RS
CEP 90619-900
Phone (51) 3320-3500
Web: http://www.pucrs.br/

Universidade Estadual do Ceará - UECE
Centro de Ciências e Tecnologia - CCT
Endereço: Campus do Itaperi
Av. Paranjana, 1700 - Fortaleza - Ceará
CEP: 60.740-903
Email: cct@uece.br
Phone: (85) 3101.9770

Universidade Estadual Paulista (UNESP)
Curso de Medicina Veterinária
Departamento de Apoio, Produção e Saúde Animal
Laboratório de Bioquímica e Biologia Molecular Animal
Campus Araçatuba
R. Clovis Pestana, 793
16050-680 ARAÇATUBA
Fax: 0055 18 36361452
Phone: 0055 18 36361355
Web: http://www.fmva.unesp.br/

Universidade Federal Fluminense (UFF)
Instituto de Física
Av. Gal. Milton Tavares de Souza s/nº.
Gragoatá, Niterói, 24210-346, Brasil
Email: if@if.uff.br
Phone: (0-XX-21) 2629-5874 / 2629-5875 Fax: (0-XX-21) 2629-5887

Universidade Federal de Pernambuco
Departamento de Energia Nuclear
Avenida Prof. Luiz Freire, 1000.
Cidade Universitária
50740-540 RECIFE, PE
Email: hjkhoury@gmail.com
Fax: 0055 81 2126 8250
Phone: 0055 81 2126 8251 / 52

Universidade de Ribeirão Preto
Faculdade de Medicina de Ribeirão Preto
Departamento de Clínica Médica
Divisão de Clínica Médica Geral e Geriatria

Av. Bandeirantes, 3900
Cep 14048-900 (6° andar do HC)
Ribeirão Preto - SP
Phone: (16) 3633-0036 / 3602-2448
Fax: (16) 36020229

Universidade do Estado do Rio de Janeiro
Campus Francisco Negrão de Lima
R. São Francisco Xavier, 524 - Maracanã - Rio de Janeiro - RJ –
Cep 20550-900
Phone: (21) 2334-0000
Web: http://www.uerj.br

Instituto de Biologia Roberto Alcântara Gomes
Departamento de Biofísica e Biometria
Laboratório de Ciências Radiológicas
Rua São Francisco Xavier, 524 - Maracanã - Pavilhão Haroldo Lisboa da Cunha - Sala 136, Térreo CEP: 20550-900
Phone: 2334-0725 | 2334-0726 | 2334-0727 - Fax: 2334-2143 –
Email: lcr@lcr.uerj.br

Universidade Federal do Rio de Janeiro (COPPE/UFRJ)
Cidade Universitária
Centro de Tecnologia, Bloco G, sala 101
Ilha do Fundão
CEP: 21945-970
Caixa Postal: 68501
Rio de Janeiro – RJ
Phone: (21) 3622-3477 / (21) 3622-3478
Fax: (21) 3622-3463
Email: diretoria@coppe.ufrj.br

Universidade Federal do Rio de Janeiro (COPPE/UFRJ)
Hospital Universitário Clementino Fraga Filho
Rua Rodolpho Paulo Rocco, 225
Caixa Postal 68509
21945-970 RIO DE JANEIRO
Email: imprensa@hucff.ufrj.br
Fax: 0055 21 2562 2827
Phone: 0055 21 25622688
Web: http://www.hucff.ufrj.br/

Universidade Federal Fluminense (UFF)
Instituto de Química
Departamento de Físico-Química
Campus Valonguinho
Rua Outeiro de São João Batista s/n
CEP 24020-150 - Niterói – RJ
Phone: 0055 21 2629 2166 (Secretaria)
Email: gfq@vm.uff.br
Web: http://www.uff.br/fisicoquimica

Universidade de São Paulo (USP)
Departamento de Engenharia de Biossistemas
Escola Superior de Agricultura Luiz de Queiroz
LEB - ESALQ - USP
Av. Pádua Dias, 11
Caixa Postal 9
Cep: 13418-900 - Piracicaba – SP
Phone: (19) 34294217 -
Fax: (19) 34478571
PABX.: (19) 3429-4100 –
Email: siesalq@esalq.usp.br

Universidade de São Paulo – USP
Instituto de Física
Rua do Matão, Travessa R, 187
CEP: 05508-090 – Cidade Universitária
SÃO PAULO
Email: if@edu.usp.br
Fax: 0055 11 3814-0503
Phone: 0055 11 3082-1015 / 0055 11 3673-7585
Web: http://www.if.usp.br

Universidade Estadual Paulista (UNESP)
Laboratório de Estudos de Bacias (LEBAC)
Instituto de Geociências e Ciências Exatas Departamento de Geologia Aplicada
Laboratório de Estudos de Bacias - LEBAC
Avenida 24-A, 1515 - Bela Vista
Rio Claro - SP
Cep 13506-900
Phone / Fax: 19 3532-5119
Email: lebac@rc.unesp.br

Universidade Federal de São Paulo (UNIFESP)
Av. Sena Madureira, 1500 - 5º andar
São Paulo - SP
CEP 04021-001
PABX: (11) 5576-4000
Web: http://www.unifesp.br

Escola Superior de Ciências da Santa Casa de Misericórdia de Vitória (EMESCAM)
Av. Nossa Sra. da Penha, 2190 - Bela Vista
Vitória – ES
CEP 29027-502
Web: http://www.emescam.br/

Annex 3: Compilation of treaties under the auspices of the IAEA

AGREEMENTS WITH THE IAEA		
• IAEA Statute	Signature:	26 October 1956
• Amendments to the Article VI and XIV of the IAEA Statute	Acceptance of amendment of Article VI	01 June 1973
• Agreement on privileges and immunities	Entry into force:	13 June 1966
• Quadripartite safeguards agreement INFCIRC/435	Entry into force:	4 March 1994
• Safeguards agreement Brazil/Germany INFCIRC/237	Suspension signed:	16 October 1998
• Safeguards agreement Brazil/USA INFCIRC/110	Entry into force:	31 October 1968
• Amendment to the safeguards agreement Brazil/USA	Signature:	27 July 1972
• Technical assistance agreement between UN, its specialized agencies and the IAEA	Signature:	29 December 1964
• Supplementary agreement on provision of technical assistance by the IAEA	Entry into force:	27 February 1991
• ARCAL	Entry into force:	September 1984
• New ARCAL Agreement	Signed:	4 August 1999
MAIN INTERNATIONAL TREATIES		
• NPT	Entry into force:	18 September 1998
• Tlatelolco Treaty	Signed:	29 January 1968
• Amendment of the Treaty	Ratified:	30 May 1994
OTHER RELEVANT INTERNATIONAL TREATIES		
• Nuclear suppliers group	Member	
• Nuclear export guidelines	Adopted	
• Missile Technology Control Regime	Member	1995
• Treaty for prohibition of experiences with nuclear weapons in the atmosphere, cosmic space and under water	Signature:	5 August 1963
• Partial test ban treaty	Entry into force:	15 December 1964
• ILO Convention	Signature:	7 April 1964
• Treaty on the prohibition of the installation of nuclear weapons and other lethal weapons in the seabed, deep ocean	Signature:	3 September 1971

floor and sub-seabed.		
• Convention on civil liability in the field of maritime carriage of nuclear material	Signature:	17 December 1971
• Convention on prevention of marine pollution by dumping of wastes and other materials	Signature:	29 December 1972
• International Convention for the Suppression of Terrorist Bombings	Entry into force:	23 August 2002
MULTILATERAL AGREEMENTS		
• Antarctica Treaty	Signature:	1 December 1959
• Convention on the physical protection of nuclear material	Entry into force:	8 February 1987
• Convention on early notification of a nuclear accident	Entry into force:	4 January 1991
• Convention on assistance in the case of a nuclear accident or radiological emergency	Entry into force:	4 January 1991
• Vienna convention on civil liability for nuclear damage	Entry into force:	26 June 1993
• Convention on nuclear safety	Entry into force:	2 June 1997
• Joint convention on the safety of spent fuel management and on the safety of radioactive waste management.	Signature:	31 October 1997
BILATERAL AGREEMENTS		
Cooperation Agreement for the Development and Use of Peaceful Applications of Nuclear Energy	Argentina	1980
Agreement for Scientific, Technological and Industrial Cooperation	Belgium	1985
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Bolivia	1966
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Canada	1996
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Chile	2002
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	China	1984
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Ecuador	1970
Cooperation Agreement for the Development of Peaceful Applications of Nuclear Energy	France	2002
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Germany	1975

Cooperation Agreement for the Peaceful Use of Nuclear Energy	Italy	1958
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Paraguay	1961
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Peru	1981
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Republic of Korea	2001
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Russian Federation	1994
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	Spain	1983
Agreement on Cooperation in the field of the Peaceful Uses of Nuclear Energy	United States of America	1997
Cooperation Agreement on Nuclear Energy for Peaceful Uses	Venezuela	1983

Annex 4: Details of Past TC Programme Achievements

[Mandatory, unless the Member State is a new TC programme recipient]

This annex should provide an overview of the key achievements of past technical cooperation activities in the country in the various thematic areas of the CPF. The table below should list the results of past technical cooperation, key counterparts and institutes, as well as key partners per thematic area. The table can be expanded to incorporate any TC thematic areas, as appropriate, by including additional rows.

- Brazil joined the IAEA TC programme since the beginning.
- Key areas and major impact include:
    - The strengthening of the skills and capabilities of human resources to apply nuclear technology in a broad range of areas (agriculture, environment, industry, brachytherapy, radiopharmaceutical production, decommissioning, waste management, regulatory infrastructure, research reactor operation, nuclear instrumentation and control), including nuclear knowledge management to ensure the sustainability in nuclear applications to contribute to the achievement of national development priorities and the economic development of Brazil.
    - the decommissioning of the Minas Gerais Uranium Mining and Milling Production Centre;
    - the introduction of state-of-the art radiotherapy and nuclear medicine techniques for cancer diagnosis and therapy in public hospitals, and the expansion and improvement of the quality of cancer services in Brazil

Thematic area	Results of past technical cooperation	Key counterpart institutes and partners
Radiation safety and security	During the past decades, the IAEA supported Brazil in strengthening national capacities to enhance nuclear and radiation safety and security in the country for the protection of people and the environment from ionizing radiation. Recently, IAEA TC support in this area focused on strengthening the national regulatory system to ensure alignment of the safety of nuclear fuel cycle facilities to the best international practices. IAEA support included the training of the regulator's staff, especially the newly hired ones, according to the current technology of nuclear fuel cycle facilities, scientific visits and expert missions.	COMISSÃO NACIONAL DE ENERGIA NUCLEAR – CNEN

EPR	Over the decades, IAEA support helped strengthen Brazil's capacities to prepare for and respond to nuclear and radiation emergencies. CNEN laboratories have the acquired the necessary human resources and technical capacities capacities to adequately prepare for and respond to emergencies related to NPP and any other nuclear accidents.	CNEN
Radioactive waste management	IAEA TC support also helped improve the institutional capacities of CNEN in radioactive waste management. IAEA support included expert services for the selection of a suitable site for final disposal of low- and medium-level waste, the revision of the radioactive waste management system, the development of a communication strategy, training of local staff in nuclear waste management according to the locally identified and the improvement of the local infrastructure to manage radioactive waste. The IAEA inter alia supported Brazil between 2009 and 2010 in the development of national demonstration facilities for waste reduction technologies under interim storage to create safe and cost-effective radioactive waste management with the aim to reduce the amount of radioactive waste stored at the research institutes of CNEN that requires further treatment and disposal. IAEA support included the development of a technical manual with recommendations for Brazilian authorities to implement a borehole type repository for disused sealed sources; the development of a prototype of a sampling tool for characterization of decommissioning solid waste constituted of parts of equipment and structures or materials contaminated in the surface.	CNEN Comissao Nacional de energia Nuclear; Centro de Desenvolvimento da Tecnologia Nuclear (CDTN) Comissao Nacional de Energia Nuclear (CNEN); Instituto de Pesquisas Energeticas e Nucleares (IPEN-CNEN/SP)
	Between 2009 and 2012, the IAEA supported Brazil in the development of a practical guidance for the implementation of a decommissioning and remediation plan for the Minas Gerais Uranium Mining and Milling Production Centre. As a result of the IAEA TC support, Brazilian decision-makers now have the proper and necessary information, as well as appropriately trained personnel, to develop and implement a plan to deal with the decommissioning and environmental remediation for the Minas Gerais Uranium Mining and Milling Production Centre.	CNEN
Food and agriculture	Between 1974 and 2000, the IAEA supported Brazil in enhancing national capacities in the application of nuclear technology to enhance crop and livestock production. Technology has been transferred for plant mutation breeding, soil management involving nitrogen fixation, sterile insect technique for medfly eradication, immunoassay techniques for animal disease diagnosis, and food analysis	University of Sao Paulo Fundacao Estadual de Pesquisa Agropecuaria; Centro de Pesquisas Veterinarias "Desiderio Finamor"; Departamento de Virologia e Imunologia

	for food safety. Between 2005 and 2008, the IAEA for instance supported the establishment of a medfly, fruit fly parasitoids and codling moth rearing facility with the aim to improve the quality of fruit grown in Brazil to meet export standards. IAEA support included the training of local staff in the latest techniques and issues regarding SIT (planning, application, monitoring, and evaluation, and the use of the equipment provided. Technology was transferred for mass rearing, sterilization and the use of radiation and release methods for medfly, codling moth and fruit fly parasitoids. Ten to twelve millions of Sterile Male Flies (SMF) are produced each week at the rearing facility. The facility receives 75 contracts per year, providing support to 423 farmers for monitoring and releases of SMF at rate of 2,000 insects per ha. The facility not only produces sterile flies, but also monitors the fruit fly population in all the Sao Francisco Valley. The Medfly Rearing Facility is a national reference centre for SIT, insect production, new irradiation technology (X ray), monitoring systems and quarantine issues. The facility has developed an atmosphere for cooperation with other organizations in order to fight with others insect pest that affects human health and welfare (such as the dengue-fever, which is carried by mosquitoes). Local producers of grapes and mangos could meet again the international standards for exportation to Europe, the United States and Japan.	
	Between 2005 and 2006, IAEA TC support helped improve the quality and safety of food through the transfer of technical skills in food irradiation and blood processing which resulted in increased revenues and diminished storage losses for food producers and markets.	Instituto de Pesquisas Energeticas e Nucleares
	Between 2016 and 2019, the IAEA helped strengthen strategies of soil and water management at the landscape level in natural and agricultural ecosystems in the Guapi-Macacu Basin (Atlantic Forest); introduced cost-effective optimization of management practices for sustainable land and water use in Atlantic Forest. IAEA support included training, the development of a website for data dissemination and of didactic materials on sustainable use of natural and agricultural areas. As a result, relevant Brazilian authorities have been capable of implementing sustainable practices for soil and water management based on scientific recommendations.	Departamento de Física,Instituto de Fisica,Universidade Federal Fluminense (UFF)

Health and nutrition *Nuclear Medicine and radiopharmaceutical production*	During the last decades, national capacities have been strengthened in applying diagnostic and therapeutic nuclear medicine applications. Between 2001 and 2002, three primary standardization system measurements operating at the same time have been established for the development of primary standardization procedures for radionuclides used in nuclear medicine or reference. These developments allow standard solutions for secondary systems, especially those used in nuclear medicine centers and instruments calibration laboratories in Brazil or other countries in the region. Between 2012 and 2013, diagnostics and therapy in the Nuclear Medicine services of the counterpart institutions have been improved through routine use of quantitative methods in emission tomography, increased availability of radiopharmaceuticals for PET and SPECT, and qualification of human resources in all fields. A network in quantitative emission tomography has been installed, so that exchanges and collaboration could continue. Participants having received training were able to train their peers and to disseminate the knowledge to other centres. Between 2014 and 2016, for instance, diagnostic and therapeutic capabilities and clinical applications were improved through the introduction of radiopharmaceuticals and cell radiolabelling and tracking techniques for molecular imaging in preclinical and clinical environments aiming at improving the early diagnosis, adequate follow-up and the management of patients with non-communicable diseases in particular cancer, neurodegenerative, and cardiovascular diseases. As a result, diagnostic and therapeutic applications of radionuclides have been strengthened. IAEA support included the strengthening of the skills and capabilities of human resources, the development and introduction of radiopharmaceuticals, the implementation of molecular imaging protocols both preclinical and clinical, the introduction of cell radiolabeling and tracking techniques, improvement of the infrastructure in particular equipment and outreach and knowledge sharing of human resources in radiopharmaceutical imaging both clinical and pre-clinical.	Centro Italo Brasileiro de Promocao Sanitaria - Monte Tabor Comissão Nacional de Energia Nuclear; Centro de Desenvolvimento da Tecnologia Nuclear (CDTN) University of Sao Paulo
Radiotherapy	Several TC projects focused on improving expanding and enhancing the quality of radiotherapy and nuclear medicine in the country. Between 2003 and 2006, a calibration and quality control network for x-ray diagnostics was established among seven official institutions coordinated by the Brazilian National	CNEN University of Sao Paulo

	Metrology Laboratory (IRD), improving type-test services for dosimeter equipment as well as the quality control equipment used in x-ray diagnosis to assure that the measuring instruments used for quality control and dosimetry in radiodiagnostics are adequate and calibrated, contributing to the safe and efficient use of ionizing radiation.	
	Between 2005 and 2006, a quality assurance programme for intensity modulated radiotherapy (IMRT) and in vivo dosimetry has been implemented at the National Cancer Institute.	COMISSÃO NACIONAL DE ENERGIA NUCLEAR – CNEN; Coordenação de Instalacoes Nucleares e Radiativas (CODIN) Instituto Nacional de Cancer (INCA); Instituto Nacional de Cancer (INCA); Programa de Qualidade em Radioterapia (PQRT)
	Between 2007 and 2008, radiological examinations in S. Paulo were improved through strengthening the local capabilities. IAEA support included training and the delivery of a CR system which has been installed in the counterpart institute and allowing more assays to be performed in the laboratory in conditions similar to the clinical ones, but without disturbing the patient attendance. The training courses that have been developed are now a reference to other institutions in the country and held on a yearly basis. Due to the better training of technicians in quality assurance and safety issues there have been demands from the hospitals involved in the program to help them to achieve a better balance between image quality and patient dose. In addition, two public hospitals in Brazil - the AC Camargo Hospital and the Clinicas Hospital – have increased and improved radiotherapy treatments through implementing IMRT and stereotactic radiosurgery techniques, training and the delivery of instruments. An emphasis has been taken in quality assurance issues.	Universidade de Sao Paulo (USP Sao Paulo); Institute de Fisica da USP; Departamento de Fisica Nuclear; Laboratorio de Dosimetria
	Between 2009 and 2011, IAEA TC support helped establish a national laboratory facility at the Nuclear Energy and Research Institute (IPEN) in São Paulo for producing high-dose rate (HDR) iridium–192 (Ir-192) sealed sources. IAEA support included the delivery of equipment and training.	CNEN; Instituto de Pesquisas Energeticas e Nucleares (IPEN-CNEN/SP)
	Between 2009 and 2010, IAEA TC support helped improve cancer treatment at the Clinicas Hospital and Pediatric Hospital Boldrini through enhancing capacities in the use of the use of new technologies in Radiotherapy, such as Intensity-Modulated radiation Therapy (IMRT), Radiosurgery and Image-Guided Radiation Therapy (IGRT).	University of Sao Paulo

	Between 2012 and 2013, human resource capacities of all radiotherapy centres were enhanced to develop protocols and implement VMAT, SBRT and IGRT.	University of Sao Paulo
Dosimetry	Between 2009 and 2011, a national network of laboratories performing radiological internal monitoring measurements and provide those laboratories with guidance on best practices for the analytical operations they carry out, which could then be directed towards accreditation, certification or other compliance with particular requirements. The objective was to enhance and ensure regular and systematic quality for the internal monitoring of workers of the nuclear area and public to be provided by the creation of a network of national accredited laboratories. Support included the introduction of harmonized monitoring techniques within the Laboratory Network for the determination of (a) iodine-131 in the thyroid and (b) actinides and gamma emitters in biological samples; training of laboratory staff on radiobioassay techniques and internal dosimetry; the dissemination of techniques on radiobioassay and internal dosimetry within the network; and validated methodologies on radiobioassay.	COMISSÃO NACIONAL DE ENERGIA NUCLEAR – CNEN; National Nuclear Energy Commission (CNEN); Instituto de Radioproteçao e Dosimetria
	Between 2012 and 2013, capacities have been enhanced to optimize doses to patients and medical staff during interventional cardiac procedures to reduce the radiological risk to patients and staff in interventional cardiology. Radiological protection training programmes for interventional cardiologists were created, standardized and implemented quality control protocols were introduced and patients and staff doses in Interventional Cardiology known through elaborated documentation.	COMISSÃO NACIONAL DE ENERGIA NUCLEAR – CNEN; National Nuclear Energy Commission (CNEN); Instituto de Radioproteçao e Dosimetria
Radiopharmaceutical production	During the past decades, the IAEA helped Brazil strengthen its capacities in radiopharmaceutical production. In 1981, a regional centre for radioimmunoassay was established to serve North-Eastern Brazil. In 1983, a suitable infrastructure was developed at the Institute of Nuclear Engineering (IEN) and at the Institute for Nuclear Energy and Research (IPEN) for radioisotope production using their cyclotrons, and routine production on a large scale is now possible. IAEA support included expert advice and services, training and the delivery of equipment.	Universidade Federal de Pernambuco; Departamento de Biofisica e Radiobiologia
	Between 2003 and 2004, a PET centre at the Institute of Nuclear Engineering -IEN/CNEN, Rio de Janeiro, was established. A fully operational radiopharmaceutical laboratory was established to produce and dispense 18-FDG. The equipment was integrated with a licensed and operational cyclotron, as part of the PET centre. FDG doses are being produced and used on a regular basis for PET scanning. IAEA support included the provision of equipment,	CNEN

	expert advice and services, as well as training.	
	Between 2007 and 2008, Brazil's capacity to safely produce radiopharmaceuticals for clinical applications improved. National laboratories and scientific facilities strengthened for the production of PET radiopharmaceuticals. • Human capacities for the appropriate use and maintenance of a cyclotron, as well as on radiopharmaceuticals production and QA/QC, strengthened and improved. • Complete and adequate quality control tests for PET and PET/CT systems are now being performed. Routine quality control checks of radiopharmaceuticals used in patients and in research projects are now being performed. • Improved oncological patient quality of life thanks to the newly acquired technical and human capabilities, by means of early detection of cases and monitoring different therapeutic procedures. • The project contributed directly to improve and strengthen national nuclear and medical programmes, contributing to the Brazilian Multi-Annual Development Plan. • Use of PET/CT technology as well as related QA/QC issues improved. • Participant institutions have become reference centres in Brazil and the region for training (graduate students and on-the-job-training alike) and development of new applications related to radiopharmaceuticals. Professional capacitated through the different activities of the project act now as trainers, therefore multiplying the knowledge and skills in the country.	CNEN Comissao Nacional de Energia Nuclear (CDTN) IPEN-CNEN UBEA-PUCRS – Pontificia Universidade Catolica University of Sao Paulo
	Between 2009 and 2011, the capacities of the research reactor IEA-R1 have been enhanced to optimize the radioisotopes production, in particular the most important primary radioisotopes like 131I and 99Mo used in nuclear medicine to reduce the importation costs and the necessity to attend more and more hospitals and clinics in the country.	IPEN-CNEN/SP
	Between 2009 and 2011, a quality assurance and quality control training network for in-house preparation of radiopharmaceuticals in nuclear medicine centres was established to enhance quality control and assurance in the country. The image qualities were improved, and the unnecessary re-examinations were reduced while optimizing patient doses.	Comissao Nacional de Energia Nuclear; Centro de Desenvolvimento da Tecnologia Nuclear (CDTN)
Communicable diseases	In 2005, the IAEA helped establish reference centres for molecular diagnosis of communicable diseases such as parasitic diseases. IAEA support included training of local human resources and the upgrading of local facilities via the provision of adequate equipment. This project improved the surveillance and control of	

	parasitic diseases in Brazil, trough diagnostic techniques for the detection of parasites implemented and a quality control programme developed, helping to decrease the mortality and morbidity rate.	
Water and Environment	The Agency assisted CDTN in the evaluation of groundwater resources of the karstic aquifer of Lagoa Santa area which was conducted by the counterpart in co-operation with other local institutions by upgrading its low-level analytical facilities and expertise. IAEA support expert services, the delivery of equipment, and training. As a result of the project, substantial improvements in the operational methodology of the tritium laboratory were achieved. Very important water resources were identified and are being monitored. These resources are discharged into a very polluted stream in the area and could be collected without harming other users of the same aquifer. A low-level tritium counting facility was completed. Facilities and capabilities the Agency helped create are also essential to CDTN's ability to successfully compete for a large portion of the hydrological investigations needed in support of the Rio Sao Francisco water harvesting and diversion multi-year project. The identification of flow paths and recharge areas in the karstic aquifer, the groundwater dynamics (residence time and velocity of groundwater), and the interconnections with surface waters of the Lagoa Santa area were determined with the help of the stable isotopes, tritium, and artificial tracer tests. The monitoring network installed allows the acquisition of data which are useful for many on-going projects in the Minas Gerais region. Capacities have also been enhanced in sustainable water resources management in a center of uranium production. The members of the Research Group learned how to manage chemical, termodynamic, isotopical, mineralogical and piezometric data to construct conceptual hydrogeological models. The IAEA support expert missions and training.	Comissão Nacional de Energia Nuclear Instituto de Radioproteçao e Dosimetria
Energy and Industry *Energy*	During the last decades, local capabilities to conduct energy planning studies were substantially enhanced. The national experts now can carry out energy planning to cover a wide spectrum of issues such as energy conservation and rational use of electricity, and environmental impacts of different technologies for generating electricity.	Companhia Energetica de Minas Gerais (CEMIG) Comissao Nacional de Energia Nuclear (CNEN); Instituto de Pesquisas Energeticas e Nucleares (IPEN-CNEN/SP); Diretoria de Pesquisa e Desenvolvimento ELETRONUCLEAR - Eletrobrás Termonuclear S.A.; Centrais Eletricas Brasileiras S.A. Comissão Nacional de Energia Nuclear

	The IAEA has also supported Brazil in the establishment of its nuclear power programme, including the commissioning, operation and monitoring of the Agra Nuclear Power Plant. IAEA support included the strengthening of technical and human capacities of the Agra Nuclear Power Plant through training, expert services and the delivery of equipment with the overall aim to improve safety and the operational performance of the Agra NPPs.	CNEN Electronuclear – Electrobras Termonuclear S.A., Training Department
Industry	Support has also been provided to enhance national capacities for uranium-gadolinium nuclear fuel fabrication. A TC project brought together four Brazilian institutions as counterparts: a nuclear material laboratory, a university, a nuclear fuel supplier and the Nuclear and Energy Research Institute (IPEN).	Universidade Estadual de Marinqa; Departimento de Fisica; Moesbauer Spectroscopy Laboratory Industrias Nucleares do Brrasil Centro Tecnologico da Marinha em Sao Paulo; Nuclear Materials Laboratory
	Between 2007 and 2008, Brazil has set up the technology to self-develop and build an industrial tomography system, mainly for the multiphase processes. IAEA TC supported the establishment of a national laboratory of iCT for end users such as oil refineries and petrochemical complexes.	Comissao Nacional de Energia Nuclear (CNEN)