PROSPECTS FOR NUCLEAR GOVERNANCE IN BRAZIL

Togzhan Kassenova

Lucas Perez Florentino

Matias Spektor

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ABOUT THE AUTHORS

Togzhan Kassenova is a senior fellow with the Project on International Security, Commerce, and Economic Statecraft (PISCES) at the Center for Policy Research, SUNY-Albany; a senior non-resident scholar at the Institute for International Science and Technology Policy and adjunct faculty at the Elliott School of International Affairs at George Washington University; and a nonresident fellow at the Carnegie Endowment for International Peace. She holds a PhD in Politics from the University of Leeds (UK), an MA in Euro-Asian Studies from the University of Reading (UK), and a BA in International Relations from the Almaty State University (Kazakhstan). Dr. Kassenova is an expert in Brazil's nuclear politics and has written the book "Brazil's Nuclear Kaleidoscope: An Evolving Identity" (Carnegie Endowment for International Peace, 2014). In addition to Brazil's nuclear politics, her current research interests include Kazakhstan's nuclear history, proliferation financing controls, and prevention of financial crime. From 2011 to 2015, Dr. Kassenova served on the UN secretary general's Advisory Board on Disarmament Matters.

Lucas Perez Florentino is a research fellow at the School of International Relations, Fundação Getulio Vargas (Brazil). He holds a master's and a bachelor's degree in International Relations from the Institute of International Relations at the Pontifical Catholic University of Rio de Janeiro (Brazil) and has spent one-semester as an undergraduate exchange student at Georgetown University. For the last seven years, he has been involved in a series of research projects on Brazil's and Latin America's nuclear politics. His current research interests are global nuclear governance and theories of International Relations.

Matias Spektor is associate dean and associate professor at the School of International Relations, Fundação Getulio Vargas (Brazil). He holds a doctorate in International Relations from the University of Oxford. Professor Spektor has published extensively on international security in Latin America and Brazilian foreign relations. He has held visiting research and teaching positions with King's College London, the LSE, the Woodrow Wilson International Center for Scholars and the Council on Foreign Relations. Professor Spektor is currently working on a series of papers on Brazil´s nuclear policies, which includes hundreds of hours of elite interviews and research in historical archives in five countries.

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Togzhan Kassenova

Lucas Perez Florentino

Matias Spektor

PREFACE

Brazil has a well-established nuclear program that includes uranium mining and milling, uranium conversion and enrichment, and nuclear energy production. As of writing, the country is on the verge of further expanding its existing capabilities to include a nuclear-powered submarine, industrial fabrication of naval nuclear fuel, the construction of a third nuclear power plant and a new research reactor, and exploration of new uranium mines. In the process, officials have begun adapting existing laws and regulations to accommodate these new projects and, in some cases, to attract private investment for the first time. The transformation and expansion of Brazil's nuclear program is shifting the balance between the civilian and the military branches of the program, with the Brazilian Navy increasingly playing a major role in both of these branches. The Brazilian nuclear policy-making context will be likely deeply transformed as a result.

This report offers a comprehensive map of Brazilian nuclear capabilities and main players and a thorough assessment of governance and accountability with a view to identifying opportunities for improvement as the country transitions to a more complex nuclear policy environment. Through analysis and in-depth interviews with stakeholders across the sector, the authors tackle issues as varied as physical and cybersecurity of nuclear facilities, nuclear safety, nuclear and environmental licensing and regulation, international nuclear safeguards, nuclear waste and spent fuel management, and human resources and education in the nuclear field.

Unlike most countries in Latin America, Brazil has developed an advanced nuclear program that incorporates a significant nuclear industry. Over the years, successive administrations put in place the institutional and legal requirements to create an environment conducive to safe, secure, and efficient nuclear use. The various government agencies that support the nuclear program at all the stages of the nuclear fuel cycle provide a basic guarantee of quality and oversight.

Still, Brazilian authorities have today a unique opportunity to improve the effectiveness of the regulatory processes that govern the nuclear sector as new players enter it and a new cycle of technological development begins, thanks to the two flagship projects currently under development – the nuclear-powered submarine and the multipurpose research reactor. The current governance system can be made more effective. In the immediate term, it would be prudent for the Brazilian government to resolve the outstanding issues involving environmental protection, waste and spent fuel management, physical and cybersecurity of nuclear facilities, nuclear safety, development of safeguards for naval nuclear fuel, creation of an independent nuclear regulator, and, last but not least, political corruption in the nuclear field. Brazil would also benefit from investing in areas that are essential for a safe and productive nuclear program in the long term. The training and retention of expert personnel is an issue that will require sustained effort on the part of government agencies and relevant education authorities. Another area for improvement is raising public awareness of nuclear issues and allowing the meaningful engagement of civil society in the public discourse. The report breaks down these broad and far-reaching objectives into more manageable parts.

Brazil's main weakness is endemic political corruption, which hinders the government's ability to deliver a sound nuclear policy for the Brazilian people. A string of recent scandals points to a vicious circle. Political parties nominate appointees to key managerial positions in the sprawling nuclear sector across the country, which are then used to attract both legal and illegal funds from business conglomerates that have or seek to have government contracts. The measures taken in the past five years to curb this type of corruption, with control institutions such as state and federal prosecutors, the Federal Court of Accounts (TCU), and the investigative federal police becoming more active in anticorruption activities within the nuclear sector, are a welcome development. International cooperation with foreign prosecutors and Interpol also has contributed to improving the national nuclear policy space. Now authorities have a chance to turn the lessons learned into a useful tool and feedback mechanism for the nuclear program as it moves forward to expand installed capacity and technology development.

As researchers, the authors do not presume to dictate specific policy paths to Brazilian officials. Rather, the purpose of this report is to frame core nuclear choices that currently confront Brazil and present a nuanced analysis of the potential consequences of such choices. The tone of the material is reflective and analytical rather than tightly prescriptive. In the process of writing this report, the authors consulted with a wide range of stakeholders and listened to a broad range of views that influence the nuclear sector. The resulting text reflects that diversity. For each policy recommendation offered, the authors explicitly mention associated costs and implications.

The report is part of the effort by the School of International Relations at FGV to increase knowledge about nuclear policy in Brazil and improve the quality of public debate and scholarly thinking in the field. The report was researched and drafted by Dr. Togzhan Kassenova (State University of New York at Albany), Mr. Lucas Perez Florentino (FGV), and Professor Matias Spektor (FGV). The team met with a wide range of government officials and nuclear policy stakeholders in 2018 and is grateful for their time and input. They included members of the Office of the President of Brazil responsible for nuclear policy; key staff from CNEN, the Brazilian Navy, and the Ministry of Foreign Affairs; federal, state, and private bodies responsible for various sections of the policy cycle; and officials overseeing nuclear facilities in Angra, Caetité, Iperó, Resende, Rio de Janeiro, and São Paulo. Every effort was made to present an objective fact-based mapping of Brazil's nuclear policy terrain. The information is current as of December 2019. In the course of writing up this report, the authors have informally presented findings and recommendations from the report to stakeholders in private conversations in 2019, as well as received comments from two external reviewers. The authors take sole responsibility for any errors.

ACRONYMS AND ABBREVIATIONS

ABACC – Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials

Abin – Brazilian Intelligence Agency

AgNSNQ – Naval Agency for Nuclear Safety and Quality

AGU – Office of the Federal Attorney General

Amazul – Blue Amazon Defense Technologies S.A

Anvisa – Brazilian Health Regulatory Agency

BNDES – National Development Bank

CBS – Sepetiba Bay Consortium

CDPNB – Committee for the Development of the Brazilian Nuclear Program

CDTN – Center for the Development of Nuclear Technology

CEA (or Aramar) – Aramar Experimental Center

CGU – Office of the Comptroller General

CINA – Aramar Nuclear Industrial Center

CNEN – National Nuclear Energy Commission

Cogesn – General Coordination of the Program for the Development of the Nuclear-Powered Submarine

CRCN-CO – Regional Center for Nuclear Sciences – Midwest

CRCN-NE – Regional Center for Nuclear Sciences – Northeast

CTMSP – Navy's Technological Center in São Paulo

DGDNTM – General Directorate for the Navy's Nuclear and Technology Development

Eletronuclear – Eletrobras Thermonuclear S.A.

GSI – Institutional Security Cabinet

HEU – highly-enriched uranium

IAEA – International Atomic Energy Agency

Ibama – Brazilian Institute of Environment and Renewable Natural Resources

ICN – Itaguaí Naval Constructions

IEN – Institute of Nuclear Engineering

INB – Nuclear Industries of Brazil

IPEN – Energy and Nuclear Research Institute

IRD – Institute for Radiation Protection and Dosimetry

Lapoc – Poços de Caldas Laboratory

Labgene – Laboratory for Nuclear-Electric Power Generation

LEU – low-enriched uranium

MPF – Federal Prosecution Service

NPT – Treaty on the Non-Proliferation of Nuclear Weapons

Nuclep – Nuclebrás Heavy Equipment S.A.

Prosub – Program for the Development of Submarines

PWR – pressurized water reactor

RMB – Brazilian Multipurpose Reactor

Sipron – System for the Protection of the Brazilian Nuclear Program

RBMN – National Repository for Low- and Medium-Level Radioactive Waste

TCU – Federal Court of Accounts

UFEM – Unit for the Fabrication of Metallic Structures

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CAPABILITIES AND MAJOR PLAYERS

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BRAZIL'S NUCLEAR CAPABILITIES AND INTENTIONS

THE NUCLEAR FUEL CYCLE

Brazil is one of a handful of countries in the world that have mastered all process steps for the front end of the nuclear fuel cycle. These steps include uranium mining and milling, uranium conversion, uranium enrichment, and production of fuel pellets and fuel assemblies. The Navy controls the uranium enrichment technology and runs the fuel cycle, starting with conversion, for its own project at laboratory scale, while the state-run company Nuclear Industries of Brazil (INB) carries out commercial nuclear fuel cycle activities. (See "The Brazilian Navy" and "Nuclear Industries of Brazil (INB)" in "1 - Capabilities and Major Players")

URANIUM MINING AND MILLING

Brazil possesses significant uranium resources, which have been mined since 1982. The total amount of confirmed and prospective reserves is 309,370 metric tons (t).[1] For its part, the International Atomic Energy Agency (IAEA) assesses that Brazil possesses 276,800 t of uranium.[2]

Until now, Brazil has established two uranium mining sites – one in the Poços de Caldas plateau (in the municipality of Caldas) in the southeast state of Minas Gerais, and the other in the Uraniferous Province of Lagoa Real (in the municipality of Caetité) in the northeast state of Bahia.

Uranium mine in Caetité, Bahia. (Photo by Marcelo Corrêa/ Acervo INB)

1 Evando Carele de Mattos and Luiz Antonio Rubini, "Reservas Brasileiras de Urânio e sua Capacidade de Atendimento à Demanda Interna (Power-point presentation, VII Congresso Geral de Energia Nuclear, Belo Horizonte, MG, 1999).

2 International Atomic Energy Agency and Nuclear Energy Agency. *Uranium 2016: Resources, Production, and Demand* (Paris: OECD, 2016), 31.

Uranium mining at Caldas at 425-500 t/year capacity ended in 1995. The total production there reached 1,300 t of U_3O_8.[3]

In Caetité, selection of areas and subsequent exploration began in the early 1970s. Mining of uranium began only in 1999. Delays in the operation occurred due to the restructuring of the commercial nuclear sector with the disbandment of Nuclebrás and the creation of INB.

There are two explored mine pits at Caetité – Cachoeira and Engenho. In 2014, all uranium mining stopped.[4]

As of 2019, INB planned to develop an underground mine in Cachoeira and a new mine in Engenho. INB encountered difficulties in receiving a license from the National Nuclear Energy Commission (CNEN) to operate this new mine at Cachoeira due to CNEN's concerns about radon – a colorless, tasteless, radioactive gas that is considered to be a health hazard – and questions about the electrical systems and equipment to be used. Delays in the licensing process are also explained by the fact that this project will be CNEN's first in which licensing an underground uranium mine is required.[5]

The total amount of production at Caetité reached approximately 3,700t of U_3O_8.[6]

A third prospective uranium site at Santa Quitéria in the state of Ceará is currently undergoing a licensing process. The annual production capacity of the project is estimated to be 1,800 t U_3O_8/year.[7]

Additional prospective uranium areas sites in Brazil include Lagoa Real/Caetité in the state of Bahia and new mines in Pitinga (Amazonas), Rio Cristalino (Pará), Campos Belos/Rio Preto (Tocantis) in the north of Brazil, Espinheiras (Paraíba) in the northeast, Amorinópolis (Goiás) in the central-west, Quadrilátero Ferrrífero (Minas Gerais) in the southeast, and Figueira (Paraná) in the south.[8]

URANIUM CONVERSION

Once uranium is mined and milled, the next stage of the fuel cycle is conversion of solid U_3O_8 into gaseous UF_6 (uranium hexafluoride). Brazil does not have its own industrial-scale conversion facility and relies on foreign partners for its conversion needs. Until 2009, the firm Nukem Energy GmbH in Germany converted Brazilian uranium into UF_6.

3 IAEA and NEA, *Uranium 2016*, 169. Renata Dalaqua, "Átomos e Democracia no Brasil: A Formulação de Políticas e os Controles Democráticos para o Ciclo do Combustível Nuclear no Período Pós-1988" (PhD diss., FGV, Rio de Janeiro, RJ, 2017), 103.

4 Nicola Pamplona, "Parada desde 2014, produção de urânio será retomada este ano, diz estatal," *Folha de São Paulo*, August 30, 2018, https://www1.folha.uol.com.br/mercado/2018/08/parada-desde-2014-producao-de-uranio-sera-retomada-este-ano-diz-estatal.shtml.

5 Consultations with INB officials and staff in Caetité, Bahia (Brazil), April, 6 2018.

6 For more information on the annual production of uranium since the opening of Caetité mine, see INB's annual reports (*Relatórios de Gestão*) from 2005 to 2017, available at http://www.inb.gov.br/Transparencia/Prestacao-de-Contas.

7 "Santa Quitéria", INB, Accessed August 13, 2019, http://www.inb.gov.br/A-INB/Onde-estamos/Santa-Quiteria.

8 Francisco Goés, Rodrigo Polito and Marcos de Mouro Souza, "Governo vai estimular parcerias para ampliar a produção de urânio", *Valor Econômico*, January 7, 2019, https://www.valor.com.br/brasil/6051649/governo-vai-estimular-parcerias-para-ampliar-producao-de-uranio.

Between 2010 and 2014, conversion services were provided by Areva (now Orano) in France.[9] INB imported natural gaseous UF_6 and did not use conversion services in 2015 and 2016.[10] A new contract for conversion services was expected to start in 2018,[11] but no further details have been released yet.

UF_6 cylinders (Photo by Acervo INB)

INB has developed a project concept for its own conversion facility, but despite earlier estimates that the facility would start operating in 2025, as of 2019, the project remained in its early stages. Due to severe budget cuts, in 2017, INB chose to postpone all planned activities for the construction of this facility for that year and instead concentrated the company's budget on fuel fabrication in order to fulfill its commitments for the provision of fuel to the Angra-1 and Angra-2 power reactors.[12]

According to INB, the investment cost of an industrial-scale conversion facility must be justified by the amount of uranium expected to be produced; the project will not be feasible unless a certain minimum production level is reached and maintained.[13]

At the industrial scale, installation of conversion capability must proceed hand in hand with the development of enrichment capacity. The cost of conversion represents a relatively small share of the total cost of a nuclear power plant's fuel, approximately 5%, while the enrichment component constitutes 35%.[14]

In 2012, the Navy opened a small-scale facility at Iperó, in the state of São Paulo, where it will carry out uranium conversion for its needs. However, due to delays in the licensing process, the facility is still being commissioned and there is no expected date to start full operation.

URANIUM ENRICHMENT

The Navy is the sole owner of uranium enrichment technology in Brazil. At the Aramar facilities in Iperó, it carries out enrichment for its own projects and for some research reactors. Overall, the Navy does not enrich to levels above 4.3% uranium-235 (U-235), except for the fuel necessary for some research reactors requiring 19.9% U-235, as in the case of

9 INB, *Relatório da Administração* 2009 (Rio de Janeiro, 2010), 3; INB, *Relatório de Gestão do Exercício* de 2010 (2011), 5.

10 INB, *Relatório de Gestão do Exercício de 2015* (Rio de Janeiro, 2016), 34; INB, *Relatório de Gestão do Exercício de 2016* (Rio de Janeiro, 2017), 35.

11 Proposta de Resolução do Conselho de Administração da INB .15/16, 24/06/2016 - Anexo II: Orçamento 2017 - Programa de Trabalho - Projeto e Atividades e Plano de Investimentos. In: INB, *Relatório de Gestão 2017*.

12 INB, *Relatório de Gestão 2017*, 52-53.

13 Ibid., 53.

14 Consultations with INB officials and staff in Resende, Rio de Janeiro, April, 13 2018.

INB Resende (Photo by Acervo INB)

IEA-R1 research reactor and the future Brazilian Multipurpose Reactor (RMB). The enrichment plant at Aramar is authorized to operate at 19.9% U-235. However, whenever the Navy decides to enrich to that level, it must notify CNEN, the IAEA, and the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) in advance, so that specific safeguards procedures can be put in place. Notification is required because the safeguards applied to enrichment for up to 5% are less complex than those required at 19.9%. Currently, the centrifuge cascade dedicated to enriching uranium for the RMB is used to enrich uranium for the IEA-R1 reactor.[15] The Navy is self-sufficient when it comes to enrichment needs for its programs, but it still depends on INB for the supply of uranium concentrate and unenriched uranium hexafluoride.

For Brazil's civilian nuclear sector, the Navy leases uranium enrichment technology to INB. At its facility at Resende, INB carries out enrichment at up to 4.3% U-235 for nuclear fuel used in the Angra-1 and Angra-2 power reactors. As of 2017, INB met only 14% of the amount needed to fuel Angra-1 and Angra-2 reactors[16] and, as with conversion, relies on foreign partners to meet its demand for enrichment. Currently, INB operates eight cascades of enrichment centrifuges and can meet an amount equivalent to 60% of Angra-1 needs.[17]

NUCLEAR FUEL FABRICATION

INB produces fuel for the Angra-1 and Angra-2 power reactors. Its installed annual capacity for fuel pellet production is 120t UO_2/year, which exceeds the demands of both units. (Angra-1 requires approximately 16 t/year; Angra-2 requires approximately 30-35 t/year.) INB's installed capacity to produce fuel assemblies is 250 t/year.[18] As of 2018, INB had already produced and stockpiled fuel for Angra-3, even though construction of the reactor has remained stopped since 2015. (See "Private Investment" in "2 - Governance and Accountability.") The Energy and Nuclear Research Institute (IPEN) and the Navy's Technological Center in São Paulo (CTMSP) at Aramar Experimental Center (CEA or Aramar) also operate facilities for fuel fabrication, which fulfill their needs for research and propulsion reactors, respectively.

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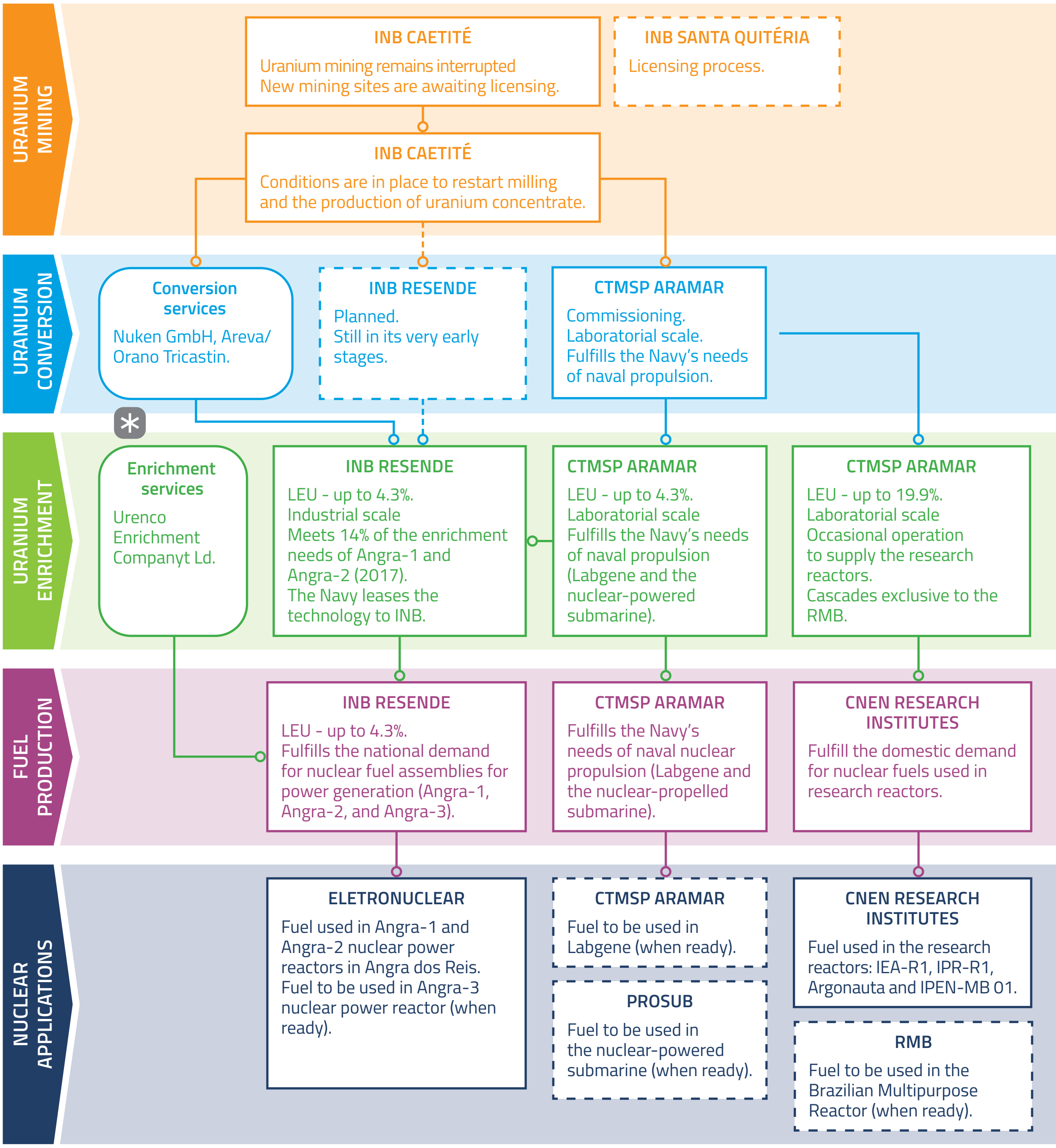
15 "Centro do Combustível Nuclear", IPEN, accessed August 29, 2019, https://www.ipen.br/portal_por/portal/interna.php?secao_id=544 ; Consultations with CTMSP and IPEN officials and staff in Iperó, São Paulo, April 4, 2018, and in São Paulo, in April 3, 2018, respectively.

16 INB, *Plano Estratégico INB 2017-2026* (2017), 36-37.

17 "Presidente da República visita INB e inaugura cascata de enriquecimento de urânio" INB, November 29, 2019, https://www.inb.gov.br/Detalhe/Conteudo/presidente-da-republica-visita-inb-e-inaugura-cascata-de-enriquecimento-de-urani/Origem/395.

18 INB, *Relatório de Gestão 2017*, 28.

Figure 1: The nuclear fuel cycle in Brazil

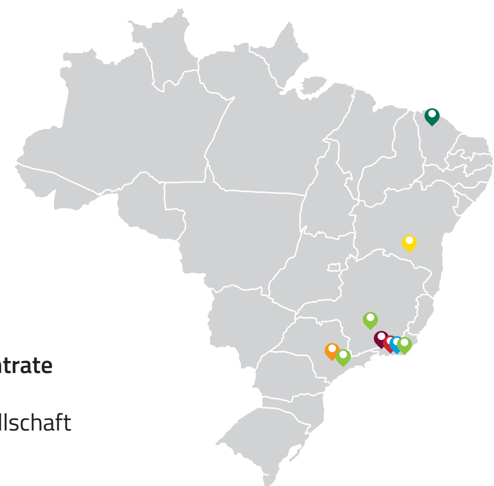


Fully operational

Under development

Domestic operator

Foreign operator



- INB, Caetité (BA)
- INB, Santa Quitéria (CE)
- INB, Resende (RJ)
- CTMSP Aramar, Iperó (SP)
- Angra-1 and Angra-2 nuclear power plants, Angra dos Reis (RJ)
- Prosub shipyard and naval base, Itaguaí (RJ)
- CNEN research institutes, Rio de Janeiro (RJ), São Paulo (SP), Belo Horizonte (MG)
- RMB, Iperó (SP) (when ready)

* **Suppliers of uranium concentrate and natural UF_6:**
Itochu Internat Inc., UG Gesellschaft GmbH, Uranium Ore, NAC Kazatomprom

THE NUCLEAR-POWERED SUBMARINE

Itaguaí shipyard in December 2018 (Photo by Marinha do Brasil)

Brazil seeks to commission a nuclear-powered submarine by 2029. A long, protracted quest for naval nuclear propulsion started in 1979, with the earliest designs for an indigenous gas centrifuge.[19] As the authors can attest from their visit to the Itaguaí shipyard in April 2018, progress on the nuclear-powered submarine project is fairly advanced; regardless of hurdles that might further delay the end date for construction in the next decade, the project appears to be irreversible.

Work on the nuclear submarine is led by the Brazilian Navy in association with the French company Naval Group (formerly DCNS). The division of labor is straightforward: the French provide the hull design and other nonnuclear technologies, while Brazil takes responsibility for all nuclear components of the submarine, including the naval nuclear propulsion reactor. The framework agreement between Brazil and France also includes construction of four conventional diesel submarines of the Scorpène class, the first of which launched in December 2018 for its first phase of testing.

The estimated cost for the entire Program for the Development of Submarines (Prosub) (four conventional submarines, one nuclear-powered submarine, and naval infrastructure for construction and operation) is approximately BRL 35.5 billion as of 2017 (approximately US$10 billion). The estimates changed over time due to unexpected additions to the original contracts, changes to the original designs, and fluctuation in the exchange rate.[20] The nuclear submarine alone accounts for BRL 12.4 billion, which does not include the costs for the reactor prototype.

Brazil's nuclear-powered submarine will be 100 meters in length with a diameter of 9.8 meters. Brazilian naval engineers estimate the submarine will carry up to 100 people onboard and will be able to submerge down to 350 meters. Its weapons system will include *conventional* torpedoes only.

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19 Matias Spektor, "The Evolution of Brazil's Nuclear Intentions," *Nonproliferation Review* 23, (2016): 635-652; M. Barletta "The Military Nuclear Program in Brazil" (working paper, Center for International Security and Arms Control, 1997).

20 Ministério da Defesa, *Relatório de Gestão – Exercício 2017* (Brasília, 2018), 91-92. These figures include the implementation of related infrastructures (BRL 12.49 bi) the development and construction of the nuclear submarine (except the propulsion reactor) (BRL 12.14 bi) and conventional submarines (BRL 10.86 bi).

The Itaguaí shipyard will feature nuclear-specific installations, including a radiological complex for fuel exchange, a specialized maintenance center for the reactor, a brigade for radiological protection, and a radiation decontamination and waste disposal area.[21] The estimated date for completion is 2029, with operations scheduled to begin in 2030.[22] Still, delays are to be expected.

The launch of the first convention submarine (Riachuelo) of the Prosub project in December 2018 (Photo by Alan Santons/PR, CC BY-NC-SA 2.0)

The submarine will rely on an 11 MWe (48 MWth) pressurized water reactor (PWR) with fuel rods containing uranium oxide (UO_2) and control rods. Each of the 21 fuel assemblies consists of 260 fuel rods, with a total of 146 kilograms of enriched UO_2 and 24,440 pellets.[23] The reactor will work with two generators: one will provide energy for the propulsion engine, and the other will generate electricity for other systems in the submarine.[24]

The Navy set up the Laboratory for Nuclear-Electric Power Generation (Labgene) to test submarine equipment in a land-based prototype reactor at the Aramar facilities of CTMSP outside São Paulo. Labgene will work as a laboratory facility intended to simulate the conditions that operators will find during the operation of the reactor inside the submarine. At an estimated cost of BRL 6.8 billion, the Labgene project encompasses research on fuel fabrication for nuclear reactors; the construction of nuclear reactors for propulsion tests and power production; and the construction, maintenance, decommissioning, logistical services and support for the nuclear-powered submarine.[25] Tests integrating the turbo generator and the engine started in June 2018, without the nuclear module. Brazilian

21 "Estaleiros e Base Naval," Prosub – Marinha do Brasil, accessed August 29, 2019, https://www.marinha.mil.br/prosub/estaleiro-e-base-naval.

22 "O Prosub e o Submarino Nuclear Brasileiro SN-BR," Aeronaval Comunicação, accessed August 29, 2019, http://www.naval.com.br/blog/2018/02/20/o-prosub-e-o-submarino-nuclear-brasileiro-sn-br/ ; "Programa Nuclear da Marinha", CTMSP – Marinha do Brasil, accessed August 29, 2019, https://www.marinha.mil.br/ctmsp/programa-nuclear-da-marinha ; "Submarino Nuclear," CTMSP – Marinha do Brasil, accessed August 29, 2019, https://www.marinha.mil.br/ctmsp/submarino-nuclear.

23 S. Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle," *Journal of Nuclear Materials Management* 42, no.3, (2014): 40-52; "Marinha Avança no LABGENE e Lança Equipamentos para Produção de Combustível Nuclear," Aeronaval Comunicação, accessed August 29, 2019, http://www.naval.com.br/blog/2018/04/10/marinha-avanca-no-labgene-e-lanca-equipamentos-para-producao-de-combustivel-nuclear/ ; "O Prosub e o Submarino Nuclear Brasileiro SN-BR," Aeronaval Comunicação, accessed August 29, 2019, http://www.naval.com.br/blog/2018/02/20/o-prosub-e-o-submarino-nuclear-brasileiro-sn-br/.

24 "O Prosub e o Submarino Nuclear Brasileiro SN-BR," Aeronaval Comunicação, accessed August 29, 2019, http://www.naval.com.br/blog/2018/02/20/o-prosub-e-o-submarino-nuclear-brasileiro-sn-br/.

25 Ministério da Defesa, *Relatório de Gestão 2017*, 83-84.

officials estimate that Labgene will be fully operational by 2021.[26]

During the authors' visit to the site in 2018, Navy officials stated that the submarine would operate on fuel enriched to 4.3% U-235, although that figure may vary over time. Over the past few years, Brazilian officials have reaffirmed that the reactor of the first submarine would use low-enriched uranium (LEU).[27] LEU is uranium enriched up to 20% U-235. Fuel for the submarine will be fabricated at the Aramar facilities and then transferred to Itaguaí.[28]

Ceremony marks the start of tests integrating the turbo generator and the engine of Labgene in June 2018 (Photo by Cesar Itibere/PR/Agência Brasil)

As the first non-nuclear-weapon state ever to build a nuclear-powered submarine, Brazil will be the first to put naval nuclear fuel under special safeguards procedures. (See "Nuclear Safeguards" in "2 - Governance and Accountability.") Technical details as to how they will achieve this remain to be determined, but as far as the authors could determine in the course of the interviews for this report, a special working group within the Navy is now actively discussing options. It remains to be seen where responsibility over safeguards will be placed.

In the course of its submarine-related work, Brazil has established a new Naval Agency for Nuclear Safety and Quality (AgNSNQ), in charge of the domestic governance of nuclear safety licensing. The agency, however, will not deal with safeguards procedures. (See "The Brazilian Navy" in "1 - Capabilities and Major Players" and "Civil-Military Relations" in "2 - Governance and Accountability.")

The nuclear submarine fits into Brazil's National Defense Strategy (2012) as a core

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[26] José Maria Tomazela, "Temer Dá Início a Testes de Submarino Nuclear e Pede 'Otimismo' em Iperó", *Estadão*, June 8, 2018, https://politica.estadao.com.br/noticias/geral,temer-inaugura-testes-de-submarino-nuclear-e-pede-mais-otimismo-no-pais,70002343057 ; "Lançamento da Pedra Fundamental do RMB e Início dos Testes de Integração dos Turbogeradores do LABGENE," Aeronaval Comunicação, accessed August 29, 2019, https://www.naval.com.br/blog/2018/06/08/lancamento-da-pedra-fundamental-do-rmb-e-inicio-dos-testes-de-integracao-dos-turbogeradores-do-labgene/.

[27] E. P. L. D. Costa, "Brazil's Nuclear Submarine: A Broader Approach to the Safeguards Issue," *Revista Brasileira de Política Internacional* 60, no.2, (2017): 1-20; Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle."

[28] Matias Spektor, "Prospects for Safeguarding Brazil`s Naval Nuclear Propulsion Program," Issue Brief, *Federation of American Scientists*, (2017); Matias Spektor, "Brazil's Nuclear Naval Fuel: Choices and a Road Map for Productive Engagement," in *Reducing Risks from Naval Nuclear Fuel*, Lobner et. al (Washington, DC: The George Washington University, 2018).

component of the fleet that will fulfill "the task of sea-use denial" against potential aggressors, while facilitating the tasks of defending "oil rigs," "naval and port facilities, archipelagos, and ocean islands in Brazilian jurisdictional waters." Brazil's coast stretches across approximately 7.5 million kilometers. The submarine will increase the capacity "to respond to any threat, from state or nonconventional or criminal forces, to sea trade routes" and improve the country's "capacity to participate in international peace operations" under the command of the United Nations or multilateral organizations "in the region."[29] The submarine is also expected to have a "deterrence" effect. In the event of combat, surface ships are considered to be a "technical or strategic reserve" force, while the submarine fleet is to be used in coordination with spatial and aerial assets for monitoring and targeted attack.[30]

There is also a recurring argument by Brazilian officials, both within the Navy and across other government agencies, that irrespective of the military utility of the submarine as expressed in the National Defense Strategy, commissioning it will bring positive technological spillovers beyond the naval industry. Finally, it is also seen as a marked improvement in Brazil's geopolitical position in the global pecking order of states.[31]

RESEARCH REACTORS

Research reactors represent an important asset in Brazil's nuclear program for research and training and for radioisotope production. In particular, they allow scientists and students to conduct tests and simulations of diverse techniques in reactors with small cores. They are also indispensable for irradiation of materials having diverse applications in medicine, industry, engineering, agriculture, and other areas.

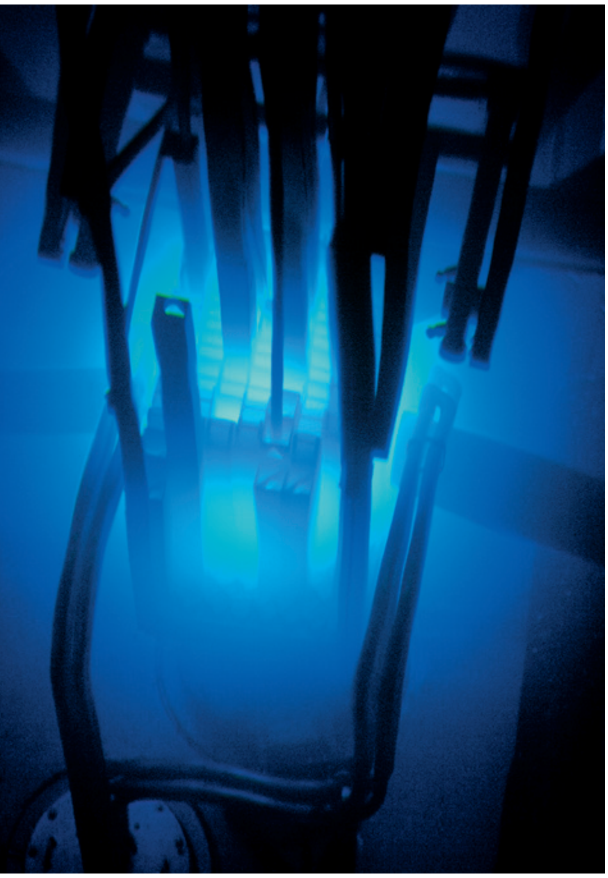
Brazil operates four research reactors – IEA-R1, IPR-R1, Argonauta, and IPEN-MB-01. The first three were installed during the 1950s and 1960s, when Brazil obtained nuclear technical assistance (for example, equipment supply and personnel training) from the United States under the Atoms for Peace program.

The IEA-R1 is a 5 MWth material testing reactor (MTR) built by Babcock & Wilcox Co. in the United States. It operates with fuel plates made of LEU (U-235 up to 19.9%) in the form of U_3O_8 and U_3Si_2 mixed with aluminum. The start of its operations in 1957 was a milestone event for the establishment of the nuclear research institute that later became known as IPEN. In addition to being an important asset for teaching and training in the field of nuclear sciences, the reactor is the country's main producer of radioisotopes and radioactive sources for use in medicine, industry, agriculture, and engineering. Examples of these isotopes include iodine-131, samarium-153, iridium-192, gold-198, bromine-82, cobalt-60, mercury-203, krypton-79, argon-40, lanthanum-140, and technetium-99. The

29 Ministério da Defesa, *National Defense Startegy*, (Brasília, 2012), 69-70.

30 Ibid., 72-73.

31 See, for instance, Togzhan Kassenova, "The Navy's Nuclear Program after Military Rule," in *Brazil's Nuclear Kaleidoscope: An Evolving Identity* (Washington, DC: Carnegie Endowment for International Peace, 2014).



IEA-R1 reactor core (Photo by Marcello Vitorino/Fullpress)

facility is also used for neutron activation analysis, neutron radiography, neutron beam utilization, silicon doping, fuel irradiation, and nondestructive test analysis.[32]

The acquisition of the IPR-R1 reactor by the state government of Minas Gerais in 1958 laid the foundation for Brazil's first nuclear research center. A 100 kWth open-pool-type Triga Mark I reactor, supplied by General Atomics in the United States, it operates on fuel rods made of LEU (uranium zirconium hydride, U-235 up to 19.9%). It is currently used for neutron activation analysis and irradiation, research on new materials for health and radiopharmaceutical applications, production of specific radioisotopes and other radioactive sources (cobalt-60, manganese-56, bromine-82, gold-198, iridium-192, phosphorus-32, argon-41), as well as training.[33]

In the 1960s, Brazilian scientists for the first time assembled a research reactor. They adopted the design for the Argonauta research reactor from the Argonne National Laboratory in the United States. Its domestic content is estimated at 93%. Housed at the Institute of Nuclear Engineering (IEN), Argonauta is a 500 Wth-1 kWth reactor,[34] operating with plate fuel, with LEU (19.91% U-235) as U_3O_8 mixed with aluminum. As of 2019, the reactor was being used primarily for research and training in nuclear physics, neutron radiography, and neutron activation analysis. Argonauta produces only a few specific radioisotopes for use in industrial and environmental fields (maganese-56, lanthanum-140, selenium-75, bromine-82, gold-198, dysprosium-165).[35]

IPEN-MB-01 is the result of the cooperation between IPEN and the Brazilian Navy carried out under the 1970s "parallel" nuclear program, a secret endeavor to develop the nuclear fuel cycle, including uranium enrichment, for nonproscribed military

[32] José Augusto Perrotta, "RMB - Tecnologia Nuclear a Serviço da Vida" (Power-point presentation, 60 Years of IEA-R1, International Workshop on Utilization of Research Reactors, IPEN, São Paulo, SP, November 28, 2017); "Reator IEA-R1," IPEN, accessed August 28, 2019, https://www.ipen.br/portal_por/portal/interna.php?secao_id=729 ; IAEA Research Reactor Database (RRDB) (accessed August 29, 2019), https://www.iaea.org/resources/databases/research-reactor-database-rrdb.

[33] Perrotta, "RMB - Tecnologia Nuclear a Serviço da Vida"; "Reator Triga IPR-R1", CDTN, accessed August 29, 2019, http://www.cdtn.br/instalacoes-de-grande-porte/reator-triga-ipr-r1 ; IAEA Research Reactor Database (RRDB) (accessed August 29, 2019), https://www.iaea.org/resources/databases/research-reactor-database-rrdb ; "History", General Atomics, accessed August 29, 2019, http://www.ga.com/triga-history.

[34] The facility has a license to operate at 500W, but it can operate in higher levels (1kW) for one hour. Its usual operation ranges between 170 and 340W. It could operate at 5kW, depending on the design. See footnote below.

[35] Perrotta, "RMB - Tecnologia Nuclear a Serviço da Vida"; "Reator Argonauta", IEN, accessed August 28, 2019, https://www.ien.gov.br/index.php/radiof/63-instalacoes/159-argonauta ; "Reator Argonauta: Construção e Montagem Parte 1," produced by Instituto Nacional de Cinema Educativo, directed by Manoel P. Ribeiro, documentary, 00:29, 1966, https://www.youtube.com/watch?v=mXcYBMQ-HJQ ; IAEA Research Reactor Database (RRDB) (accessed August 29, 2019), https://www.iaea.org/resources/databases/research-reactor-database-rrdb.

activities (mainly naval propulsion). (See "Civil-Military Relations" in "2 - Governance and Accountability.") IPEN oversaw its design, and the Navy financed and built the reactor. Construction of IPEN-MB 01 started in 1983, and the reactor began operation in 1988. IPEN-MB-01 was the first reactor designed in Brazil and has a layout that is different from that of the other three reactors. It is a zero-power critical facility that can reach 100Wth. The reactor has an open core, which can be adapted to perform different types of functions. Initially, nuclear engineers designed and assembled it to create conditions similar to those in a nuclear propulsion reactor. As a result, until early 2018, the reactor operated with fuel rods containing LEU (U-235 up to 4.3%) in UO_2 form.[36] As of 2019, plans are in place to change the reactor's core plate to allow simulations of the Brazilian Multipurpose Reactor.

THE BRAZILIAN MULTIPURPOSE REACTOR

Brazil is currently developing a US$500 million project for the construction of an intermediate-scale, multipurpose research reactor and related laboratories. The facilities will be located close to the existing laboratories of Aramar in Iperó, São Paulo, but will remain under the control of the Ministry of Science, Technology, Innovations, and Communications. The Brazilian government sees the RMB as a key piece for the establishment of a technological center on nuclear sciences in the region, alongside the Navy's existing laboratories.

The main equipment of the RMB project will be a 30 MWth open-pool-type research reactor with multiple applications in radioisotope production, neutron-activation analysis, material analysis, and testing of fuel and reactors (including propulsion and power reactors). Its design resembles that of an Argentine 30 MWth research reactor developed by Invap, whose baseline reference is an Australian 20 MWth, open-pool-type, light-water reactor (Opal) from 2007.[37] The RMB will operate with LEU fuel (up to 19.9% U-235) in the form of 21 U_3Si_2-Al plate fuels (uranium silicide dispersed in aluminum).[38]

The RMB will represent an increase of almost 600% in installed capacity in the field of nuclear research, science, and technology in Brazil. Nevertheless, it does not entail any major change in the availability of fissile material. The RMB operates at 30 MWth, with only 30 kg of uranium, at standard temperature and pressure, while reactors for energy production in Brazil have a capacity of 4,000 MWth power, working with 109 tons of uranium, at 300° C and 150 atmospheric pressure.[39]

With the RMB, Brazil is seeking to meet the national demand for radioisotopes,

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[36] Perrotta, "RMB - Tecnologia Nuclear a Serviço da Vida"; "Reator de Pesquisa IPEN-MB/01", IPEN, accessed August 29, 2019, https://www.ipen.br/portal_por/portal/interna.php?secao_id=723 ; IAEA Research Reactor Database (RRDB) (accessed August 29, 2019), https://www.iaea.org/resources/databases/research-reactor-database-rrdb.

[37] José Augusto Perrotta, "Escopo e Estrutura do Empreendimento RMB," in *Simpósio Reator Multipropósito Brasileiro* (Belo Horizonte, MG: Instituto Casa da Educação Física, 2019): 17-46; Evanildo Silveira, "Instrumento de Radiação," *Revista de Pesquisa FAPESP* 221, (2014): 78-81.

[38] Perrotta, "Escopo e Estrutura do Empreendimento RMB," 32, 42.

[39] Ibid., 78.

especially molybdenum-99 (Mo-99). As of 2016, Brazil's research institutes run by CNEN produced around 23,000 curies (Ci) of 38 radiopharmaceuticals each year (440 Ci per week), which are applied in nearly 2 million procedures at more than 430 clinics nationwide.[40] Since 2006, after the state monopoly over the production of radioisotopes with a half-life of less than two hours ceased to exist, private companies have entered the market in a very specific niche, namely the production of fludeoxyglucose-18. Therefore, the overall supply of radiopharmaceuticals remains mostly a state responsibility.

Official figures indicate that the supply of radiopharmaceuticals does not meet the national demand.[41] Studies from the Brazilian Society of Nuclear Medicine, for example, show that Brazil ranks 25th worldwide in terms of the number of nuclear-medicine procedures per 1,000 people. Each year, only 2.5 nuclear-medicine procedures occurred per 1,000 people in the country, whereas 11.1 and 34.1 procedures took place in Argentina and the United States, respectively.[42] The data on per capita medical exams in nuclear medicine support this perspective: Argentina and the United States, respectively, carried out 2.5 and 6 times more exams using nuclear medicine than Brazil.[43]

Capabilities in this field are constrained because the research reactors in the country do not produce Mo-99, making Brazil entirely dependent on imports. Brazilian government officials view this dependency as a major vulnerability because Mo-99 is used in generators and converted into technetium-99m, a radioisotope that accounts for 80% of all nuclear-medicine procedures.[44] Weekly demand for Mo-99 alone in Brazil is around 450 Ci.[45]

Brazil's dependence on the price and availability of Mo-99 on the global market jeopardizes production of generators in Brazil. There are only few remaining suppliers worldwide, research reactors are being shut down due to aging, and prices are rising.[46]

In 2009, a defect in Canada's National Research Universal (NRU) reactor caused an international crisis in the production of Mo-99. At that time, the Canadian company MDS Nordion, which operated the reactor, was CNEN's sole provider of Mo-99.[47] Then, the price of 1 Ci Mo-99 reached US$800, compared to previous price of US$400-500.[48] In those circumstances, Brazil resorted to other international companies in South Africa, Argentina, and Russia in order to accommodate variations in the global market.[49]

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[40] CNEN, *Relatório de Gestão do Exercício de 2016* (Rio de Janeiro, 2017), 29-39.

[41] CNEN, *Relatório de Gestão 2016*, 30-31; Perrotta, "Escopo e Estrutura do Empreendimento RMB", 18.

[42] Marina Panham, "Crescimento Inexorável," *Medicinanuclear* 15, no.1, (2013): 17-21.

[43] CNEN, *Relatório de Gestão 2016*, 30.

[44] Ibid.

[45] Perrotta, "Escopo e Estrutura do Empreendimento RMB," 27.

[46] Ibid., 28.

[47] CNEN, *Relatório de Gestão 2016*, 12.

[48] Perrotta, "Escopo e Estrutura do Empreendimento RMB," 28.

[49] Odair Dias Gonçalves, "O Programa Nuclear Brasileiro e a Física Médica no Brasil," *Revista Brasileira de Física Médica* 3, no. 1, (2009): 151-6; CNEN, *Relatório de Gestão 2016*, 37.

Another complication results from the time-sensitive nature of operations involving Mo-99. If radioisotope processing takes too long due to logistics involved in importation (for example, transportation from suppliers abroad to processing facilities in Brazil), radioactivity is significantly reduced due to the high level of decay of Mo-99. Every 66 hours, its radioactivity drops by half.[50]

Brazil also relies on imports of cobalt-60, chromium-51, iodine-131, iodine-125, indium-111, iridium-192, lutetium-177, and yttrium-90.[51]

CNEN sees the entrance of private companies into the production of radioisotopes as a risk for the continuation of its presence in this niche market.[52] Moreover, profits obtained from the sale of radioisotopes by CNEN do not convert into direct budget allocation to keep production running, which instead shrank in the last years.[53] (See "Private Investment" in "2 - Governance and Accountability.") Such budgets limitations also compromise the maintenance, adaptation, and renovation of equipment, such as cyclotrons, used in the production of other radiopharmaceuticals.[54] Finally, the regime of working hours of nuclear personnel and the reduction of human resources might also affect the country's capacity to produce radioisotopes.[55] (See "Human Resources and Education" in "2 - Governance and Accountability.")

In this context, the Brazilian government views the RMB as a means to overcome some gaps in the production of radiopharmaceuticals in Brazil, especially Mo-99. The new reactor could increase and diversify production, as well as optimize fabrication procedures. Officials in the nuclear sector estimate that the RMB could produce 1,000 Ci/week of Mo-99. Figure 2 shows how the RMB could improve Mo-99 supply in Brazil, compared to imports. The RMB could produce other radiopharmaceuticals as well, such as iodine-131 and lutetium-177.[56]

[50] Perrotta, "Escopo e Estrutura do Empreendimento RMB," 27-28.

[51] Perrotta, "RMB - Tecnologia Nuclear a Serviço da Vida." Slide 8.

[52] CNEN, *Relatório de Gestão 2016*, 38.

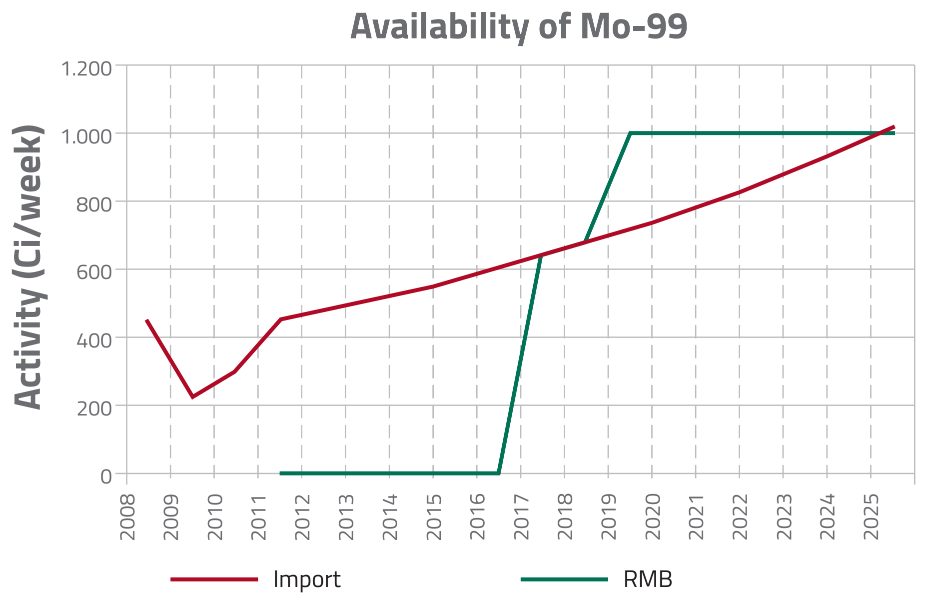
[53] Relatório CNEN 2016 p.38-39.

[54] Ibid., 38-39.

[55] Ibid., 38-39.

[56] Silveira, "Instrumento de Radiação."

Figure 2: Evolution of Mo-99 supply in Brazil (imports vs. RMB)[57]



Source: Adapted from Perrotta, "RMB - Tecnologia Nuclear a Serviço da Vida," 26.

In December 2017, Argentina and Brazil signed agreements for the development of the RMB. Financial support comes from Brazil's state company (Finep) supporting projects in science, technology, and innovation at companies, universities, technology institutions, and other sorts of public and private organizations. Together, Argentina's state company Invap S.E. and the Brazilian Navy's company Blue Amazon Defense Technologies S.A. (Amazul) are designing the details of the project for the reactor.[58] In March 2018, the Ministry of Health signed a technical cooperation agreement with Amazul, making BRL 750 million available for the project. These funds will be gradually allocated by the Ministry of Health over the coming years until 2022.[59] In June 2018, a formal ceremony celebrated the symbolic start of construction.[60] In 2016, IPEN and the Navy had completed the installation of enrichment cascades to operate in the RMB fuel cycle[61] and in 2017, assembled the first RMB-type fuel element plate, which will be used in simulations in the IPEN-MB-01 reactor.[62]

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57 The chart was developed by CNEN and estimated that the RMB would have started to operate in 2016, which did not happen. Nevertheless, it depicts the expected evolution of the production of Mo-99 when the RMB starts to operate.

58 "CNEN Dá Continuidade ao Projeto do RMB", CNEN, accessed August 29, 2019, http://www.cnen.gov.br/ultimas-noticias/410-cnen-da-continuidade-ao-projeto-do-rmb.

59 "Marinha Lança Pedra Fundamental do RMB e Inicia Testes de Turbogeradores do Labgene," Amazul, accessed August 29, 2019, https://www.marinha.mil.br/amazul/rmb-evento-8-junho.

60 "Reator Multipropósito Vai Ampliar Acesso da População à Medicina Nuclear," CNEN, accessed August 29, 2019, http://www.cnen.gov.br/ultimas-noticias/450-lancamento-da-pedra-fundamental-do-rmb.

61 "Nova Cascata de Enriquecimento em Iperó," ABEN, accessed August 29, 2019, http://www.aben.com.br/noticias/nova-cascata-de-enriquecimento-em-ipero.

62 "Elemento Combustível que Vai Simular o RMB É Lançado no IPEN", IPEN, accessed August 29, 2019, https://www.ipen.br/portal_por/portal/interna.php?secao_id=38&campo=9170.

NUCLEAR POWER

Nuclear power plants in Brazil, 2009 (Photo by Sturm/Wikipedia Commons)

Brazil is one of only three countries in Latin America to produce nuclear power. (The other two are Argentina and Mexico.) There are two operating nuclear power units in Álvaro Alberto Nuclear Power Station, located in Angra dos Reis County, Rio de Janeiro State – Angra-1 and Angra-2. Angra-1 is a PWR supplied by Westinghouse and has a capacity of 640 MWe. It began operation in 1985. Angra-2 is also a PWR-type reactor; it was provided by Siemens/KWU, currently Framatome. It began operation in 2001 and has a capacity of 1,350 MWe. Angra-1 and Angra-2 represent 1.3% of the installed electric generation capacity in Brazil. In 2017, they accounted for 2.7% of the country's generation.[63]

Site preparation for construction of the third unit, Angra-3 – intended to be a second Siemens/KWU PWR with the same design as Angra-2 – started in 1984. But after just two years and even though equipment was already delivered to the site, work on the site was suspended in favor of concentrating resources on completing Angra-2. Twenty years later, the government recommitted itself to completing Angra-3. In 2010, after 24 years, construction of Angra-3 resumed. The milestone of construction start – that is, the first pouring of concrete – occurred in June 2010. Since 2015, the project has run into serious obstacles, including corruption scandals and financial constraints such as debts with creditors and suppliers.[64] As of 2019, Angra-3 construction remains frozen; civil works and electromechanical assembly contracts have been canceled. Once Angra-3 is complete, it will add 1,405 MWe to the Brazilian grid.[65]

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63 EPE – Ministério de Minas e Energia, "Anuário Estatístico de Energia Elétrica 2018 - Ano Base 2017," (Rio de Janeiro, 2018), 56, 58.

64 Vinicius Sassine, "Angra 3: Uma obra à deriva e paralisada desde 2015," *OGlobo*, December 18, 2017, https://oglobo.globo.com/economia/angra-3-uma-obra-deriva-paralisada-desde-2015-22204452.

65 "Angra 3", Eletronuclear, accessed on October 7, 2019, https://www.eletronuclear.gov.br/Nossas-Atividades/Paginas/Angra-3.aspx.

HUMAN RESOURCES AND EDUCATION

State institutions constitute the core of Brazil's nuclear sector. Apart from a handful of companies in the radioisotopes market, two private-business associations (the Brazilian Association on Nuclear Energy and the Brazilian Association for the Development of Nuclear Activities), the local offices of international nuclear industry firms such as Rosatom, and the Odebrecht/Naval Group consortia for the nuclear-powered submarine, the Brazilian state dominates the field. As a result, most professionals involved in the nuclear sector are state employees. This has a range of repercussions for Brazil's nuclear policy that this section explores.

Statistics on human resources in Brazil's nuclear sector are sorely lacking. The various government bodies report on their human-resource situation regularly, but there are no systematic accounts. Furthermore, information on human resources pertaining to institutions such as the System for the Protection of the Brazilian Nuclear Program (Sipron) and the General Directorate for the Navy's Nuclear and Technology Development (DGDNTM) remains imprecise. By the authors' calculation based on publicly available sources,[66] there are roughly 10,000 professionals working in the nuclear sector, including scientists, technicians, managers, and support personnel. The distribution of human resources across institutions is summarized in Table 1.

Table 1: Human resources in the Brazilian nuclear sector

ORGANIZATION	NUMBER OF EMPLOYEES	MAIN ACTIVITIES
Blue Amazon Defense Technologies S.A (Amazul)	1,817 (2018)[67]	▪ Provides technical assistance for the construction of the RMB ▪ Provides additional personnel for the construction and operation of Labgene ▪ Provides additional personnel for the planning and operation of the Navy's nuclear program ▪ Participates in nuclear policy making at the Navy's nuclear organizations ▪ Provides additional personnel to the Prosub program, including submarine construction and project coordination

[66] This table is based on the information from different sources and years in the absence of a unified database on human resources in the Brazilian nuclear sector. It is an estimate but not hard data on human resources in the Brazilian nuclear sector. To a large extent, the authors relied on direct consultations with nuclear stakeholders and the most recent annual reports submitted by governmental entities to the Federal Court of Accounts (TCU). In cases when nuclear-related institutions do not report to TCU directly, the authors relied on the information submitted to TCU by the bodies that oversee these institutions (https://portal.tcu.gov.br/contas/contas-e-relatorios-de-gestao/). However, these reports do not make distinctions among the entities under their institutional umbrella, which hampers the collection of precise information. For this particular reason, the authors could not include in their calculation the human resources allocated at Sipron and DGDNTM. In the case of CTMSP, the authors used earlier reports to give an estimate of human resources, as reports pertaining to fiscal years beyond 2014 fiscal are not available in TCU's database. The numbers for CTMSP do not include the employees who are hired by Amazul and who work at CTMSP's facilities; they are included in Amazul's tally of human resources. Finally, no primary source on human resources working at Prosub private consortia is available. In this case, the authors used a secondary source, as cited.

[67] Amazul, *Relatório de Gestão do Exercício de 2018* (São Paulo – SP, 2019), 58.

ORGANIZATION	NUMBER OF EMPLOYEES	MAIN ACTIVITIES
Eletrobras Thermonuclear S.A. (Eletronuclear)	1,741 (2018)[68]	▪ Nuclear power generation
General Coordination of the Program for the Development of the Nuclear-Powered Submarine. (Cogesn)	291 (2017)[69]	▪ Coordination of the Prosub program
Itaguaí Naval Constructions (ICN)	1,100 (2015)[70]	▪ Submarine construction in the Prosub program
National Nuclear Energy Commission (CNEN)	1,775 (2019)[71]	▪ Design, construction, and operation of the Brazilian Multipurpose Reactor (RMB) ▪ Fuel fabrication for research reactors ▪ National waste management ▪ Production of radioisotopes ▪ Regulations, licensing, and monitoring ▪ Research and development ▪ Safeguards application ▪ Safety and security procedures
Naval Agency for Nuclear Safety and Quality (AgNSNQ)	33 (2017) (64 - planned)[72]	▪ Licensing and regulation of the nuclear-powered submarine during its construction and operation
Navy's Technological Center in São Paulo (CTMSP)	746 (2013)[73]	▪ Construction and operation of Labgene ▪ Planning and operation of the Navy's Nuclear Program for the nonindustrial fuel cycle (uranium conversion and enrichment, fuel fabrication) ▪ Submarine design and logistical support to the Prosub program
Nuclear Industries of Brazil (INB)	1,308 (2018)[74]	▪ Industrial fuel cycle (uranium mining, milling, and enrichment; fuel fabrication)
Nuclep Heavy Equipment (Nuclep)	1,034 (2018)[75]	▪ Heavy industry for the nuclear sector (Prosub, Labgene, Angra-3). It also provides heavy equipment to non-nuclear sectors.

Sources: See footnotes.

68 Eletronuclear, *Relatório de Gestão 2018* (Rio de Janeiro – RJ, 2019), 15.

69 Cogesn, *Relatório de Gestão do Exercício de 2017* (Rio de Janeiro – RJ, 2018), 53. This figure includes the staff that is involved in the construction of the conventional submarines.

70 "ICN Sente Os Efeitos Da Crise e Adota Sistema de Dispensas Pontuais," Aeronaval Comunicação, accessed August 29, 2019, http://www.naval.com.br/blog/2015/03/17/icn-sente-os-efeitos-da-crise-e-adota-sistema-de-dispensas-pontuais/. This figure includes the staff that is involved in the construction of the conventional submarines.

71 SIAPE CNEN – Quadro de Cargos Efetivos por Carreira e Unidade (accessed in February 2019).

72 Consultations with the AgNSNQ staff and officials in Rio de Janeiro, April 10, 2018.

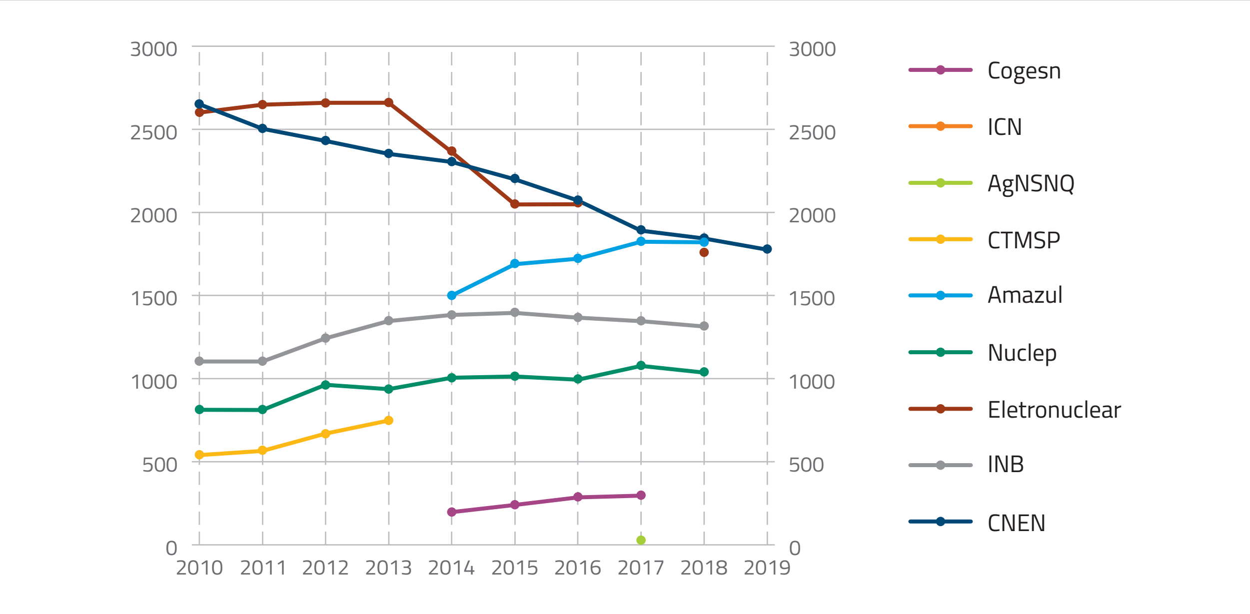
73 CTMSP, *Relatório de Gestão do Exercício de 2013* (São Paulo, 2014), 49. TCU ceased publishing CTMSP annual reports online in 2013.

74 INB, *Relatório Integrado 2018* (Rio de Janeiro – RJ, 2019), 33.

75 Nuclep, *Relatório de Gestão do Exercício de 2018* (Itaguaí – RJ, 2019), 33.

In recent years, the Navy's nuclear organizations and Amazul have seen a surge in professional hiring to fulfill the demands for the nuclear submarine and related projects, while CNEN and Eletronuclear suffered a significant decrease in their workforce due to high rates of retirement and the lack of funds from the central government to hire a new generation of professionals. These dynamics are shifting the balance between civilian and military nuclear professionals in the country. (See "Civil-Military Relations" and "Human Resources and Education" in "2 - Governance and Accountability.")

Figure 3: Human resources in the Brazilian nuclear sector (2010-2018)



Sources: See footnote 66.

Amazul in particular has become a key player in the expansion of personnel working under the military arm of the Brazilian nuclear sector. Related to the nuclear-powered submarine project (and to a lesser extent, the RMB program), Amazul has secured the funds to offer career opportunities while retaining existing staff across the field. The table below depicts their distribution in the nuclear sector, as of 2018.

Table 2: Distribution of Amazul's personnel across the Brazilian nuclear sector

CTMSP ARAMAR	COGESN	DGDNTM	ITAGUAÍ FACILITIES	RJ	AMAZUL'S HEADQUARTERS	CTMSP HEADQUARTERS
895	33	28	16	12	183	650

Source: Adapted from Amazul, *Relatório de Gestão 2018*, 2019, 58.

EDUCATION AND TRAINING

Brazil trained its first generation of nuclear experts in the 1950s and 1960s under the auspices of the US Atoms for Peace program, mostly through international exchange programs in Europe and in the United States. Hundreds of Brazilian scientists and managers who trained abroad returned to populate the sprawling nuclear sector. But it was only in the 1970s, when Brazil signed a major technical assistance program with West Germany, that a dedicated program (Pronuclear) was put in place to provide sector-wide training opportunities in the country. From 1976 to 1986, the federal government program introduced nuclear-related science in undergraduate curricula, sponsored the opening of graduate-level courses and degrees, designed on-the-job training programs, and built new capacity to meet the demand of the then-nascent nuclear industry. Pronuclear also promoted high-school-level technical courses and courses on nuclear technology.[76] Most existing nuclear education initiatives at the university level today still rely on the foundations laid down by Pronuclear.[77]

Currently, technical and academic professionals in the nuclear sector are highly skilled even though nuclear science education is still limited to university departments of engineering and physics and CNEN's own research institutes. In some cases, CNEN maintains a close collaboration with the state universities hosting its research institutes (for example, IPEN and the University of São Paulo (USP); and the Regional Center for Nuclear Sciences – Northeast (CRCN-NE) and the Federal University of Pernambuco (UFPE)). There are three leading academic programs in operation today: IPEN/USP; the Alberto Luiz Coimbra Graduate and Research Institute of Engineering (Coppe) at the Federal University of Rio de Janeiro (UFRJ); and CRCN-NE and UFPE.

As of late 2017, there were 1,202 active students in graduate level programs in nuclear engineering at seven departments across Brazil.

Table 3: Graduate programs in nuclear sciences in Brazil (2017)

STATE	UNIVERSITY	GRADUATE PROGRAM	YEAR PROGRAM BEGAN	NUMBER OF STUDENTS
Rio de Janeiro	Federal University of Rio de Janeiro (Coppe)	Nuclear engineering	1968	159
Minas Gerais	Federal University of Minas Gerais (School of Engineering)	Nuclear sciences and technologies	1968	78
Rio de Janeiro	Military Institute of Engineering (IME)	Nuclear engineering	1969	27
São Paulo	University of São Paulo (IPEN)	Nuclear technology	1976	567

[76] Winston Gomes Schmiedecke, "Schmiedecke, "O Pronuclear (1976-1986) e a Formação de Recursos Humanos para a Área de Energia Nuclear no Brasil," (master's thesis, Pontifícia Universidades Católica – São Paulo, 2006), 55-56.

[77] For an assessment of results in Pronuclear, see Schmiedecke, "O Pronuclear (1976-1986) e a Formação de Recursos Humanos para a Área de Energia Nuclear no Brasil."

STATE	UNIVERSITY	GRADUATE PROGRAM	YEAR PROGRAM BEGAN	NUMBER OF STUDENTS
Pernambuco	Federal University of Pernambuco (and the CRCN- NE)	Nuclear energy technologies	1977	169
Minas Gerais	Center for the Development of Nuclear Technology (CDTN)	Science and technology in radiation, minerals, and materials	2003	146
Rio de Janeiro	Nuclear Engineering Institute (IEN)	Nuclear Science and technology	2010	56

Source: Based on CAPES (Programas da Pós-Graduação Stricto Sensu No Brasil 2017, database, accessed August 29, 2019), https://dadosabertos.capes.gov.br/dataset/coleta-de-dados-programas-da-pos-graduacao-stricto-sensu-no-brasil-2017

Even though the Navy does not have its own graduate program in nuclear engineering, the CTMSP's Center for Studies Coordination in São Paulo at the Polytechnic School of USP is the key center for the education of future military engineers, who participate in the Navy's nuclear activities and other technological programs.[78] At the undergraduate level, Brazil has only one program in nuclear engineering (since 2010) at Coppe-UFRJ. To this day, there is no graduate program on *nuclear* physics in Brazil. It is within the broader discipline of physics that students are introduced to nuclear physics.

Other training in nuclear-related sciences and policy occurs across the nuclear sector. This is the case for the Program on Radiation Protection and Dosimetry offered by the Institute for Radiation Protection and Dosimetry (IRD) of CNEN and the Program on Nuclear Energy in Agriculture offered by the Center of Nuclear Energy in Agriculture (USP).[79]

Table 4: Graduate programs in nuclear-related sciences in Brazil (2017)

STATE	UNIVERSITY	GRADUATE PROGRAM	YEAR PROGRAM BEGAN	NUMBER OF STUDENTS
SP	CENA/USP	Nuclear Energy in Agriculture (category: Sciences)	1972	137
RJ	IRD/CNEN	Radiation Protection and Dosimetry (category: Interdisciplinary programs)	2001	71

Source: Based on CAPES (Programas da Pós-Graduação Stricto Sensu no Brasil 2017, database, accessed August 29, 2019), https://dadosabertos.capes.gov.br/dataset/coleta-de-dados-programas-da-pos-graduacao-stricto-sensu-no-brasil-2017

[78] "Centro de Coordenação de Estudos em São Paulo (CCEMSP)," Brasil – Ministério da Defesa, accessed August 29, 2019, https://www.defesa.gov.br/ensino-e-pesquisa/instituicoes-de-ensino-militar/instituicoes-de-ensino-e-pesquisa-vinculadas-a-marinha/centro-de-coordenacao-de-estudos-em-sao-paulo-ccemsp.

[79] CAPES (Programas da Pós-Graduação Stricto Sensu No Brasil 2017, database, accessed August 29, 2019, https://dadosabertos.capes.gov.br/dataset/coleta-de-dados-programas-da-pos-graduacao-stricto-sensu-no-brasil-2017.

Besides graduate academic programs, CNEN promotes occasional training and capacity-building programs for its current personnel.[80] The commission also provides scholarships to undergraduate students developing initial scientific research on nuclear energy at its own institutes and at various universities nationwide.[81] Finally, CNEN is a member of the Latin American Network for Education in Nuclear Technology,[82] an IAEA initiative created in 2010 to preserve, promote, and share nuclear knowledge across Latin America.

Perhaps the single most striking feature of nuclear-related education in Brazil is the limited availability of training in the field of nuclear politics and policy making. In 1977, Pronuclear sponsored a course on “Nuclear Law” at the State University of Rio de Janeiro (UERJ), but the initiative did not survive, fizzling out after just one year.[83] Despite occasional training courses on nuclear norms, nonproliferation, and safeguards at CNEN,[84] there is no structured program for education in this particular field of expertise within the nuclear sector. Similarly, graduate and undergraduate programs in political science, international relations, and defense studies dedicate only marginal attention to nuclear-related issues in their curricula.

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[80] CNEN, *Relatório de Gestão 2017*, 176-81, 132-133; CNEN, *Relatório de Gestão 2018*, 118-119, 163-164.

[81] CNEN, *Relatório de Gestão do Exercício de 2018* (Rio de Janeiro, 2019), 94-95. As of 2018, the list included, for example, the Center for the Development of Nuclear Technology (CDTN), *Faculdade Pequeno Príncipe*, the Institute of Nuclear Engineering (IEN), the Energy and Nuclear Research Institute (IPEN), the Institute for Radiation Protection and Dosimetry (IRD), the Pontifical Catholic University of Goiás, the State University of Rio de Janeiro (UERJ), the Fluminense Federal University (UFF), the Federal University of Minas Gerais (UFMG), the Federal University of Pernambuco / Regional Center of Nuclear Sciences (Northeast), the Federal University of Rio Grande do Sul (UFRGS), the Federal University of Rio de Janeiro (UFRJ), the Federal University of Sergipe (UFS), and the University of São Paulo (USP).

[82] For more information, see “Latin American Network for Education in Nuclear Technology”, accessed August 29, 2019, https://www.lanentweb.org/en.

[83] Schmiedecke, “O Pronuclear (1976-1986) e a Formação de Recursos Humanos para a Área de Energia Nuclear no Brasil,” 71.

[84] CNEN, *Relatório de Gestão 2016*, 61; CNEN, *Relatório de Gestão 2017*, 64, 134.

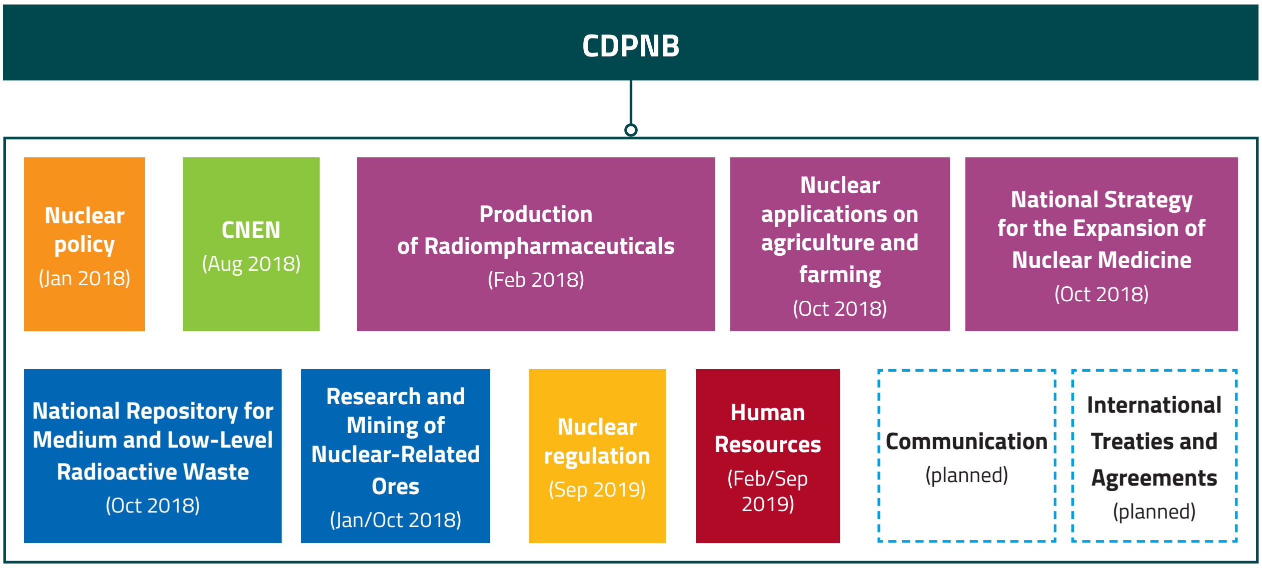
MAJOR PLAYERS IN THE BRAZILIAN NUCLEAR SECTOR

INSTITUTIONAL SECURITY CABINET

Brazil's Institutional Security Cabinet (GSI) acts as the president's coordinating body and a focal point within the government for security, intelligence, cyber operations, nuclear policy, and sensitive issues in foreign relations. In the system of Brazilian institutions, the GSI is akin to the National Security Council in the United States. For the past few years, presidents have appointed four-star generals to head the GSI.

The oversight of nuclear policy within the GSI was transformed in 2017, with a view to modernize existing processes in Brazil. More specifically, the previously established[85] Committee for the Development of the Brazilian Nuclear Program (CDPNB or Nuclear Committee) has been empowered through the creation of a permanent full committee and the setting up of several thematic technical groups as illustrated in Figure 4. The Navy admiral commanding the Secretariat for Systems Coordination at the GSI has been appointed to oversee the policy process.[86]

Figure 4: The Nuclear Committee's technical groups (2018-2019)



Source: See table 5 below.

[85] Decreto de 2 de Julho de 2008, *Presidência da República*, July 2, 2008.

[86] Decreto de 22 de Junho de 2017, *Presidência da República*, June 22, 2017; GSI, Portaria nº 118, de 19 de outubro de 2017, *Diário Oficial da União*, October 23, 2017; GSI, Portaria nº 128, de 29 de novembro de 2017, *Diário Oficial da União*, November 30, 2017; GSI, Resolução GSI/PR nº 1, de 18 de outubro de 2017, *Diário Oficial da União*, October 19, 2017; Decreto nº 9.828, de 10 de junho de 2019, *Diário Oficial da União*, June 11, 2019.

Table 5 describes the goals and expected results of the thematic technical groups of the Nuclear Committee, which have been set up in the last year or so with a view to developing focused discussions on specific issues and challenges pertaining to the nuclear sector.

Table 5: Goals and expected results of the Nuclear Committee's technical groups

GENERAL GUIDELINES		
Technical Group	**Goal**	**Expected Results**
Nuclear Policy[87]	To draft a revision of Brazil's nuclear policy	Brazilian Nuclear Policy document. Concluded. Document approved in December 2018.
NUCLEAR REGULATION		
Technical Group	**Goal**	**Expected Results**
CNEN[88]	To present actions necessary to separate CNEN's regulatory authority from its promotional activities in the nuclear sector	A proposal for a legal act to create a regulatory structure of norms, licenses, authorizations, regulation, and monitoring of the nuclear sector. Concluded. In May 2019, the committee's plenary session decided to separate CNEN's regulatory authority from its promotional activities and place them in a new institution. (See "Nuclear Regulation" in "2 - Governance and Accountability.")
Nuclear Regulation[89]	To make the regulatory framework of the nuclear sector more dynamic	A report containing guidelines and goals to make the regulatory framework of the nuclear sector more dynamic. Expected submission: March 2020.
NUCLEAR FUEL CYCLE		
Technical Group	**Goal**	**Expected Results**
Research and Mining of Nuclear Ores (1)[90]	To assess the loosening of the state monopoly over research and mining of nuclear ores	A report containing proposals of norms for the loosening of the state monopoly. Concluded. (See "Private Investment" in "2 - Governance and Accountability.")
Research and Mining of Nuclear-Related Ores (2)[91]	To stimulate research and mining of nuclear-related ores	A report containing a strategy to stimulate the nuclear mining sector, including proposals to change related normative acts. Expected submission: October 2019.[92]

87 GSI, Resolução GSI/CDPNB nº 2, de 11 de janeiro de 2018, *Diário Oficial da União*, January 16, 2018; GSI, Portaria GSI nº2, de 16 de janeiro de 2018, *Diário Oficial da União*, January 17, 2018; GSI, Resolução GSI nº 7, de 14 de junho de 2018, de *Diário Oficial da União*, June 15, 2018.

88 GSI, Resolução GSI/CDPNB no 8, de 22 de agosto de 2018, *Diário Oficial da União*, August 23 2018; GSI, Portaria GSI nº 70, de 30 de agosto de 2018, *Diário Oficial da União*, August 31, 2018.

89 GSI, Resolução GSI/CDPNB nº 15, de 27 de setembro de 2019, *Diário Oficial da União*, September 30, 2019.

90 GSI, Resolução GSI nº 3, de 11 de janeiro de 2018, *Diário Oficial da União*, January 16, 2018; GSI, Portaria GSI/PR nº3, de 16 de Janeiro de 2018, *Diário Oficial da União*, January 17, 2018.

91 GSI, Resolução GSI nº 9, de 2 de Outubro de 2018, *Diário Oficial da União*, October 3, 2018; GSI, Portaria GSI/PR nº 84, de 2 de Outubro de 2018, *Diário Oficial da União*, October 3, 2018; GSI, Portaria GSI nº 41, de 28 de Março de 2019, *Diário Oficial da União*, April 1, 2019.

92 GSI, Resolução GSI nº 3, de 28 de Março de 2019, *Diário Oficial da União*, April 1, 2019.

NUCLEAR FUEL CYCLE		
Technical Group	**Goal**	**Expected Results**
National Repository for Low- and Medium-Level Radioactive Waste (RBMN)[93]	To establish guidelines and goals for the development of the National Repository for Low- and Medium-Level Radioactive Waste	A technical report containing guidelines and goals for the development of the National Repository for Low- and Medium-Level Radioactive Waste. Expected submission: October 2019.[94]
APPLICATIONS OF NUCLEAR ENERGY		
Technical Group	**Goal**	**Expected Results**
Production of Radiopharmaceuticals[95]	To assess the loosening of the state monopoly over the production of radiopharmaceuticals	A report containing proposals for a change of legal norms and normative acts on the matter. Concluded.
Nuclear Applications in Agriculture and Farming[96]	To stimulate application of nuclear technology in agriculture and farming	A technical report containing an analysis of potential applications of nuclear technology in agriculture and farming. Expected submission: December 2019.
National Strategy for the Expansion of Nuclear Medicine[97]	To develop the National Strategy for the Expansion of Nuclear Medicine	A proposal for the National Strategy for the Expansion of Nuclear Medicine. Expected submission: October 2019.[98]
CAPACITY BUILDING		
Technical Group	**Goal**	**Expected Results**
Human Resources (1)[99]	To stimulate continuous capacity building in the nuclear sector	A technical report containing guidelines and goals for stimulating capacity building in the nuclear sector. Expected submission: September 2019.
Human Resources (2)[100]	To stimulate capacity building in the nuclear sector	A report containing guidelines and goals for fostering a scientific and technological network in the nuclear sector in order to stimulate continuous capacity building in the nuclear sector. Expected submission March 2020.

Source: *Diário Oficial da União*. See footnotes.

93 GSI, Resolução GSI/CDPNB nº 9, de 2 de Outubro de 2018, *Diário Oficial da União*, October 30, 2018. GSI, Portaria GSI nº 92, de 29 de Outubro de 2018, *Diário Oficial da União*, October 30, 2018.

94 GSI, Resolução GSI/CDPNB nº 5, de 18 de Abril de 2019, *Diário Oficial da União*, April 24, 2019.; GSI, Retificação, *Diário Oficial da União*, April 25, 2019.

95 GSI, Resolução GSI nº 4, de 2 de fevereiro de 2018, *Diário Oficial da União*, February 5, 2018; GSI, Portaria GSI nº 7, de 5 fevereiro de 2018, *Diário Oficial da União*, February 7, 2018; GSI, Resolução GSI nº 6, de 4 de junho de 2018, *Diário Oficial da União*, June 5, 2018.

96 GSI, Resolução GSI/CDPNB nº 12, de 8 de novembro de 2018, *Diário Oficial da União*, November 9, 2018., GSI, Resolução GSI/CDPNB nº 6, de 6 de maio de 2019, *Diário Oficial da União*, May 8, 2019.

97 GSI, Resolução GSI/CDPNB nº 10, de 23 de outubro de 2018, *Diário Oficial da União*, October 24, 2018; GSI, Portaria nº 89, de 23 de outubro de 2018, *Diário Oficial da União*, October 24, 2018.

98 GSI, Resolução PR/GSI/CDPNB nº 5, de 18 de abril de 2019, *Diário Oficial da União*, April 24, 2019.

99 GSI, Resolução GSI/PR nº 1, de 13 de Fevereiro de 2019, *Diário Oficial da União*, February 15, 2019. GSI, Portaria GSI/CDPNB nº 21, de 13 de fevereiro de 2019, *Diário Oficial da União*, February 15, 2019.

100 GSI, Resolução GSI/CDPNB nº 12, de 4 de setembro de 2019, *Diário Oficial da União*, September 6, 2019.

The Committee also plans to create at least two new technical groups to assess the status of Brazil's international treaties and agreements on nuclear energy and to strengthen the communication strategy in the nuclear sector, respectively.[101]

In December of 2018, the CDPNB completed the new Brazilian Nuclear Policy document, signed by President Michel Temer days before he left office. The officials in the new Bolsonaro administration have thus far reassured interlocutors that they would maintain the document as it was and would retain the committee's working groups with a view to implementing the various recommendations in the course of 2019 and beyond.

It is worth noting that the GSI is also responsible for the strategic dimension of nuclear safety and security nationwide through Sipron.[102] In practice, this body plans and coordinates emergency activities and has oversight responsibilities over the protection of individuals who operate nuclear facilities and handle nuclear materials and, more broadly, over the population, the environment, and nuclear facilities and materials themselves.[103] It also coordinates emergency drills across Brazil's nuclear facilities. Various federal and state authorities charged with preserving the integrity, invulnerability and protection of nuclear materials, facilities, knowledge, and technology participate in Sipron meetings. When meetings focus on emergency preparedness, and in the case of actual emergencies, Sipron invites municipal authorities as well.

These competencies do not overlap with CNEN's regulatory authority, which develops and issues the national norms on nuclear security and safety, performs nuclear licensing, and conducts periodic inspections to verify the compliance with the established best practices in safety and security. Neither do they overlap with nuclear operators' "prime responsibility" over the safety and security of daily routines at nuclear facilities.[104] (See "Nuclear Safety and Security" in "2 - Governance and Accountability.")

For the past 10 years, the military has maintained the leadership of Sipron and will most likely continue to do so under the Bolsonaro administration.[105]

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101 "GSI e representantes da indústria alimentícia se reúnem, no IPEN, para debater uso da radiação de alimentos", IPEN, August 7, 2019, https://www.ipen.br/portal_por/portal/interna.php?secao_id=38&campo=12604.

102 "Sipron – Histórico", GSI, accessed August 29, 2019, http://www.gsi.gov.br/sipron-1/historico.

103 Lei No. 12.731, de 21 de Novembro de 2012, *Diário Oficial da União*, November 22, 2012; Decreto No. 9.600, de 5 de Dezembro de 2018, *Diário Oficial da União*, December 6, 2018; Decreto No. 9.668, de 2 de Janeiro de 2019, *Presidência da República*, January 2, 2019.

104 IAEA, Fundamental Safety Principles (2006), https://www-pub.iaea.org/MTCD/publications/PDF/Pub1273_web.pdf ; IAEA, Objective and Essential Elements of a State's Nuclear Security Regime (2013), https://www.iaea.org/publications/10353/objective-and-essential-elements-of-a-states-nuclear-security-regime ; IAEA, Convention on Nuclear Safety, INFCIRC/449 (June 17, 1994), art. 9.

105 Decreto No. 9.668, de 2 de Janeiro de 2019, *Presidência da República*, January 2, 2019.

THE BRAZILIAN NAVY

GENERAL DIRECTORATE FOR THE NAVY'S NUCLEAR AND TECHNOLOGICAL DEVELOPMENT

Since 2016,[106] the General Directorate for the Navy's Nuclear and Technological Development (DGDNTM) has acted as the national naval nuclear authority under the Navy Command, exercising executive command over Navy nuclear policies and activities.[107] More specifically, the General Directorate has responsibility over the Navy's nuclear program, including (a) design, construction, commissioning, operation, and maintenance of PWRs; (b) development and operation of the nuclear fuel cycle (known as the Navy's Nuclear Program - PNM); and (c) the Navy's submarine program (Prosub), a three-part endeavor comprising the construction of four conventional submarines and one nuclear-powered submarine, besides the supporting infrastructure. Currently, the General Directorate is also involved with regulations, nuclear-safety inspections, and quality controls for the nuclear-powered submarine project.

NAVY'S TECHNOLOGICAL CENTER IN SÃO PAULO

The Navy's Technological Center in São Paulo (CTMSP) coordinates on-site implementation of the Navy's nuclear program within the remit of the General Directorate described above. More specifically, it runs existing Navy nuclear projects through its Directorate for the Navy's Nuclear Development and controls nuclear facilities in operation through the Nuclear Industrial Center of Aramar (CINA). As far as the nuclear fuel cycle is concerned, CTMSP operates uranium enrichment and fuel fabrication facilities on a laboratory scale to fulfill the Navy's needs in nuclear research and development activities. CTMSP houses the Laboratory for Isotopic Enrichment, which operates regularly at enrichment levels up to 5%. Occasionally, it enriches uranium to a level of 19.9% U-235 for use in research reactors run by CNEN. In the future, one of the cascades will provide enriched uranium exclusively to the RMB. Both the laboratories for isotopic enrichment and fuel fabrication are housed at Aramar and are subject to the CINA's command. The Center is about to commission and operate the Pilot Plant of Uranium Hexafluoride for uranium conversion also at Aramar. While CTMSP is not involved in uranium mining or milling (both under INB's purview), it will in the future be responsible for converting U_3O_8 (yellowcake) into UF_6 gas, enriching uranium, reconverting the UF_6 into uranium dioxide (UO_2) feedstock for fuel fabrication, and fabricating nuclear fuel pellets to be used as nuclear fuel for the propulsion reactor

[106] The directorate results from the reform process the Navy's governance for science and technology has gone through since the late 2000s. In 2008, the Directorate's predecessor – the Secretariat for Science, Technology, and Innovation – was created to centralize all research and development activities of the Brazilian Navy under a single structure. In 2012, the Secretariat acquired the status of a directorate, but the last reform, which shaped the current form of the Directorate, happened in 2016, when the Secretariat was renamed as the DGDNTM and incorporated both the Prosub Coordination (Cogesn) and the Navy's Nuclear Program – the former had been under the Navy's General Directorate of Materials – under the same institutional framework. "DGDNTM – Histórico", DGDNTM – Marinha do Brasil, accessed August 29, 2019, https://www.marinha.mil.br/dgdntm/node/49.

[107] Decreto No. 8.900, de 10 de Novembro de 2016, *Diário Oficial da União*, November 11, 2016.

in the submarine. CTMSP provides logistical support for the submarine project, and its Laboratory for Tests of Propulsion Equipment runs complementary tests on propulsion.

The Center oversees the specialized brigade on nuclear, biological, chemical, and radiological defense in charge of safety and security response at Aramar. Moreover, its Radioecological Laboratory works on environmental protection of the Center's laboratory facilities.

All the CTMSP facilities involved in the nuclear fuel cycle are subject to the IAEA's and ABACC's comprehensive safeguards, CNEN's nuclear regulatory authority, and the Brazilian Institute of Environment and Renewable Natural Resources' (Ibama's) environmental regulation and monitoring. Since the Navy owns the uranium enrichment technology, CTMSP leases enrichment to INB (for commercial purposes).[108]

In the reactor sector, CTMSP is responsible for all the R&D and construction of PWRs, especially those designed for propulsion purposes. There are plans in place to produce small modular reactors for power production in the future. Currently, the Center focuses on finishing the construction and commissioning of the reactor prototype to simulate electrical and thermal power conditions for the PWR in the nuclear submarine at Aramar (Labgene).[109]

The Labgene building is based on a "safeguards by design" model and will remain subject to IAEA and ABACC safeguards inspections and the regulatory authority of both CNEN and Ibama when it is completed.

The Center also provides training to military engineers through its unit at the University of São Paulo.[110]

GENERAL COORDINATION OF THE PROGRAM FOR THE DEVELOPMENT OF THE NUCLEAR-POWERED SUBMARINE

Third-party foreign and private national companies carry out construction projects for Prosub. To oversee the contracts and to manage and coordinate the project, in 2008 the Navy created the General Coordination of the Program for the Development of the Nuclear-Powered Submarine (Cogesn), which was incorporated into the DGDNTM's structure in 2016.

The French company Naval Group (formerly known as DCNS) is the main technology provider for the nonnuclear components in the submarines. More specifically, the Naval Group has signed several contracts with the Navy to design, build, operate, and maintain the submarines; to supply nonnuclear materials for the fabrication, construction, and delivery of the nuclear-powered submarine (including secondary

[108] "Missão", CTMSP – Marinha do Brasil, acessed August 29, 2019, https://www.marinha.mil.br/ctmsp/missao , it. 5.

[109] Private construction firms sign third-party commercial contracts with the Navy. "Missão", CTMSP – Marinha do Brasil, acessed August 29, 2019, https://www.marinha.mil.br/ctmsp/missao , it. 5.

[110] "Centro de Coordenação de Estudos em São Paulo (CCEMSP)", Brasil – Ministério da Defesa, accessed August 29, 2019, https://www.defesa.gov.br/ensino-e-pesquisa/instituicoes-de-ensino-militar/instituicoes-de-ensino-e-pesquisa-vinculadas-a-marinha/centro-de-coordenacao-de-estudos-em-sao-paulo-ccemsp.

systems of the propulsion engines); and to provide torpedoes and countermeasures.[111]

Cooperation with France does not include any technical assistance on the nuclear portion of the nuclear-powered submarine. In fact, the nuclear propulsion reactor and its primary system is a black box. For personnel who do not have the proper authorization, access is limited by a demarcated "redline." The Center for the Development of Submarines (CDS) housed at CTMSP is in charge of the detailed projects for the nuclear submarine. Besides developing Labgene, CTMSP is also building the propulsion reactor, whose heavy equipment is provided by Nuclep.[112]

The Navy has signed commercial contracts with two private, purpose-specific consortia on a public-private partnership under the name Itaguaí Naval Constructions (ICN) and Sepetiba Bay Consortium (CBS). At ICN, the two private conglomerates involved are the Naval Group and the Brazilian construction firm Odebrecht, which hold 59% and 41% of the shares, respectively. The Navy holds so-called "golden share" veto power exercised through Emgepron, its state defense company for naval projects. ICN currently carries out the projects at Unidade de Fabricação de Estruturas Metálicas (UFEM) and the shipyard in Itaguaí.

In turn, CBS plans, coordinates, and manages contracts. Odebrecht and the Naval Group hold equal shares of the company's capital (50%).

Odebrecht alone was hired for the construction of all naval and industrial infrastructure associated with the Prosub project.

The responsibility for the submarines once they are commissioned will migrate to Brazil's Submarine Command Force, which will also be responsible for (re)fueling and waste management (in the case of the nuclear-powered submarine).

NAVAL AGENCY FOR NUCLEAR SAFETY AND QUALITY

The Naval Agency for Nuclear Safety and Quality (AgNSNQ) completes the institutional framework of the DGDNTM. Created in 2018, the agency acts as the technical, executive advisory body to the naval nuclear authority on matters pertaining to the safety regulation and monitoring of naval vessels with nuclear propulsion (including emergency plans) as well as their quality and metrological standardization. It follows an "integrated licensing" approach that combines norms, codes, and protocols concerning nuclear safety and radiological protection with naval doctrines and regulations. The agency does not formally deal with nuclear security or safeguards, but by virtue of having a say on access to submarines, it will have a role in these matters. In the future, the agency is expected to host the Center for Response to Naval Nuclear and Radiological Emergencies.

The agency's work is still in its early stages. So far, it has been involved in the elaboration of normative instructions on nuclear safety and radiological protection in combination

[111] For a table of contracts, see TCU, Acórdão 2952/2013, Processo TC 005.910/2011-0, Relator: Min. Raimundo Carreiro, 30.10.2013, 25, *Diário Oficial da União* [D.O.U.], 30.09.2014, 104 (Braz.).

[112] Cogesn, *Relatório de Gestão do Exercício de 2017* (Rio de Janeiro, 2018), 30.

with norms and protocols for design, construction, maintenance, operational doctrines, and deployment of the nuclear-powered submarine. On the nuclear side, the agency follows regulations from CNEN and the IAEA, and draws upon the guidelines of the US Nuclear Regulatory Commission and France's Nuclear Safety Authority and Defense Nuclear Safety Authority. One particular challenge is the fact that under its statute, the IAEA may not engage in cooperation pertaining to a military application of nuclear technology. Consequently, safety regulations for naval nuclear reactors do not exist in the IAEA's portfolio of best practices.

In the naval segment, the guiding examples are the ones already applied to other naval vessels by the Brazilian Navy and those implemented by the General Directorate of Armament (France), the Naval Group (France), Bureau Veritas (international), and Det Norske Veritas (Norway). In this regard, the AgNSNQ has dedicated special attention to norms and protocols in the following areas: regulation and licensing, management systems, radiation protection and safety of radioactive sources, safety assessments, decommissioning and radioactive waste management, preparation for nuclear and radioactive emergency response, naval nuclear propulsion plant, transportation of radioactive materials, diving safety, fire safety, pyrotechnic and armament safety, operational and maintenance safety, and occupational and workplace safety.

With this new structure, the Navy is establishing a new footprint in the nuclear sector but it is creating its own field of competence and expertise – naval nuclear regulation – which is not meant to overlap with CNEN's work.

Before AgNSNQ was created, CNEN was the only actor involved in nuclear regulation and inspection nationwide. With this new structure, the Navy is establishing a new footprint in the nuclear sector but it is creating its own field of competence and expertise – naval nuclear regulation – which is not meant to overlap with CNEN's work. A technical cooperation agreement between the two regulatory actors sets the limits of each one's authority.

BLUE AMAZON DEFENSE TECHNOLOGIES S.A.

Blue Amazon Defense Technologies S.A. (Amazul) is a state company under the Navy Command created in 2013 to (a) facilitate the hiring of professional and support personnel for the submarine program (hiring laws for state employees being cumbersome and costly), (b) consult on issues of nuclear licensing and other technical services, (c) provide project management, and (d) secure the human resources to operate facilities.[113] It employed over 1,800 employees as of late 2018.[114] Since its inception,

[113] "Sobre a Amazul", Amazul, accessed August 29, 2019, https://www.marinha.mil.br/amazul/empresa/sobre-a-amazul.

[114] Amazul, *Relatório de Gestão 2018*, 2019, 58.

Amazul has expanded its original remit to include a range of nonmilitary projects in the nuclear sector, such as the provision of personnel and technical expertise for the RBM. Amazul's headquarters are in São Paulo, but its staff is deployed across various locations, especially in the military nuclear sector. The Navy Command appoints the company's director; acting or retired Navy admirals compose the company's directorship, while civilian representatives of the nuclear sector populate the Board of Administration.

NATIONAL NUCLEAR ENERGY COMMISSION

Created in 1956, the National Nuclear Energy Commission (CNEN) is the most powerful actor in the civilian nuclear sector. As a semiautonomous federal agency, the Commission enjoys managerial independence to execute its mandate, whereas politically and financially it is subordinate to the Ministry of Science, Technology, Innovations, and Communications. Historically, CNEN's duties included development and execution of the country's nuclear policy, but over the years, the institution accumulated a series of additional responsibilities. In Brazil, the nuclear sector does not have a separate, exclusively regulatory authority. CNEN acts as the implementing agency of some activities in the nuclear sector, and at the same time, it serves as the national nuclear regulatory authority. (See "Nuclear Regulation" in "2 - Governance and Accountability.")

> **Historically, CNEN's duties included development and execution of the country's nuclear policy, but over the years, the institution accumulated a series of additional responsibilities.**

As an executor of nuclear activities, CNEN carries out R&D activities, provides technological services, and produces radiological and nuclear products such as radioisotopes. Most of these activities are performed by the Commission's research institutes (IPEN, IEN, IRD, CRCN, CDTN), which have been gradually incorporated into its managerial structure.

As a regulator, it sets the standards for nuclear safety and security in the country and oversees all key nuclear and radiological facilities. CNEN also cooperates with ABACC and the IAEA in implementing nuclear safeguards. In 2017, CNEN participated in 57 inspections related to the control and accounting of nuclear materials.[115]

CNEN has been politically associated with the Navy. Its very creation was a maneuver to rebalance the political power of the armed forces in the 1970s, and its first president was a former Navy officer who advised Admiral Álvaro Alberto, the individual instrumental in creating the Brazilian nuclear program.[116] CNEN's research institutes, especially IPEN, have closely cooperated whit the Navy in R&D projects, including in those pertaining

115 CNEN, *Relatório de Gestão 2017*, 63.

116 Ana Maria Ribeiro de Andrade and Tatiane Lopes dos Santos, "A dinâmica política da criação da Comissão Nacional de Energia Nuclear, 1956-1960, *Bol. Mus. Para. Emílio Goeldi. Cienc. Hum.* 8 (2013): 113-128.

to the nuclear fuel cycle and nuclear reactors. (See "Civil-Military Relations" in "2 - Governance and Accountability.") Even though historical links with the Navy remain strong, leadership positions at CNEN are also affected by partisan political groups.

CNEN is one of the largest institutions in the nuclear sector in terms of human resources at its disposal. Yet, over the last few years, staff population has significantly fallen. (See "Human Resources and Education" in "1 - Capabilities and Major Players" and in "2 - Governance and Accountability.")

ENERGY AND NUCLEAR RESEARCH INSTITUTE

The Energy and Nuclear Research Institute (IPEN) stands out among CNEN's institutes as Brazil's primary nuclear research institution. Established in 1956 as the Institute for Atomic Energy, it serves several essential functions. IPEN hosts two research reactors and produces radioisotopes for a variety of research, health, and nuclear industry uses. Its staff researches a wide range of topics in nuclear and related disciplines. IPEN also serves an important educational function; students from the University of São Paulo and other universities use its facilities to conduct research and experiments.

Nuclear medicine relies on IPEN for radiopharmaceutical products critical in diagnosing and treating a range of ailments, especially cancer. IPEN produces 38 radiopharmaceuticals that are used in 1.6 million medical procedures a year at 430 hospitals and clinics around the country.[117]

Constitutional Amendment 49 partially lifted the state monopoly over the production of radioisotopes having a half-life no longer than two hours, but IPEN remains the sole producer of some radioisotopes, a situation that results in supply vulnerabilities on some occasions, especially in the production of technetium-99 (See "The Brazilian Multipurpose Reactor" in "1 - Capabilities and Major Players". See also "Private Investment" in "2 - Governance and Accountability")

IPEN operates two of the four Brazilian nuclear research reactors. The IEA-R1 reactor is the only research reactor in the country with a sufficient power level to be used for a wide range of research in nuclear and related sciences. It is also used for production of radioisotopes for medical and other applications. Together with the Navy, IPEN developed the IPEN-MB-01 reactor, which is mostly used to measure reactor physics parameters. (See "Research Reactors" in "1 - Capabilities and Major Players.") IPEN assembles its own fuel elements.

In addition to two nuclear research reactors, IPEN, on behalf of CNEN, and in cooperation with the Navy, participates in the design and development of the Brazilian Multipurpose Reactor (RMB). (See "The Brazilian Multipurpose Reactor" in "1 - Capabilities and Major Players")

IPEN's reactors and fissile materials are subject to nuclear safeguards carried out by ABACC and the IAEA, while the production of radioisotopes is subject to the rules

117 CNEN, *Relatório de Gestão 2016*, 29-39.

and standards of Brazilian Health Regulatory Agency (Anvisa). Moreover, the institute must comply with the nuclear and environmental norms set by CNEN and Ibama, respectively. Finally, the institute is subject to the state controls of TCU and the Office of the Comptroller General (CGU).

As a facility that works with nuclear and radioactive material, IPEN follows norms and regulations on nuclear safety and security set by CNEN. In recent years, IPEN has given increased attention to the strengthening of nuclear security practices and culture. IPEN regularly hosts workshops and training on nuclear safety and security, often with the participation of the IAEA representatives and international partners.

IPEN falls under the auspices of CNEN and through CNEN, depends on the Ministry of Science, Technology, Innovations, and Communications for its budget allocation.

About half of CNEN's overall budget for human resources is allocated to IPEN and around 80 percent of CNEN's budget for production (for example, production of radioisotopes) is allocated to IPEN. IPEN's production generates BRL 122 million, which covers the Institute's costs, except for salaries. But since CNEN does not retain its revenues, all generated profit goes to the federal budget without any guarantee that it will be reflected in IPEN's budget. (See "Private Investment" in "2 - Governance and Accountability.")

ELETROBRAS THERMONUCLEAR S.A.

Eletrobras Thermonuclear S.A. (Eletronuclear) operates the existing nuclear power plants and oversees construction of new ones in Brazil.

Eletronuclear is a subsidiary of state-owned Eletrobras, Brazil's major holding company for the generation and transmission of electricity. Eletrobras holds 99.91% of Eletronuclear's shares. The national government retains around 65% of Eletrobras's shares and exercises control over the company. The Ministry of Mines and Energy is the supervising authority of Eletrobras and, consequently, of Eletronuclear.[118]

Prior to nuclear industry reforms in the 1980s and 1990s, the Brazilian nuclear power sector was fragmented. State-owned Nuclebrás's subsidiaries (Nuclen and afterwards, Nucon) and the German firm KWU/Siemens collaborated in project development and construction of nuclear power plants, while the company Furnas/Eletrobras carried out managerial and business activities relating to nuclear power generation, including the financing and signing of contracts and the operation of the nuclear power plants. After the restructuring of Nuclebrás in the late 1990s, Nuclen and the nuclear segment of Furnas formed a new subsidiary, Eletronuclear. Created in 1997, this company combined the predecessor firms' responsibilities under a single governance structure within Eletrobras.[119]

According to the Brazilian Constitution, nuclear power generation is the exclusive

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118 Eletronuclear, *Relatório de Gestão 2017* (Rio de Janeiro, 2018), 27-33.

119 Dalaqua, "Átomos e Democracia no Brasil", 97-174; Tatiana Coutto, "O papel das comissões parlamentares de inquérito na política nuclear brasileira" in *Ciência no Brasil contemporâneo*, ed. Ana Lúcia Villas-Bôas and Marta de Almeida (Rio de Janeiro: Museu de Astronomia e Ciências Afins, 2014), 186-213.

domain of the federal government. This means that the federal government delegates the operation of the two existing nuclear power plants to Eletronuclear, which produces energy from nuclear sources and owns the profits from selling it to the distribution companies. Eletronuclear is not in charge of energy transmission, even though its holding company (Eletrobras) is a major actor in this area nationwide. In fact, energy produced by Angra-1 and Angra-2 is transmitted through one of Eletrobras' transmission systems, which delivers it to the distribution companies.[120] The National Operator of the Electric System, a private association, manages and coordinates the National Interconnected System of energy generation, transmission, and distribution.[121]

Besides routine operations, Eletronuclear is responsible for the upgrade of Angra-1 and Angra-2 equipment to increase operational performance of the units, the adoption of safety and security policies reflecting international best practices (for example, post-Fukushima measures), and responses to the demands location-specific needs (for example, the increase in local violent criminal activity near the Angra site during the years 2017-2019). (See "Nuclear Safety and Security" in "2 - Governance and Accountability.") Finally, Eletronuclear serves as the main training center for future operators of nuclear power plants in the country.

In the end of 2019, the Angra-3 project remained frozen, as it has been since 2015, due to a lack of financing and a corruption investigation involving CEOs of Eletronuclear and private companies.

Operation of the nuclear power plants depends on the nuclear fuel supplied by INB. The IAEA, ABACC, and CNEN carry out nonproliferation-related inspections of all of Eletronuclear's facilities handling nuclear and radioactive materials.[122] Moreover, Eletronuclear must comply with licensing and operation rules set by the national nuclear and environmental regulatory authorities (CNEN and Ibama, respectively), and, as a state-owned company, is subject to external controls by CGU and TCU. Since no decision has been made on the final disposition of spent fuel, Eletronuclear hosts and manages pools for cooling and storage of these materials in situ at the Angra dos Reis facilities. The company has also been working to expand its facilities for dry storage of spent fuel as well as low- and medium-level radioactive waste. (See "Radioactive Waste and Spent Fuel Management" in "2 - Governance and Accountability.")

Besides operating existing nuclear power plants, Eletronuclear oversees the construction of new ones. Eletronuclear is in charge of signing commercial contracts with private companies for the provision of related products and services,

[120] Eletronuclear, *Relatório de Gestão 2017*, 12-18.

[121] "O que é ONS", ONS, accessed August 29, 2019, http://www.ons.org.br/paginas/sobre-o-ons/o-que-e-ons.

[122] CNEN's regulations differentiates between "nuclear facilities" and "radioactive facilities"

which are financed by national development banks. In the end of 2019, the Angra-3 project remained frozen, as it has been since 2015, due to a lack of financing and a corruption investigation involving CEOs of Eletronuclear and private companies. (See “Corruption” in “2 - Governance and Accountability.”) These facts require a revision of the business model for the construction and operation of nuclear plants in order to accommodate the company’s current financial situation. (See “Private Investment” in “2 - Governance and Accountability.”) Most the company’s activities pertaining to Angra-3 concern the renegotiation of the business model and the search for new foreign partners, while finding technical and financial means to preserve the structures that had been already built and the materials and equipment that had been received. (See “Nuclear Safety and Security” in “2 - Governance and Accountability.”)

In addition to exercising political and administrative control over Eletrobras/ Eletronuclear, the Ministry of Mines and Energy is one of the key players in the decision-making process on national energy policy, including the nuclear power sector. The ministry relies on the advice and support from the Company for Energy Research, which prepares systematic studies and plans assessing the challenges and prospects for the energy sector in Brazil.[123] The minister of mines and energy presides over the National Council for Energy Policy, which advises the Office of the Presidency on matters regarding national energy policies (for example, tariffs and business models).[124] The regulatory agency – the National Electric Energy Agency – oversees the operation of companies in the entire power sector and sets the tariffs for the energy sector.[125]

NUCLEBRÁS HEAVY EQUIPMENT S.A.

Nuclebrás Heavy Equipment S.A. (Nuclep) is a state-owned company that produces heavy equipment used in the nuclear, naval, and oil industries. Established in 1975 with the initial goal of producing heavy-equipment components for nuclear power plants, the company eventually diversified its product line to include semisubmersible hulls for platforms used by Petrobras in oil production and submarine hulls for the Navy.[126] Most recently, it expanded its project portfolio, seeking partnerships with INB in the uranium enrichment process.[127]

Nuclep continues to hold a prominent position in the Brazilian nuclear industry and continuously expands its activities and workforce. (See “Human Resources and

123 “Quem somos”, EPE, accessed August 29, 2019, http://epe.gov.br/pt/a-epe/quem-somos.

124 “CNPE”, Brasil – Ministério de Minas e Energia, accessed August 29, 2019, http://www.mme.gov.br/web/guest/conselhos-e-comites/cnpe.

125 “A ANEEL”, ANEEL, accessed August 29, 2019, http://www.aneel.gov.br/a-aneel.

126 “The Company”, Nuclep, accessed August 29, 2019, http://www.nuclep.gov.br/en/company ; “Quem Somos”, Nuclep, accessed August 29, 2019, http://www.nuclep.gov.br/pt-br/linha-tempo.

127 “INB e Nuclep Firmam Parceria para Nacionalizar os Cilindros de Urânio”, INB, accessed August 29, 2019, http://www.inb.gov.br/Media-Center/Detalhe/Conteudo/inb-e-nuclep-firmam-parceira-para-nacionalizar-os-cilindros-de-uranio-4008/Origem/593.

Education" in "1 - Capabilities and Major Players.") It fabricates the components for the Angra-3 nuclear reactor (such as steam generators and condensers, accumulators, and pressurizers), the Labgene prototype reactor at CTMSP (for example, the pressure vessel and tanks), and the reactor and submarine hulls for the Prosub project.[128] Moreover, it provides technical assistance for the autoclaves and fabricates storage and transportation cylinders for UF_6 gas at INB facilities in Resende.[129] Nuclep might participate in the construction of the multipurpose reactor in the near future.[130]

Until 2019, CNEN held 99.9 percent of the company's shares and exerted significant influence on its Administration Council.[131] Yet, recent modifications to the institutional structure of Nuclep have introduced new dynamics into its governance. Nuclep was formerly linked to the Ministry of Science, Technology, Innovations, and Communications, but in January of 2019, in one of its first decrees, the new Bolsonaro administration transferred oversight over Nuclep to the Ministry of Mines and Energy.[132]

As a state-owned company, Nuclep remains dependent on the federal budget and is subject to the controls of TCU, CGU, and the new legislation for state companies.[133] Given the applications that Nuclep's products have in the nuclear sector, they are certified by CNEN, the national nuclear regulatory authority. They also go through certification by other nonnuclear quality-assurance institutions.[134] As a heavy-industry company, Nuclep does not handle nuclear materials and therefore is not subject to nuclear verification by CNEN, IAEA, or ABACC.

Nuclep has had a close relationship with the Navy thanks to its involvement in the naval submarine programs. In the context of Prosub, it builds submarine hulls and leases its space and facilities to the Navy's unit specializing in the fabrication of metallic structures (UFEM).[135] From an institutional perspective, the Navy exerts its influence through its authority to nominate a former Navy official for the position of Nuclep's director for industrial activity. (See "Civil-Military Relations" in "2 - Governance and Accountability") The company has also been susceptible to partisan appointments and politics in the national context and in the state of Rio de Janeiro. (See "Corruption" in "2 - Governance and Accountability.")

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128 Nuclep, *Relatório de Gestão 2017*, 22. "Energia Nuclear," Nuclep, accessed August 29, 2019, http://www.nuclep.gov.br/pt-br/energia-nuclear ; "Defesa", Nuclep, accessed August 29, 2019, http://www.nuclep.gov.br/pt-br/defesa.

129 "Nuclep Faz História Produzindo Cilindros para Armazenamento de Urânio", Nuclep, accessed August 29, 2019, http://www.nuclep.gov.br/pt-br/nuclepfazhistriaproduzindocilindrosparaarmazenamentodeurnio ; "Nuclep Assina Contrato com a INB", Nuclep, accessed August 29, 2019, http://www.nuclep.gov.br/pt-br/content/nuclep-assina-contrato-com-inb ; "Nuclep Entrega Quatro Cilindros 30B ao CTMSP", Nuclep, accessed August 29, 2019, http://www.nuclep.gov.br/pt-br/nuclepentregaquatrocilindros30baoctmsp-0.

130 Nuclep, *Relatório de Gestão 2017*, 16.

131 Ibid., 11, 22.

132 Felipe Macial, "Nuclep e INB Passam para o Ministério de Minas e Energia", EPBR, accessed August 29, 2019, https://epbr.com.br/nuclep-e-inb-passam-para-o-mme/.

133 Lei No. 13.303, de 30 de Junho de 2016, *Diário Oficial da União*, July 1, 2016.

134 "Certificações", Nuclep, accessed August 29, 2019, http://www.nuclep.gov.br/pt-br/certificacoes.

135 Consultations with Cogesn officials and staff in Itaguaí, Rio de Janeiro, April 11, 2018.

NUCLEAR INDUSTRIES OF BRAZIL

Nuclear Industries of Brazil (INB) is Brazil's state-owned company responsible for the production of nuclear fuel on an industrial scale.

INB resulted from the restructuring of Nuclebrás in 1988. In the process, most of Nuclebrás's subsidiaries were regrouped into INB's single structure, with the exceptions of Nuclen, whose responsibilities were incorporated by Eletronuclear, and Nuclep, which established a separate company for heavy nuclear components. INB's shares were transferred to CNEN, which held more than 99.9 percent of them until 2019. INB was administratively tied to the Ministry of Science, Technology, Innovations, and Communications until 2019.[136] In January 2019, the Bolsonaro administration transferred the oversight over INB to the Ministry of Mines and Energy.[137]

> **The Navy leases enrichment technology to INB under so-called "black box" conditions. This means that INB uses the technology but does not have access to the technology itself, which is proprietary and classified**

INB provides Angra's reactors with nuclear fuel.[138] To that end, the company carries out some stages of the nuclear fuel cycle and manages the purchase and allocation of foreign products and services to meet the national demand for nuclear fuel.

INB has mined and milled uranium in the Caetité region (Bahia) and plans to expand these activities to Santa Quitéria (Ceará). Work at Caetité stopped in 2014. INB is in the process of applying for licenses for new mines in both locations. In Brazil, nuclear safeguards do not apply to mining facilities.

INB carries out uranium enrichment and fuel fabrication at its facilities in Resende (Rio de Janeiro), which are subject to ABACC and IAEA safeguards. At the uranium enrichment stage, the company works closely with and depends on the Navy, which owns the enrichment technology. The Navy leases enrichment technology to INB under so-called "black box" conditions. This means that INB uses the technology but does not have access to the technology itself, which is proprietary and classified. INB also depends on the Navy for the acquisition of new enrichment centrifuges. (See "Civil-Military Relations" in "2 - Governance and Accountability.")

Despite carrying out most of the industrial processes of the fuel cycle, the company is not self-sufficient and cannot by itself fulfill the nuclear power plants' total demand for nuclear fuel. For uranium conversion, INB relies *exclusively* on foreign partners. Another bottleneck is uranium enrichment: INB is expanding centrifuge enrichment capacity

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[136] INB, *Relatório de Gestão 2017*, 17-20, 29.

[137] Felipe Macial, "Nuclep e INB Passam para o Ministério de Minas e Energia", EPBR, accessed August 29, 2019, https://epbr.com.br/nuclep-e-inb-passam-para-o-mme/.

[138] INB also provides IPEN with some components for fuel fabrication.

but has not reached the scale and capacity to meet the national demand for both uranium feedstock and uranium enrichment services. For this reason, the company must import enriched UF_6 from abroad and use it in the fabrication of nuclear fuel. Foreign companies also provide minor inputs throughout the entire nuclear industrial fuel cycle. (See “The Nuclear Fuel Cycle” in “1 - Capabilities and Major Players”)

INB exports UO_2 powder and some components used in the fabrication of fuel elements, provides engineering services to nuclear reactors, and mines heavy minerals.[139]

Currently, there are four priorities in the company’s business plan: (1) to restart mining and milling; (2) to pursue self-sufficiency by expanding enrichment capacity and installing conversion facilities; (3) to increase export of services and products; and (4) to reduce the dependence on financial inputs from the federal budget and eventually terminate them. (See “Private Investment” in “2 - Governance and Accountability”)

As a state-owned company, INB is subject to the controls of TCU and CGU and the legislation on state companies.[140] It must also comply with the requirements of nuclear and environmental regulations established by CNEN and Ibama, respectively.

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[139] INB, *Relatório de Gestão 2017*, 17.

[140] Lei No. 13.303, de 30 de Junho de 2016, *Diário Oficial da União*, July 1, 2016.

GOVERNANCE AND ACCOUNTABILITY

2

CIVIL-MILITARY RELATIONS

As Brazil's nuclear program unfolded, the military – and more specifically, the Navy – has gained, retained, and expanded its influence over the nuclear policy process. Confounding many observers, the growing reach of military influence in Brazilian nuclear politics coincided with ever-greater commitments to nonproliferation and the peaceful use of nuclear energy. This observation is consistent with conclusions in scholarly work that draws on troves of newly declassified documents. Documentary evidence demonstrates that Brazil's choice in the late 1970s to pursue naval nuclear propulsion as a flagship project to anchor broader technology acquisition and development efforts put to rest any previous talk in official circles of a nuclear-weapon option.[141] Yet, the ascent of the military as a dominant player in Brazil's nuclear sector raises the question of how much the military's position affects long-term Brazilian nuclear capabilities and intentions, and what types of dynamics ensue as military and civilian leaders negotiate the terms of their engagement in current nuclear policy.

The ascent of the military as a dominant player in Brazil's nuclear sector raises the question of how much the military's position affects long-term Brazilian nuclear capabilities and intentions, and what types of dynamics ensue as military and civilian leaders negotiate the terms of their engagement in current nuclear policy.

The issue of nuclear civil-military relations is vexing because it involves balancing two vital and potentially conflicting sets of priorities. On the one hand, the military has become the institutional home to nuclear R&D and a staunch advocate for nuclear power amid budget cuts and criticism from domestic and international actors. This is particularly significant for a sector that has not been economically viable and likely would have disappeared were it not for powerful supporters with easy access to public coffers. On the other hand, just as the military has protected and nurtured Brazil's nuclear industry, its growing role raises concern to whether the nuclear sector is governed through resilient democratic controls and

[141] Spektor, "The Evolution of Brazil's Nuclear Intentions"; Carlo Patti, *O Programa Nuclear Brasileiro: Uma História Oral*. Rio de Janeiro: Editora FGV, 2014.

appropriate transparency measures. There also have been fears that the acquisition of technological and industrial capabilities might someday give way to potential proliferation advocates within and around the armed forces. The Brazilian case highlights the degree to which civil-military relations shape the nuclear arena. In particular, the common question is, "Who controls the guardians?"

All over the world, critics of military involvement in sensitive policy areas, such as nuclear policy, point out the possibility that a parasitic military can drain society of its resources under the banner of fighting "the enemies of the state." Another concern is that military hegemony can involve the state in conflicts abroad that are contrary to society's interests or expressed will. There is concern as well over how far in a democracy the military will obey its civilian leaders and whether military cadres might end up using their power to resist civilian control. And, finally, in a global community marked by deep suspicions about the proliferation intentions of states even when they profess their commitments to the peaceful uses of nuclear energy, there is concern that military oversight may, in the future, prevent full implementation of global nonproliferation commitments.

This section surveys civil-military relations in Brazil's nuclear program today. The authors find that the hierarchy of de jure authority favors civilians over the military, but the underlying distribution of de facto power favors the military. This extends to flows of private investment in the nuclear sector, the regulation and control of nuclear power generation and distribution, the leasing of enrichment services, nuclear licensing, production of industrial equipment for the nuclear sector, production of radioisotopes, nuclear R&D generally, and the conduct of Brazil's nuclear diplomacy. Military involvement in nuclear policy has a long pedigree, with Navy officers being the main institutional entrepreneurs supporting the acquisition and development of nuclear technologies since the dawn of the nuclear era in Brazil.[142] From the outset, military officials have held managerial positions in CNEN,[143] and they were key players in Brazil's development of enrichment capabilities outside international safeguards in the 1980s. In the process, the Navy, in particular, came to dominate scientific innovation and managed to steer the nuclear program in the direction of nuclear propulsion first,[144] and more recently in the direction of radioisotope production.

This trend seems likely to continue under the new Bolsonaro administration. Thus, the current balance in civil-military relations has several implications for policy governance and democratic controls in Brazil's nuclear sector.

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142 Leandro da Silva Batista Pereira, "Vitória na Derrota: Álvaro Alberto e as Origens da Política Nuclear Brasileira" (master's thesis, FGV, 2013); Carlo Patti, "The Origins of the Brazilian Nuclear Programme 1951-1955," *Cold War History* 15, No. 3 (July 2015): 353-373.

143 Ana Maria Ribeiro de Andrade and Tatiane Lopes dos Santos, "A Dinâmica Política da Criação da Comissão Nacional de Energia Nuclear, 1956-1960," *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas* 8, No. 1 (April 2013): 113-128; Tatiane Lopes dos Santos, "Os Militares e a Política Nuclear Brasileira" (Power-point presentation, XIII Encontro de História Aupuh-Rio, Rio de Janeiro, August 4, 2008); Miguel Patrice Philippe Dhenin, "O Papel das Forças Armadas no Planejamento e na Implantação da Matriz Energética Brasileira: os Casos do Petróleo e da Energia Nuclear" (master's thesis, UFF, 2010).

144 Spektor, "The Evolution of Brazil's Nuclear Intentions"; Michael Barletta, "The Military Nuclear Program in Brazil" (working paper, Center for International Security and Arms Control, Stanford University, Stanford, 1997); Marly Motta, "As Peças do Quebra-Cabeça: Rex Nazaré e a Política Nuclear Brasileira," Revista de História Oral 13, No. 2 (2010): 115-135; João Roberto Martins Filho, "O Projeto do Submarino Nuclear Brasileiro," *Contexto Internacional* 33, No. 2 (December 2011): 277-314.

MEASURING THE BALANCE OF INFLUENCE BETWEEN CIVILIANS AND THE MILITARY

Military influence in policy is notoriously hard to measure. To assess it, in the case of the Brazilian nuclear sector, it is important to focus on those fields in which the military directly controls government action and in which it can shape the action without enjoying direct oversight. As demonstrated below, the Brazilian military has extensive institutional prerogatives over the conduct of nuclear policy, but it has also become a major source of expert advice and political support in Congress, as well as an advocate of nuclear power for businesses, professional politicians, and other interested parties in the nuclear field. Having built a position largely unchallenged as the main institutional pillar of the Brazilian nuclear program, the military has never struggled to get its views and preferences heard by the civilian leadership.

The consultations that the authors have held with nuclear stakeholders in Brazil over the course of the research indicate that civilian authorities made a conscious decision to delegate the bulk of nuclear policy to the military, which tends to be seen as a responsible stakeholder by actors across the political spectrum. Currently, levels of trust in the military role in nuclear policy are high, and there seems to be no detectable fear among civilians of current or future insubordination. Adding to the military's reputation as benign and efficient guardians of nuclear policy are several facts: vigorous leadership in the Navy with politically savvy commanders who seem to dominate nuclear policy debates; politicians and businesspeople who benefit from current nuclear policy and count on the military as major advocates for sustained budgets; a growing gap between the scientific expertise the military can mobilize and the dwindling of human resources in other parts of the nuclear sector; a civil society that has by and large ignored issues of nuclear policy; and general sympathy for the involvement of the military in the nuclear field by academics and the press.

The remainder of this section examines the various ways in which the military exerts influence over the nuclear policy process.

POLICY OVERSIGHT

As pointed out above, military actors are prominent players at the GSI, the coordinating body for nuclear policy within the Brazilian presidency.

Within the GSI, Navy officials are formally assigned to participate in and, in some cases, coordinate national nuclear policy making at high levels of the government. The scope of discussions extends beyond the matters concerning military applications of nuclear energy. President Bolsonaro will likely preserve the GSI's political prominence as a whole, including in nuclear policy making, under the command of General Augusto Heleno. As of 2019, no major changes in the political arrangements within the GSI appear to be likely. An Army general with political influence in Brasília commands the Cabinet and responds directly to the president, while thematic working groups and units within the cabinet are generally distributed among high-ranking officials in all three branches of the armed forces. More specifically, responsibility for nuclear safety and security falls under the purview of a Navy admiral. Navy officers also staff the GSI technical working groups. In 2017, the CDPNB (formerly placed within the office of the president's chief of staff) was relocated to the GSI, further entrenching the military in everyday management of the nuclear program.[145] Furthermore, officials with a Navy background are ubiquitous in the leadership positions in the bodies within the Brazilian administration that are represented in GSI committee meetings. These may include managers in policy areas as varied as uranium mining, production of radiopharmaceuticals and nuclear medicine, and nuclear applications in agriculture and farming.

Anecdotal evidence the authors collected in the course of their field research indicates that Navy officials within the GSI were pivotal in designing the new nuclear policy framework issued by President Temer and maintained by President Bolsonaro. As this report indicates elsewhere, the new framework regulates core aspects of nuclear policy that go well beyond the military components of the program. The authors have also learned that the Navy leadership was crucial in unlocking the funds for the RMB project, which nominally falls under the purview of the Ministry of Health. The Navy leaders have also shaped the conversation about the need to split CNEN's executive and regulatory functions and restore investment in education and capacity building in nuclear science.

URANIUM ENRICHMENT

The Navy holds full proprietary ownership over the "technology deployed in the design and fabrication of ultracentrifuges" nationwide.[146] The ownership makes the Navy the sole provider of ultracentrifuges cascades in the country. In practical terms, it means that the Navy leases enrichment services to other actors in the nuclear sector. The military retains control over the ultracentrifuge cascade project, assembly and commissioning, fabrication of related equipment and materials, the training of personnel, and the sharing of licensing information.[147]

There are strict controls to prevent access to information related to the "design and fabrication of ultracentrifuges," including secrecy clauses.[148] The Navy retains its "right to introduce visual barriers to the cascades" it leases to INB at the Resende facility. It also demands INB comply with a list of obligations that includes reporting any anomalies during the use of equipment (for technical and security purposes), sharing information about the operation of the cascades, allowing the Navy officers access to the centrifuges at any time, banning changes in procedures without prior Navy consent, guaranteeing the integrity of the Navy's seals that prevent

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[145] Decreto de 22 de Junho de 2017, *Presidência da República*, June 22, 2017; GSI, Portaria nº 118, de 19 de outubro de 2017, *Diário Oficial da União*, October 23, 2017.

[146] INB - CTMSP, "Contrato INB No 2/00/007, Contrato CTMSP No. 89100/2000-013/00," 8, cl.6.1.1. The original contract and its amendments were obtained by means of the Information Access Act (*Lei de Acesso à Informação*). Sensitive information is redacted.

[147] Ibid., 8, cl. 6.1.1; 8-10, 7.2.

[148] Ibid., cl.6.1.1, 13.2.

access to the interior of the centrifuges, and keeping an on-site support facility for the Navy, among others.[149] Even access to the building that houses the centrifuges at Resende is strictly regulated; the Navy issues a special authorization to select INB personnel who operate the centrifuges.[150] Existing controls are in place due to the expressed "strategic value" of centrifuge design, whose disclosure could "cause grave damage to the Navy and the country itself."[151]

Visual barriers to the cascades at CTMSP in August 2008 (Photo by Valter Campanato/Agência Brasil)

In the past, TCU contested the Navy's control over enrichment activities[152] when inspectors noted that INB was deprived of its contractual right and duty to audit effectively the products related to the contract. For TCU, this would have required INB personnel to have full access to the CTMSP equipment and materials involved in the fabrication of enrichment equipment,[153] but the original contract applies secrecy clauses to information regarding the fabrication.[154] In 2008, an amendment to the initial document loosened such strict control by allowing INB's auditors to have access to "items for fabrication of the ultracentrifuges that do not compromise industrial secrecy," as long as they went through "accreditation and one-month early notification."[155] An audit report likewise describes that in 2003, TCU auditors were denied visual access to INB ultracentrifuges. On that occasion, an INB official informed that a preliminary approval from the Brazilian Intelligence Agency (Abin) were needed to grant TCU officials access.[156] In the previous years, TCU officials noted, there had not been obstacles to carrying out the auditing.[157] It is worth noting that a 2003 agreement between the Navy and INB established that the INB's director for isotopic enrichment would from that moment onward be nominated by the Navy Command.[158]

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149 Ibid., cl. 18.

150 Consultations with INB officials and staff in Resende, Rio de Janeiro, April, 13 2018.

151 INB - CTMSP, "Contrato," 4, intro, it. 5.

152 TCU, Decisão No. 1019/2001, Processo No. 003.223/2001-8, Rapporteur: Min. Benjamin Zymler, 04.12.2001, *Diário Oficial da União*, 24.01.2002; TCU, Decisão No. 956/2002, Processo No. 005.446/2002-0, Rapporteur: Min. Benjamin Zymler, 31.07.2002, http://www.tcu.gov.br/Consultas/Juris/Docs/judoc/Dec/20020809/TC%20005.446.doc; TCU – Secretaria-Geral de Controle Externo – SECOB – SECEX – RJ, Plano Especial de Auditoria de Obras 2003, PT: 12.364.0041.5081.0033 (2003).

153 TCU, Decisão No. 956/2002, Processo No. 005.446/2002-0, Rapporteur: Min. Benjamin Zymler.

154 INB - CTMSP, "Contrato INB No 2/00/007, Contrato CTMSP No. 89100/2000-013/00," 8, cl.13.2.

155 INB - CTMSP, "Aditamento n° 5 - Contrato INB No 2/00/007, Contrato CTMSP No. 89100/2000-013/00", cl.11.

156 TCU – Secretaria-Geral de Controle Externo – SECOB – SECEX – RJ, Plano Especial de Auditoria de Obras 2003 , PT: 12.364.0041.5081.0033 (2003), 26-27.

157 Ibid., 26.

158 Dalaqua, "Átomos e Democracia no Brasil," 208.

NUCLEAR DIPLOMACY AND SAFEGUARDS

The fact that the Navy owns enrichment technology also gives it formal and informal influence over the country's nuclear diplomacy, especially in negotiations over nuclear safeguards. This is to be expected, given the Navy's role as a guardian of a safeguarded facility, but it goes beyond formal engagement with the IAEA.

Besides the secrecy requirements mentioned above, the contract with INB sets, for example, clear roles and responsibilities regarding the operationalization of nuclear safeguards, especially those involving the ultracentrifuges. The Navy participates alongside INB in the elaboration and modification of design information questionnaires,[159] which are sent to CNEN and then to the IAEA and ABACC. It also oversees the negotiations of the terms of procedures for inspections and facility arrangements. Finally, the contract establishes that all inspections of INB enrichment facilities must be communicated to the Navy in advance and that a Navy representative can be assigned to participate alongside INB officials during the inspection.[160]

In the end, it is up to CNEN to negotiate with the IAEA and ABACC and make the final decision on the terms of safeguards agreements to be applied at every facility (even the military ones), but consultations with the Navy are frequent, especially on decisions pertaining to the balance between secrecy protection and the effectiveness of safeguards.

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These provisions have meant that measures for technology protection designed by the Navy have an impact on the development of international negotiations for the INB facilities. This is illustrated by an episode in 2004 when Navy officials got directly involved in resolving a dispute between Brazilian officials and the IAEA on the access to Resende. As a result, Brazil and the IAEA adopted middle-ground solutions – for example, minimal visual barriers – to balance the requirements of safeguards effectiveness with the preservation of national technological secrets.

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[159] The design information questionnaire is a document submitted by a state to the IAEA with design information of a facility in accordance with the terms of a safeguards agreement. This document includes "a description of the form, location and flow of nuclear material; a general layout; description of features relating to nuclear material accountancy, containment and surveillance; and a description of existing and proposed procedures for nuclear material accountancy and control and the procedures for physical inventory taking".
The IAEA treats the document as "highly confidential" (Source: IAEA, *Safeguards Implementation Practices Guide on Provision of Information to the IAEA* (June 2016), 5, 120-128).

[160] INB - CTMSP, "Contrato," cl. 14.

RESEARCH AND DEVELOPMENT

The Navy's ties to IPEN go back 40 years in the fields of R&D and nuclear-science education.[161] In 1982, IPEN staff worked alongside Navy nuclear engineers on Brazil's first-ever attempt at uranium enrichment, when they teamed up with the Navy in the design, fabrication, installation, and commissioning of enrichment cascades.[162] The Navy was behind the 1988 IPEN-MB-01 research reactor, whose purpose was to develop know-how on what later would become the design of reactor cores for naval propulsion.[163] In 1980, the Navy also housed its first conversion project at IPEN, producing UF_6 gas in pilot units.[164] A decade later, in 1990, IPEN transferred its stockpile of 30 tons of UF_6 to the Navy at Aramar.[165]

As capacity developed within the IPEN labs, Navy officials drew on that expertise to set up a nuclear materials facility at Aramar focusing on nuclear fuel assemblies and the fabrication of nuclear fuel elements for nuclear propulsion reactors.[166] As of writing, the Navy still exercises significant influence at IPEN, mostly through the RMB project. The Navy was instrumental in fundraising for the project, and it has offered land within the Aramar complex to host the reactor once it is ready to operate. Navy officials sit as heads of *Fundação Pátria*, a nonprofit foundation that facilitates cooperation between IPEN and the Argentine public-private technology company Invap, a major stakeholder in the RMB project. The Navy also sits on both the governing board and the executive board of the RMB project.[167] At the time of the writing of this report, the Navy was operating the RMB-exclusive cascades enriching up to 19.9% at Aramar. When the reactor is ready, the enriched uranium will then be shipped to the fuel-element fabrication unit for the RMB at IPEN in São Paulo and will return as fuel assemblies to the future RMB site in Iperó, next to the existing Aramar facilities.

HEAVY EQUIPMENT

The Brazilian government set up Nuclep in the 1970s to build heavy equipment such as pressure vessels and steam generators for the power reactors for the Angra complex. As funds ebbed in the wake of a major financial crisis and transition to democracy in the 1980s, however, Nuclep found a niche in the naval sector. It first built submarine hulls for the Tupi class, and it then built the hull for the first Tamoio-class submarine.[168]

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161 Marcelo Linardi, *O IPEN e a Inovação Tecnológica: Passado, Presente e Futuro*. São Paulo: SENAI-SP, 2016, 23-36.

162 Ibid., 36.

163 "Reator de Pesquisa IPEN-MB/01", IPEN, accessed August 29, 2019, https://www.ipen.br/portal_por/portal/interna.php?secao_id=723.

164 Research on purification of uranium concentrates had started in the 1960s, but only picked up from 1979 onwards, Motta, "As Peças do Quebra-Cabeça"; Linardi, *O IPEN e a Inovação Tecnológica*, 34-35.

165 Ivan Carlos Oliveira, *III Décadas: De História do CTMSP*, São Paulo: CTMSP, 2018, 50-51.

166 Linardi, *O IPEN e a Inovação Tecnológica*, 37-38.

167 "Amazul Ingressa no Comitê Diretor do RMB e Será Coexecutora do Empreendimento", CNEN, accessed August 29, 2019, http://www.cnen.gov.br/ultimas-noticias/333-amazul-ingressa-no-comite-diretor-do-rmb-e-sera-coexecutora-do-empreendimento.

168 "Quem Somos", Nuclep, accessed August 29, 2019, http://www.nuclep.gov.br/pt-br/linha-tempo.

By the time the administration of Luiz Inácio Lula da Silva (Lula) signed its contract with France for the building of five Scorpène subs – one of them nuclear-powered – Nuclep was the main supplier of heavy naval equipment in the country. It built the pressure vessel for the land-based prototype reactor at Labgene, and it has secured the contracts for the fabrication of the hull and other sections of the new Scorpène fleet.[169] The interaction between the Navy and Nuclep is extremely close, and it includes a shared facility in the Itaguaí complex. The Navy's influence, however, is not just informal and a function of its financial leverage over Nuclep; it is also institutionalized. Even though CNEN operates as a controlling shareholder of Nuclep, the company's director for industrial activities is a retired naval official appointed by the Brazilian Navy.[170]

CIVIL-MILITARY NUCLEAR REGULATION[171]

In 2013, the Navy started consultations with CNEN on the regulatory framework to be put in place for the nuclear-powered submarine, including licensing and monitoring of nuclear safety. Given the lack of an off-the-shelf model to govern regulations of naval nuclear equipment – in particular, during operations at sea – and in light of international best practices, the decision was made to set up a new tailor-made naval nuclear agency. The Naval Agency for Nuclear Safety and Quality (AgNSNQ) was formally launched in March 2018, and for the first time in Brazil, there is a nuclear regulatory body other than CNEN. Under the new scheme, CNEN will continue to exercise its authority over the licensing and monitoring of all land-based nuclear facilities, while AgNSNQ will set and verify the norms and procedures on safety and quality of the designing, commissioning, operation, and decommissioning of the nuclear-powered submarine.

This means that that licensing and monitoring of all nuclear activities and facilities at CTMSP (including Labgene), the shipyard, and the naval base (including the radiological center for refueling and the waste facility) will likely remain under CNEN's purview. AgNSNQ will oversee Cogesn and the future submarine command facilities as well as deploy inspectors inside the submarine while at sea. It appears that the two regulatory bodies have developed a good rapport that includes a web of cooperation agreements to share information and personnel, train their respective staff members, negotiate the terms of reference for their respective licensing and monitoring duties, and develop a joint plan for emergency response.

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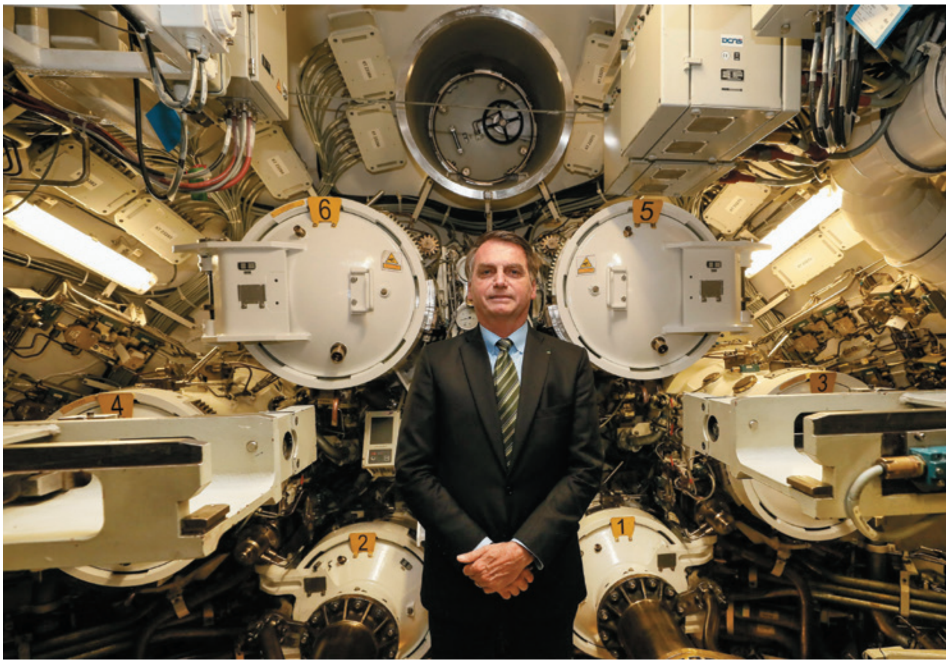
169 "Quem Somos", Nuclep, accessed August 29, 2019, http://www.nuclep.gov.br/pt-br/linha-tempo. Consultations with Nuclep officials and staff in Itaguaí, Rio de Janeiro, April 11, 2018.

170 Consultations with Nuclep officials and staff in Itaguaí, Rio de Janeiro, April 11, 2018.

171 Guilherme Sineiro, "Medidas Nacionais e Regionais para a Segurança de Instalações Nucleares Existentes; Riscos Decorrentes do Terrorismo Sectário; Cooperação Regional e Sub-regional para os Usos Pacíficos da Energia Nuclear; Tratamento e Eliminação de Resíduos Radioativos" (Roundtable presentation, Seminário Internacional – América do Sul na Era Nuclear: Riscos, Desafios e Perspectivas, UFSM, Santa Maria, RS, August 20, 2018); Tuxaua Q. de Linhares, "Agência Naval de Segurança Nuclear e Qualidade" (VI Semana de Engenharia Nuclear, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, October 16, 2018).

DEVELOPMENTS UNDER PRESIDENT BOLSONARO



President Bolsonaro visits the interior of the second conventional submarine of PROSUB in October 2019 (Photo by Isac Nobrega/Agência Brasil)

From the outset of his administration, President Bolsonaro has reassured the public about his commitment to the nuclear submarine project. To a significant degree, he has reinforced the influence of the Navy across the board since his inauguration. The new administration has appointed the former director for the Navy's nuclear and technological development, Admiral Bento Costa Lima Leite de Albuquerque Júnior, as minister for mines and energy, an influential position with oversight duties over a range of areas, including uranium mining and nuclear power. The admiral has publicly stated his commitment to seeing Brazil export nuclear fuel via INB, complete construction work at the Angra-3 power plant site, and possibly privatize a portion of the nuclear energy generation business. (See "Private Investment" in "2 - Governance and Accountability."). Starting in August 2019, the Navy-run company Amazul and Fundação Pátria collaborate with Eletronuclear within the scope of the project for the extension of Angra-1 power plant lifetime.[172] For their part, INB and Nuclep were removed from their former institutional home – the Ministry of Science, Technology, Innovations, and Communication – and placed under Admiral Leite at the Ministry of Mines and Energy.[173] Meanwhile, CNEN has remained within the Ministry of Science, Technology, Innovations, and Communications. Finally, the newly appointed president is a retired Navy captain. It remains to be seen what real impact these set of measures will have on the Navy's control over the nuclear sector.

172 "Cerimônia marca início de cooperação técnica entre Eletronuclear e Amazul," Eletronuclear, August 9, 2019, accessed on October 21, 2019, https://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/Cerimônia-marca-in%C3%ADcio-de-cooperação-técnica-entre-Eletronuclear-e-Amazul.aspx.

173 Medida Provisória No. 870, de 1º de Janeiro de 2019, *Diário Oficial da União*, January 1, 2019.

NUCLEAR REGULATION

Over the years, CNEN has become the main supervisory body for nuclear policy and at the same time, the nuclear regulatory agency in Brazil. This arrangement places regulation together with nuclear policy development and implementation. In the course of research for this report, the authors encountered a growing number of national experts in the field who believe these functions ought to be formally separated. Such separation is necessary for the country's successful transition to a more robust policy-regulatory framework to underpin the expansion of the nuclear sector.

Calls for an independent nuclear regulator in Brazil are not new, but in the past, they did not bear fruit. During President Temer's administration (2016-2018), serious discussions of the matter took place in government circles. It remains to be seen whether these debates will continue under President Bolsonaro.

As the national nuclear regulatory authority, CNEN establishes the norms and procedures for the operation of nuclear and radiological facilities nationwide and oversees their compliance with security, safety, and nonproliferation standards. CNEN also serves as the national point of contact for the IAEA and negotiates the terms of the IAEA's safeguards approaches and specific safeguards details, called facility attachments, to be applied nationwide (including at the military installations).[174]

At the same time, it implements key nuclear policies regarding the research and development, production, and commercialization of radioisotopes and radiopharmaceuticals; radioactive waste management; provision of technical services; nuclear education; special projects such as the RMB and the National Repository for Low- and Medium-Level Radioactive Waste (RNMB); and emergency preparedness and response. At the strategic level, CNEN participates in the high-level debates of the Committee for the Development of the Brazilian Nuclear Program at the GSI.

CNEN's expanded responsibilities shape the power dynamics within Brazil's public sector. More specifically, its current institutional arrangement raises issues of self-regulation, recurring internal disputes, and potential conflicts of interest in the nuclear sector.

From the perspective of international law, some participants argue that CNEN's dual role as nuclear planner-executor and regulator could be seen as a violation of the Convention on Nuclear Safety, which states that parties should "take appropriate steps to ensure an effective separation between the functions of the regulatory body and

[174] For the detailed competencies of CNEN, see CNEN, *Relatório de Gestão* 2017, 16-17.

those of any other body and organization concerned with the promotion or utilization of nuclear energy."[175] Other officials in the Brazilian nuclear sector, however, claim that functional differentiation is effective within the CNEN, thanks mainly to the divisions between the Directorate for Research and Development and the Directorate for Radiation Protection and Nuclear Safety, and that CNEN's institutional design would thus comply with the terms of the Convention.[176]

The remainder of this section focuses on CNEN's evolution over time and the implications for nuclear policy today.

OVERREACH

From its early days in the 1950s to today, CNEN's reach has grown exponentially, and over time, it has become one of the major players in Brazil's nuclear governance. At the outset, the commission was set up to guide and implement nuclear policy[177] but early on, it also became the central command for the expansion of a state-led domestic nuclear industry. When the government created the Brazilian Company of Nuclear Technology in 1971 with long-term plans to mine and mill uranium, enrich uranium, fabricate nuclear fuel, and reprocess spent fuel, CNEN received control of 51% of its shares.[178]

The first legal expansion of CNEN's responsibilities to include regulatory authority occurred in 1962 when new legislation declared its responsibility over the establishment of "rules and norms of safety concerning the use of radiation and nuclear materials" and related facilities, and the verification of their compliance.[179]

The same legal act made clear CNEN's main responsibility for the promotion of R&D, training, and education in the nuclear sector. [180]

In 1974, these responsibilities were reaffirmed and refined.[181]

The first pushback against CNEN's all-encompassing authority in the nuclear field came that same year as CBNT morphed into a state conglomerate of subsidiary companies called Nuclebrás in order to implement an ambitious bilateral agreement between Brazil and West Germany. The agreement included commitments to technology transfers and construction of several nuclear power reactors in the decades to come. The shareholding structure of the new company explicitly excluded

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175 IAEA, *Convention on Nuclear Safety*, INFCIRC/449 (June 17, 1994), Art. 8; Rogerio dos Santos Gomes and Edson Carlos Magalhaes Ennes Ennes, "Diagnosis of the Brazilian Nuclear Regulatory Body" (12th International Congress of the International Radiation Protection Association (IRPA): Strengthening radiation protection worldwide, Argentina, 2008).

176 TCU, Acórdão No. 519/2009, Processo No. 017.897/2007-5, Relator: Min. Augusto Sherman, 23.03.2009, https://contas.tcu.gov.br/sagas/SvlVisualizarRelVotoAcRtf?codFiltro=SAGAS-SESSAO-ENCERRADA&seOcultaPagina=S&item0=5041.

177 Decreto No. 40.110, de 10 de Outubro de 1956, *Diário Oficial da União*, October 10, 1956.

178 Lei No. 5.740, de 1 de Dezembro de 1971, *Diário Oficial da União*, December 2, 1971.

179 Lei No. 4.118, de 27 de Agosto de 1962, *Diário Oficial da União*, September 19, 1962, art. 4, it. IV.

180 Ibid.

181 Lei No. 6189, de 16 de Dezembro de 1974, *Diário Oficial da União*, December 17, 1974.

CNEN, transferring all of its shares to the federal government. The Ministry of Mines and Energy rather than CNEN was given administrative control over Nuclebrás.[182] Yet, within a decade, Nuclebrás's position declined due to a litany of problems in the nuclear sector; West Germany, in response to pressure from the United States, pulled out of the part of the deal covering the transfer of ultracentrifuge technology, which was considered sensitive from a proliferation standpoint, and provided instead the jet nozzle technology that was underdeveloped and untested; and Brazil sank into a long-lasting economic recession coupled with a checkered transition to democracy. By the mid-1980s, CNEN had regained its powerful role in the nuclear field.[183]

CNEN managed to retain its commanding role in the nuclear sector even as the Brazilian Navy's own nuclear R&D projects took off from 1979 onward, with the focus on developing an indigenous uranium enrichment capability. As the Navy established a framework for scientific cooperation with IPEN, CNEN took IPEN under its wing in 1982, effectively positioning itself as a nationwide commission with a stake in the nascent military arm of the country's nuclear program. As the Navy's nuclear activities grew, so did its ties to CNEN. Relations between the two organizations remain close.[184]

For 30 years (1989-2019), CNEN retained majority shares of and presided over the state-owned companies INB and Nuclep in the nuclear industry. This chain of command changed in 2019 when the restructuring of the state apparatus carried out by Bolsonaro's administration withdrew both companies from the Commission's oversight. The companies are now under the institutional umbrella of the Ministry of Mines and Energy.

Still, CNEN continues to have far-reaching influence as a key nuclear stakeholder in Brazil, encompassing a group of associated research institutes and laboratories, as well as executive bodies of governance in a wide range of areas. As of 2019, the legislation specifies that the Commission is in charge of nuclear policy making; research and development; promotion of peaceful uses of nuclear energy; and regulation, licensing, authorization, control, and monitoring of all nuclear and radiological activities in the country.[185] Figure 5 illustrates the evolution of CNEN's responsibilities and the network of related institutes and centers of research under its umbrella.

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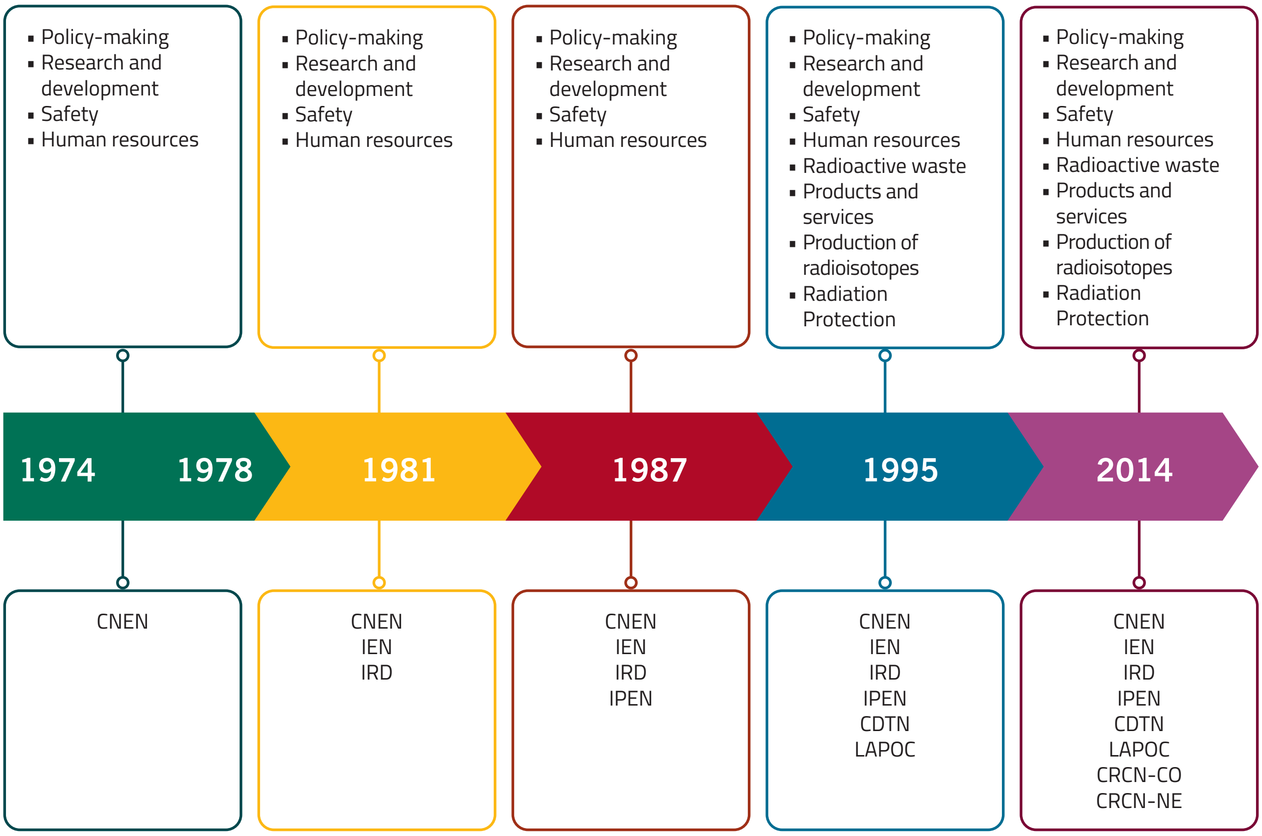
[182] Ibid.

[183] Motta, "As Peças do Quebra-Cabeça"; Coutto, "O Papel das CPIs na Política Nuclear Brasileira"; Spektor, "The Evolution of Brazil's Nuclear Intentions"; Marly Motta, "Projeto Nuclear Brasileiro: História e Memória," in Ana Lucia Villas-Bôas and Marta de Almeida (orgs.), *Ciência no Brasil Contemporâneo*, Rio de Janeiro: Museu de Astronomia e Ciências Afins, 2014, 151-184.

[184] Motta, "As Peças do Quebra-Cabeça"; Coutto, "O Papel das CPIs na Política Nuclear Brasileira"; Motta, "Projeto Nuclear Brasileiro"; Linardi, *O IPEN e a Inovação Tecnológica*; IPEN, *Relatório de Gestão 2016* (São Paulo, 2017), 1.

[185] Decreto No. 8.886, de 24 de Outubro de 2016, *Diário Oficial da União*, October 25, 2016.

Figure 5: The evolution of CNEN's responsibilities and institutions



Source: Adapted from CNEN, *Relatório de Gestão 2017*, 4.

GOVERNANCE ISSUES

INTERNAL DIVISIONS: SELF-REGULATION AND INTERNAL DISPUTES

CNEN's current institutional design reflects the functional differentiation between policy implementation and regulation. Its Directorate for Research and Development promotes, executes, and coordinates activities on research, development, innovation, and transfer of nuclear technologies; application of nuclear techniques; provision of products and services (for example, radioisotopes); radioactive waste management; emergency preparedness and response; and nuclear education. In turn, its Directorate for Radiation Protection and Nuclear Safety deals with regulation – licensing and monitoring of nuclear and radiological facilities and waste storage sites and procedures, control of facilities handling natural radionuclides, nuclear and radiological safety, radiological and nuclear emergencies, monitoring of waste management, safeguards, nuclear security, control of materials, certification of professionals, control of transport, norm development, and formulation of emergency plans.[186]

Irrespective of how effective the functional differentiation may be, the fact that the

[186] Ministério da Ciência e Tecnologia, Portaria MCT No. 305, de 26.04.2010, *Diário Oficial da União*, April 27, 2010, Section I, 5; Decreto No. 8.886, de 24 de Outubro de 2016, *Diário Oficial da União*, October 25, 2016. Decreto 8886 de 24 de outubro de 2016 - http://www.planalto.gov.br/ccivil_03/_Ato2015-2018/2016/Decreto/D8886.htm#art9.

two directorates are under the same institutional roof creates conditions for self-regulation. Consider the example of the licensing process of the multipurpose research reactor. While CNEN's Directorate for Research and Development is in charge of the project's execution, it is up to the Radiation Protection and Nuclear Safety team to assess whether all standards are met and to decide whether to grant the authorization for the construction and operation of the reactor. This means that CNEN sets policy while at the same time regulating and monitoring itself.[187]

Another telling example is the case of the Institute for Radiation Protection and Dosimetry (IRD). Over the years, IRD has moved from one CNEN directorate to another. From 1974 to 2007, IRD was housed in the Directorate for Radiation Protection and Nuclear Safety; from 2008 to 2016, it was a part of the Directorate for Research and Development; in 2017, it returned to the Directorate for Radiation Protection and Nuclear Safety;[188] and in 2018, it moved again to the Directorate for Research and Development, where it is housed now.[189] The oscillating profile of IRD is reflected in the Institute's mandate, which combines research and development activities (for example, promotion of scientific research, development of nuclear technologies, provision of services, education, and training in radiation protection, dosimetry, and metrology) with regulatory responsibilities (such as technical and scientific support to the regulatory bodies of CNEN on matters affecting the licensing of nuclear and radiological facilities and activities).[190] Nowadays, CNEN's Deliberative Commission, its highest decision-making body, recognizes that that IRD executes mainly research and development activities and therefore must be placed under the Directorate for Research and Development.[191]

This breeds internal disputes. In 2004, IRD and the Coordination of Nuclear Facilities, a department in charge of the regulation and inspection of nuclear facilities, belonged to the same regulatory directorate but issued different recommendations in relation to an episode involving the violation of nuclear safety norms by INB mining activities in Caetité. The Coordination department identified twenty-five instances of errors or violations of nuclear safety standards, including three critical ones, and recommended suspension of the authorization for the initial operation of uranium mining at INB Caetité. The president of CNEN, Odair Gonçalves, and his council of directors found the report to be inconclusive. In turn, the IRD team issued a second report, which identified the same critical problems but recommended that the license be renewed. CNEN eventually renewed the INB's authorization.[192]

[187] "DPD Entrega à DRS Relatório Preliminar de Análise de Segurança (RPAS) do Reator Multipropósito Brasileiro," CNEN, accessed August 29, 2019, http://www.cnen.gov.br/ultimas-noticias/518-dpd-entrega-a-drs-relatorio-preliminar-de-analise-de-seguranca-rpas-do-reator-multiproposito-brasileiro-rmb.

[188] "Histórico", IRD, accessed August 29, 2019, http://www.ird.gov.br/index.php/historico.

[189] Comissão Nacional de Energia Nuclear, Resolução no. 232, de 5 de setembro de 2018, *Diário Oficial da União*, September 17, 2018.

[190] Ministério da Ciência e Tecnologia, Portaria MCT No. 305, de 26.04.2010, *Diário Oficial da União*, April 27, 2010, Section I, 5; Decreto No. 8.886, de 24 de Outubro de 2016, *Diário Oficial da União*, October 25, 2016.

[191] CNEN, Resolução no. 232, de 5 de setembro de 2018, *Diário Oficial da União*, September 17, 2018.

[192] Greenpeace, *Ciclo do Perigo: Impactos da Produção de Combustível Nuclear no Brasil* (São Paulo: Greenpeace, 2018); Comissão de Meio Ambiente e Desenvolvimento Sustentável, Rapporteur: Edson Duarte, Relatório do Grupo de Trabalho Fiscalização e Segurança Nuclear, Câmara dos Deputados, at 97 (2007); "Licença para Mina de Urânio Causa Demissão," Folha de São Paulo, December 12, 2004, https://www1.folha.uol.com.br/fsp/brasil/fc1212200417.htm.

This raises issues of accountability. Even though CNEN is subject to external checks by TCU and CGU on nonnuclear issues, the Commission is self-regulated. In 2009, TCU asked whether the combination of regulatory and policy functions within the same institution could compromise impartiality and effectiveness of surveillance and accountability practices in the nuclear sector.[193] In 2014, members of the Federal Prosecution Service (MPF) in Rio de Janeiro who were in charge of that office's Working Group on Nuclear Energy questioned the practice of self-licensing and argued for the establishment of an independent regulator for the sector with an emphasis on nuclear safety.[194] These types of problems are likely to recur as Brazil's nuclear policies become more ambitious.

THE NUCLEAR INDUSTRY AND CNEN: CONFLICT OF INTEREST?

Before the 2019 reforms, conflict of interest was a recurrent issue of concern, especially during the period when CNEN licensed and inspected state companies that were under its administrative control. This applied to INB and Nuclep, in which CNEN held 99.9% of the shares from 1989 to 2019. Even though INB and Nuclep had their own executive boards to conduct nuclear industrial activities, CNEN remained in control of their presidencies, their administrative boards, and the appointment of executive directors. According to TCU, the overlap between executive and monitoring functions could have created conflicts of interest that could have gotten in the way of effective regulation.[195] In 2009, TCU went as far as arguing for the need to withdraw the shared control from CNEN in order to avoid this type of conflict.[196]

This scenario changed in 2019. The rearrangement of the federal administration carried out by Bolsonaro's government in its first legal act altered the status of INB and Nuclep, which now answer to the Ministry of Mines and Energy, run by Admiral Bento.[197] The authors could not determine what factors motivated this shift, but some hypotheses are worth noting. First, this could have been a necessary adaptation to the new legislation on state companies approved in 2016, which mandates that members of regulatory agencies cannot participate in the administrative boards of companies that are subject to their control.[198] In practice, the government could no longer appoint the president of CNEN to preside over the boards of INB and Nuclep.

Second, from a political perspective, the transfer of the nuclear industry to the watch of the Ministry of Mines and Energy indicates the tendency toward the militarization of nuclear governance in the country in recent years. The Navy's former director for

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193 TCU, Acórdão No. 519/2009, Processo No. 017.897/2007-5, Relator: Min. Augusto Sherman, 23.03.2009, https://contas.tcu.gov.br/sagas/SvlVisualizarRelVotoAcRtf?codFiltro=SAGAS-SESSAO-ENCERRADA&seOcultaPagina=S&item0=5041.

194 Isabela Vieira, "MPF/RJ Diz que Brasil Precisa de Agência Reguladora para Setor Nuclear", *Empresa Brasil de Comunicação*, October 8, 2014, http://agenciabrasil.ebc.com.br/geral/noticia/2014-10/mpfrj-diz-que-brasil-precisa-de-agencia-reguladora-para-setor-nuclear.

195 TCU, Acórdão No. 519/2009, Processo No. 017.897/2007-5, Relator: Min. Augusto Sherman, 23.03.2009, https://contas.tcu.gov.br/sagas/SvlVisualizarRelVotoAcRtf?codFiltro=SAGAS-SESSAO-ENCERRADA&seOcultaPagina=S&item0=5041.

196 Ibid.

197 Medida Provisória No. 870, de 1º de Janeiro de 2019, *Diário Oficial da União*, January 1, 2019.

198 Lei No. 13.303, de 30 de Junho de 2016, *Diário Oficial da União*, July 1, 2016, art. 17 §2, it. I.

nuclear and technological development now presides over the boards of INB and Nuclep. (See “Civil-Military Relations” in “2 - Governance and Accountability.”)

Third, this shift could be a response to an “administrative unbalance” affecting the Ministry of Science and Technology, that is, the fact that INB and Nuclep absorbed large amounts from the limited budget of their former ministry.[199]

Finally, former officials in the nuclear sector claim that this shift could lower the bar of CNEN’s regulation over nuclear facilities nationwide. The rationale behind this argument is counterintuitive: the conflict of interests that marked CNEN’s regulation over INB and Nuclep did not favor the operation of the industry with flexible regulation, but actually created an “excess of concern” with regulatory standards.[200] By presiding over the boards of both companies, the president of CNEN could have been held responsible if any disruption in operation were to occur. To avoid this risk, standards for licensing and inspection were kept high. This is a common perception among the sector’s operators, who claim this counterintuitive conflict of interests compromised the continuation of INB’s activities, especially in the mining sector. (See “Environmental Regulation” in “2 - Governance and Accountability.”)[201] It is still unclear, however, whether this institutional rearrangement will actually change CNEN’s approach to regulation and inspection and what new conflicts of interests might emerge from this dynamic.

THE PUSH FOR AN INDEPENDENT REGULATOR

Most stakeholders in the nuclear and scientific communities recognize the need to adopt an institutional separation between regulatory and implementation functions given the complexity of the country’s nuclear policy and therefore support establishment of a new regulatory agency independent from CNEN. However, budget limitations, the lack of consistent strategic planning, and gaps in nuclear labor legislation are likely to restrict the prospects for such a profound reform. Between 2008 and 2014, the agenda for the establishment of the new regulatory nuclear agency slightly advanced. A formal proposal was presented to the chief of staff and the former Ministry of Planning (now incorporated into the Ministry of Economy), but no further action for implementation was taken.[202]

In conversations with the authors, several high-ranking officials dismissed the proposal described above, arguing that it prescribed an unsustainable, overloaded structure of human resources. Nevertheless, they also expressed readiness to move forward with

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[199] Carlos Feu Alvim and Olga Mafra, “A Concretização da Política Nuclear Brasileira,” Economia e Energia, accessed August 29, 2019, http://ecen.com.br/?p=3014.

[200] Ibid.

[201] Consultations with INB officials and staff in Caetité, Bahia, April, 6 2018.

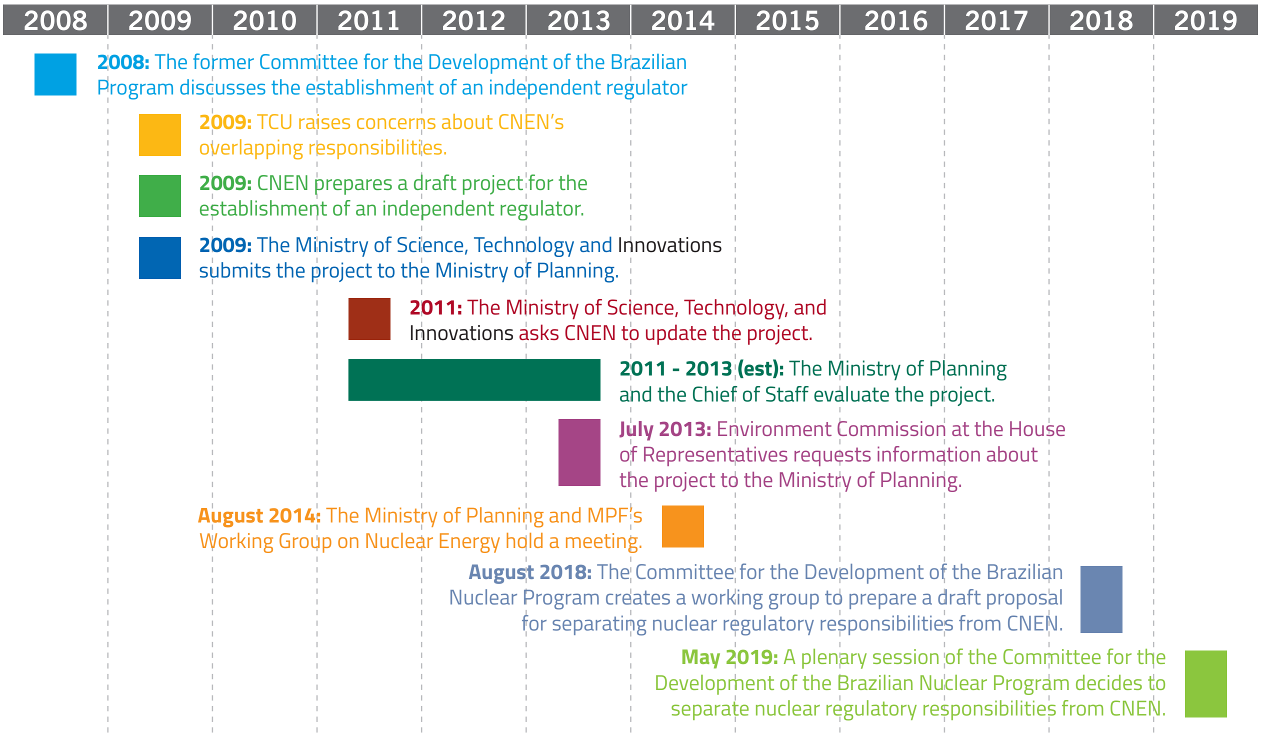
[202] “Penna Questiona Ministério sobre Agência Reguladora de Energia Nuclear”, Bancada Verde, accessed August 29, 2019, http://bancadaverde.org.br/noticias/energia-nuclear/; “Proposta de Criação de Agência Reguladora para Energia Nuclear Está na Casa Civil,” ABIPTI, accessed August 29, 2019, http://portal.abipti.org.br/proposta-de-criacao-de-agencia-reguladora-para-energia-nuclear-esta-na-casa-civil/; Carolina Gonçalves, “Brasil Deve Seguir Bons Exemplos de Energia Nuclear, Diz CNEN,” EXAME, October 4, 2011, https://exame.abril.com.br/mundo/brasil-deve-seguir-bons-exemplos-de-energia-nuclear-diz-cnen/; Câmara dos Deputados, Requerimento de Informação – RIC 297/2011, Fernando Jordão, March 16, 2011, https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra?codteor=849148&filename=RIC+297/2011; Vieira, “MPF/RJ Diz que Brasil”.

the reform agenda. The 2018 Brazilian Nuclear Policy Paper stated that the nuclear sector “will have a regulatory structure” to develop norms and to license, authorize, control, and regulate nuclear activities nationwide. In line with this trend, in 2018 the Committee for the Development of the Brazilian Nuclear Program established a technical group specifically dedicated to developing a legal proposal to separate CNEN’s regulatory and executive functions.

In May 2019, the committee’s plenary session formally decided to separate the regulatory structures from CNEN and place them in a new institution. Currently, the plans to implement this decision envisage a two-phase restructuring. First, CNEN’s Directorate for Radiation Protection and Nuclear Safety will become the National Authority for Nuclear Safety. Second, the authority will serve as a baseline for the creation of a National Agency for Nuclear Safety at a later stage.[203] The research institutes tied to CNEN will not undergo any major changes.[204] The timeline in Figure 6 illustrates some of the actions between 2008 and 2019.

Figure 6: Actions for the establishment of an independent regulator (2008-2019)

Source: See footnotes 202 and 203.



[203] “Presidente da CNEN se Reúne com Dirigentes do IPEN para um ‘Diálogo Aberto’ sobre Gestão e Perspectivas,” IPEN, accessed August 29, 2019, https://www.ipen.br/portal_por/portal/interna.php?secao_id=38&campo=12133.

[204] Ibid.

ENVIRONMENTAL REGULATION

The intersection between environmental protection and the nuclear program is a highly disputed topic among Brazilian nuclear operators, regulatory authorities, accountability institutions, the judiciary, civil society organizations, and local grassroots movements. There is a dearth of detailed studies in this field, but the authors' conversations with the primary stakeholders revealed the presence of several unresolved points of tension.

The existing governance mechanisms fail to mediate or resolve the underlying conflicts that emerge. In particular, communication among operators, regulators, the population, and social movements has not always been effective. This challenge is not limited to the nuclear field, as several environmental and human disasters in the mining field demonstrated recently. A complicating factor in the case of nuclear projects is the overlapping authorities of nuclear and environmental agencies, narrowing space for coming up with solutions. In addition, in sharp contrast with other areas of Brazilian public life, there are hardly any significant social movements or organized civil society groups in the nuclear space. Such groups could draw attention to the problem and point to international best practices as a road map to assist Brazil in improving the quality of nuclear governance.

Consequently, the question of how to guarantee that the nuclear program evolves without causing damage to the environment and human life remains open.

MAIN ISSUES AT STAKE

Assessing the environmental records of Brazilian nuclear and radioactive operations is a challenge for external observers, as disputes regarding the scope, magnitude, and effects of incidents and accidents persist among operators, regulatory authorities, local populations, and social movements. First, nuclear and environmental authorities sometimes hold different views about the same event and ways to handle it. These divergences have the potential to create an information gap about the actual state of affairs because the activities and the safety procedures might fall into both radiation protection and environmental policies. Second, operators and regulatory authorities diverge on the appropriate methodologies for measuring environmental impact. Third, operators' opacity and ineffective communication about usual and unusual events creates confusion about the actual impact of activities on the environment. For example, it is hard to know whether or not certain incidents are part of ordinary operations and whether certain geological conditions are natural. More importantly, it is challenging to know the real magnitude of accidents. As a result, all the main stakeholders – nuclear operators, the local population, social movements, and other accountability institutions such as the judiciary – distrust each other.

A unified narrative about the environmental record of the nuclear sector is very unlikely in the near future due to these hurdles, but, in this research effort, every attempt was made to listen to distinct voices in the debate in order to understand where these disputes stand. The authors relied on documents from the Brazilian Congress,[205] CNEN,[206] and the national environmental regulatory authority,[207] reports and advocacy campaign materials by social movements,[208] theses and reports by academics,[209] media reports, and interviews conducted with nuclear operators from INB (Caetité and Resende), Eletronuclear (Angra dos Reis) and CTMSP (São Paulo and Iperó) in April 2018.

Assessing the environmental records of Brazilian nuclear and radioactive operations is a challenge for external observers, as disputes regarding the scope, magnitude, and effects of incidents and accidents persist among operators, regulatory authorities, local populations, and social movements.

URANIUM MINING AND MILLING

In the nuclear sector, the most contentious subject among operators, regulatory authorities, local populations, and civil society concerns uranium mining and milling. Since 2000, when INB started to operate in Caetité, Ibama, regional environmental authorities, the Congress, the judiciary, employees and trade unions in the local mining sector, the local population, and civil society groups have reported occasional incidents

205 Comissão de Meio Ambiente e Desenvolvimento Sustentável, Rapporteur: Edson Duarte, Relatório do Grupo de Trabalho Fiscalização e Segurança Nuclear, Câmara dos Deputados.

206 See "Nota à Imprensa Sobre Denúncia / Resposta à Imprensa.", available at Luis Nassif, "O Caso CNEN, por Sérgio Rezende", *GGN*, April 1, 2011, https://jornalggn.com.br/tecnologia/o-caso-cnen-por-sergio-rezende/.

207 For a list of documents concerning Ibama's regulatory activities on nuclear and radioactive facilities and uranium mining, see: Sistema Informatizado de Licenciamento Ambiental Federal (accessed August 29, 2019), https://servicos.ibama.gov.br/licenciamento/index.php. Specific documents are cited in each case, as applicable.

208 Marijane Vieira Lisboa, José Guilherme Carvalho Zagallo and Cecília Campello do A. Mello, *Relatório da Missão Caetité: Violações De Direitos Humanos no Ciclo do Nuclear* (Curitiba: Plataforma Brasileira de Direitos Humanos Econômicos, Sociais, Culturais e Ambientais, 2011); Greenpeace, *Ciclo do Perigo; De Caetité (BA) a Santa Quitéria (CE) - As sagas da exploração do urânio no Brasil*, produced by Núcleo Tramas – UFC, 2013, 65 min, https://www.youtube.com/watch?v=4sA_-ClFaZA; "INB Esconde Vazamento de Urânio," Greenpeace, accessed on November 17, 2017, http://www.greenpeace.org/brasil/pt/Noticias/inb-esconde-vazamento-de-ur-ni/.

209 Dalaqua, "Átomos e Democracia no Brasil"; Renan Finamore Gomes da Silva, "Riscos, saúde e alternativas de produção de conhecimentos para a justiça ambiental: o caso da mineração de urânio em Caetité, BA" (PhD diss., Fiocruz, Rio de Janeiro, RJ, 2015); Marcelo Firpo de Souza Porto; Renan Finamore; Bruno Chareyron, *Justiça Ambiental e Mineração de Urânio em Caetité/BA: Avaliação Crítica da Gestão Ambiental e dos Impactos à Saúde da População* (Rio de Janeiro: Fiocruz, 2014). For an anthropological perspective, see Suzane de Alencar Vieira, "Resistência e *Pirraça* na Malhada: Cosmopolíticas Quilombolas no Alto Sertão de Caetité" (PhD diss., UFRJ, Rio de Janeiro, RJ, 2015).

Crushing of rocks containing uranium ore at INB Caetité (Photo by Marcelo Corrêa/Acervo INB)

at INB mining and milling facilities in Caetité (Bahia). For the most part, these included the overflow and/or leakage of toxic and/or chemical substances (in some cases, containing low-level radioactive materials) at the milling facilities in 2000, 2004, 2009, 2010, 2012, and 2013. Not all of them caused external environmental damage, but on at least four occasions (2004, 2009, 2010, 2012), environmental and/or nuclear authorities confirmed contamination.[210]

There were reports pertaining to the contamination of water wells both inside and outside the geographic area under INB's monitoring responsibility in 2011 and 2015. In those cases, disputes centered around appropriate methodologies to measure INB's environmental impact, the "naturalness" of the presence of uranium in the region, and the division of regulatory responsibilities over the potability of water.[211] In addition, in 2010, CNEN reported the contamination of a monitoring well.[212]

In 2011, MPF inquired with the national environmental authority (Ibama) about a possible overexploitation of underground waters by INB, which could damage water capacity in the region. When the environmental agency polled local residents, some of them said they faced water shortages while others did not.[213] Ibama could not reach any conclusion regarding the water capacity based on information provided by INB.[214]

Another incident related to uranium mining took place in 2011 and concerned the improper treatment and transportation of hazardous materials. At the time, CTSMP sent a cargo of uranium concentrates to INB for redrumming, causing

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[210] Duarte, Relatório do GT Fiscalização e Segurança Nuclear, (2007), 94-98; Ibama – Coordenação de Mineração e Obras Civis, Informações sobre Eventos não Usuais na URA-Caetité, Informação Técnica No. 008/2011 (2011); Ibama – Coordenação de Energia Elétrica, Nuclear e Dutos, Análise do Relatório "Evento de Transbordamento do Decantador DC – 1602" ocorrido em 28/10/09 na URA, Caetité/BA, PAR. No. 03/2010 (2010); Ibama – Coordenação de Energia Elétrica, Nuclear e Dutos, Análise do Relatório "Evento Não Usual na AA 140 da URA", PAR. 53/2010 (2010); Ibama – Coordenação de Mineração e Obras Civis, Vistoria à URA-Caetité, no período de 25 a 28 de março de 2013, PAR. 004362/2013 (2013); Finamore, "Riscos, Saúde e Alternativas de Produção de Conhecimentos", 95-96; Dalaqua, "Átomos e Democracia no Brasil", 117-121.

[211] Ibama – Coordenação de Mineração e Obras Civis, Manifestação das Indústrias Nucleares do Brasil S.A. sobre a suposta ocorrência de danos ambientais em Riacho da Vaca, localidade de Caetité, PAR. 139/2011 (2011); Ibama – Coordenação de Mineração e Obras Civis, Vistoria à área da URA – Caetité/BA, Relatório de Vistoria No. 029/2011 (2011); Ibama – Coordenação de Mineração e Obras Civis, Analisa e Avalia a Documentação Apresentada pela INB por meio da Correspondência ASSRPR-181-15, em Resposta ao Of. 02001.009422/2015-51, PAR. 02001.003642/2015-71 (2015); André Borges and Dida Sampaio, "Urânio Contamina Água na Bahia," *Estadão*, August 22, 2015, https://brasil.estadao.com.br/noticias/geral,uranio-contamina-agua-na-bahia,1748686.

[212] See "Nota à Imprensa Sobre Denúncia / Resposta à Imprensa.", available at Nassif, "O Caso CNEN".

[213] Ibama – Coordenação de Mineração e Obras Civis, Vistoria à área da URA – Caetité/BA, Relatório de Vistoria No. 016/2011 (2011); Ibama – Coordenação de Mineração e Obras Civis, Manifestação das Indústrias Nucleares do Brasil S.A. sobre a suposta ocorrência de danos ambientais em Riacho da Vaca, localidade de Caetité, PAR. 139/2011 (2011).

[214] Ibama – Coordenação de Mineração e Obras Civis, Manifestação das Indústrias Nucleares do Brasil S.A. sobre a suposta ocorrência de danos ambientais em Riacho da Vaca, localidade de Caetité, PAR. 139/2011 (2011).

commotion and fear among the local population, who believed the content to be radioactive waste.[215]

Ibama's inspections have also reported occasional problems at INB's facilities in Caetité on various occasions in 2011,[216] 2012,[217] and 2013,[218] with different degrees of urgency and risk. These included, for instance, inadequate storage and discarding of solid wastes of all sorts (including contaminated, nonradioactive ones), oil disposal at INB's gas station, and lack of maintenance of drains and pipes.

DECOMMISSIONING

The cases involving a uranium mine in Caldas and monazite sands in São Paulo illustrate the environmental problems that occur as a result of poor or nonexistent decommissioning practices. In 2017, both CNEN and INB reported the deposit of radioactive waste and heavy materials in the open-pit mining area, the waste rock piles, and the tailings dam, with potential (albeit monitored) leakage of radioactive and toxic substances into the environment on the Poços de Caldas plateau.[219] INB itself sees the former uranium mine as a significant environmental liability in the company's portfolio of activities.[220] At INB's Interlagos Unit, the leakage of hazardous substances contaminated the terrain between 1998 and 2002.[221] (See "Radioactive Waste and Spent Fuel Management" in "2 - Governance and Accountability.")

DISUSED SEALED RADIOACTIVE SOURCES

In 1987, the abandonment by a private radiotherapy clinic of a sealed radioactive source containing cesium-137 led to a large-scale radiological accident in Goiânia, leaving a long-lasting trail of health damage, stigma, and trauma.[222] This was the world's single most damaging radioactive accident.

[215] Ibama – Coordenação de Mineração e Obras Civis, Transporte de Material Nuclear para Reentamboramento na URA – Caetité/BA, Informação No. 10/2011 (2011); Ibama – Coordenação de Mineração e Obras Civis, Vistoria à área da URA – Caetité/BA, Relatório de Vistoria No. 016/2011 (2011); "Urânio entre o Caos e o Silêncio", Instituto Humanitas Unisinos, accessed August 29, 2019, http://www.ihu.unisinos.br/noticias/43456-uranio-entre-o-caos-e-o-silencio; Lisboa, Zagallo, Mello, *Relatório da Missão Caetité*, 29-63. For a narrative of the events of this episode, see Dalaqua, "Átomos e Democracia no Brasil", 155-158.

[216] Ibama – Coordenação de Mineração e Obras Civis, Vistoria à área da URA – Caetité/BA, Relatório de Vistoria No. 016/2011 (2011); Ibama – Coordenação de Mineração e Obras Civis, Vistoria à área da URA – Caetité/BA, Relatório de Vistoria No. 020/2011 (2011); Ibama – Coordenação de Mineração e Obras Civis, Vistoria à área da URA – Caetité/BA, Relatório de Vistoria No. 029/2011 (2011).

[217] Ibama – Coordenação de Mineração e Obras Civis, Vistoria à área da URA – Caetité/BA, Relatório de Vistoria No. 023/2012 (2012).

[218] Ibama – Coordenação de Mineração e Obras Civis, Vistoria à URA-Caetité, no período de 25 a 28 de março de 2013, PAR. 004362/2013 (2013).

[219] CNEN et al., *National Report of Brazil 2017 for the 6th Review Meeting of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* (Brasil, 2017), 97-98; INB, *Relatório de Gestão 2017*, 55-57.

[220] INB, *Relatório de Gestão 2017*, 57.

[221] CNEN et al., *Report for the 6th Review Meeting of the Convention on Safety of Spent Fuel and Radioactive Waste Management*, 96; INB, *Relatório de Gestão 2016*, 55.

[222] IAEA, *Radiological Accident in Goiânia*, Vienna: IAEA, 1988.

Despite the devastating consequences of the Goiânia incident, Brazil continues to struggle with adequate disposal of disused radioactive sources. In late January 2017, prosecutors launched an investigation into the risk of a radiological accident at hospital facilities in Dourados inappropriately storing disused radioactive sources containing Cs-137.[223]

In January 2019, reports claimed that a disused sealed source containing Cs-137 had been thrown away without proper conditions at a junkyard in Arapiraca, Alagoas, in northeastern Brazil.[224] CNEN sent a team of technicians and determined that the equipment was, in fact, X-ray equipment without any radioactive substance in it. The item can emit radiation if it is connected to a power source.[225] Still, the management of disused radioactive sources continues to be a significant challenge for Brazil's environmental (and nuclear) safety. (See "Radioactive Waste and Spent Fuel Management" in "2 - Governance and Accountability.")

TRANSPORTATION

There have also been reports of problems with the transportation of nuclear and radioactive cargo in Brazil. To date, at least four episodes of inadequate transportation and/or storage have become known. These include the combined transportation of uranium at Brazilian ports on two occasions in 2004, inappropriate storage of uranium cargo due to a breakdown in logistics between land and sea transportation in 2008, and an unusual return of yellowcake from CTMSP to Caetité for redrumming in 2011 (as described above).[226] Between 2014 and 2017, the Brazilian government made significant efforts to adopt legislation on transportation of nuclear and radiological materials. (See "Nuclear Safety and Security" in "2 - Governance and Accountability.")

URANIUM ENRICHMENT AND NUCLEAR FUEL FABRICATION FACILITIES

In the 1990s, the national media reported abnormal situations at enrichment laboratories at Aramar's complex involving limited leakage of uranium hexafluoride inside the facilities.[227]

At INB enrichment and fuel fabrication facilities in Resende, the local community

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[223] "Procuradoria Abre Inquérito sobre Depósito Radioativo em Dourados," IPEN, accessed August 29, 2019, https://www.ipen.br/portal_por/portal/interna.php?secao_id=40&campo=8112; Eduardo Miranda, "Destinação de Fontes Césio 137 em Dourados É Alvo de Investigação," *Correio do Estado*, January 19, 2017, https://www.correiodoestado.com.br/cidades/dourados/destinacao-de-fontes-cesio-137-em-dourados-e-alvo-de-investigacao/295962/; "MP Investiga Risco de Acidente Radiológico em Dourados," IPEN, accessed August 29, 2019, https://www.ipen.br/portal_por/portal/interna.php?secao_id=40&campo=8063.

[224] Aliny Gama, "Vigilância Sanitária Diz Ter Achado Césio-137 em Arapiraca, mas Volta atrás," *Folha de São Paulo*, January 23, 2019, https://www1.folha.uol.com.br/cotidiano/2019/01/capsula-com-cesio-137-e-achada-em-ferro-velho-e-al-evita-acidente-nuclear.shtml.

[225] "Nota de Esclarecimento 1 - Material Encontrado em Arapiraca," CNEN, accessed January 23, 2019, http://www.cnen.gov.br/component/content/article?id=527; "Nota de Esclarecimento 2 - Material Encontrado em Arapiraca," CNEN, accessed August 29, 2019, http://www.cnen.gov.br/component/content/article?id=528.

[226] Duarte, Relatório do GT Fiscalização e Segurança Nuclear, (2007), 185-88; Greenpeace, *Ciclo do Perigo*, 26-27.

[227] "Aramar Teve Acidentes Radioativos," *Jornal do Brasil*, December 28, 1996, 3.

has expressed concerns about the impact on the regional environment during the construction and initial operation of the facility,[228] but the authors could not find indication that any major incident has taken place there.

NUCLEAR POWER PLANTS

No major accident has been reported at nuclear power reactors in Angra dos Reis. Environmental social movements have called attention to potential effects the reactors' operation might have on the ambient aquatic environment due to the discharged coolant water from the plant.[229] The environmentalists also have argued the site is not geologically appropriate. In response, Eletronuclear maintains that the nuclear power reactors and the nuclear power station are fully regulated by CNEN and Ibama and that the company is in full compliance with both nuclear and environmental norms. It also claims that geological survey classify the site as an appropriate location for the nuclear power plants.

The Brazilian government is now discussing how to implement a less restrictive policy for the ecological protection area of Tamoios in Angra dos Reis. This decision might affect the functioning of the nuclear complex, because the existence of a protection area surrounding the nuclear station is one of the conditions with which Eletronuclear must comply as part of the licensing process for the Angra-1, Angra-2, and Angra-3 units. The preservation of this ecological environment is mandated by law and is essential to monitor and verify the potential impacts of the Angra reactors throughout the region.[230]

RESEARCH REACTORS

The authors did not find any data to indicate any major incidents or environmentally hazardous activities at research reactors.

GOVERNING ENVIRONMENTAL PROTECTION IN THE NUCLEAR SECTOR

In Brazil, environmental licensing in the nuclear sector is a federal responsibility. Ibama leads the licensing process of projects "with significant environmental impact in the national or regional scope," and more specifically those "intended to research, mine, produce, benefit, transport, store, and deploy radioactive materials, in any stage, or those that use nuclear energy in any forms and applications, according to

[228] Dalaqua, "Átomos e Democracia no Brasil," 229-37.

[229] "MPF Move Ações por Morte de Tartarugas na Costa Verde," *O Globo*, April 18, 2016, https://oglobo.globo.com/rio/mpf-move-acoes-por-morte-de-tartarugas-na-costa-verde-19111067.

[230] Lucas Altino, "Unidade Ambiental que Bolsonaro Quer Transformar em 'Cancún' É Obrigatória para Funcionamento de Usina Nuclear," *O Globo*, May 19, 2019, https://oglobo.globo.com/rio/unidade-ambiental-que-bolsonaro-quer-transformar-em-cancun-obrigatoria-para-funcionamento-de-usina-nuclear-1-23677393.

assessment by the National Nuclear Energy Commission – CNEN."[231] In practice, this means it is up to Ibama to oversee the process and make the final decision on the licenses' approval, in accordance with the norms and guidelines set by the National Council for the Environment (Conama).[232] In 2015, Ibama adopted specific procedures for the licensing and decommissioning of radiological facilities.[233]

Overall, the environmental licensing process consists of three main components, namely the analysis of the studies that describe and measure the environmental impact of projects; field inspections; and the determination of requirements for the project's installation, including compensation and mitigation measures and plans for environmental monitoring. Processes might also involve public hearings, "whenever suitable, in accordance with pertinent legislation." As part of the licensing process, Ibama first assesses the project's environmental impact and defines the steps that the licensee must take in order to obtain the authorization. If the licensee meets those requirements, Ibama authorizes the construction and finally the operation of the projects in question.

It is also up to Ibama to monitor possible environmental damage caused by operators of nuclear and radiological facilities and investigate and punish them accordingly. In this regard, Ibama issues technical assessments of the periodic reports of environmental monitoring submitted by the operators. It might also conduct inspections in order to verify compliance with the environmental legislation and the terms of the licenses applied to the operation of each facility or investigate and respond to specific episodes of potential or actual damage to the environment. Unlike CNEN, which can only punish by revoking licenses, Ibama can impose a fine or even require a facility to suspend operations. Local environmental authorities at the state level might also intervene to promote environmental protection by means of inspections and imposition of corrective measures.

CNEN's regulations on radiation protection and nuclear safety also include provisions on environmental preservation. Operators must present a program for the radiological monitoring of the environment before activities start, setting a reference baseline for future monitoring. Once the facility starts to operate, the licensee must periodically submit reports on radiological operational monitoring to CNEN, which will check for possible environmental damage vis-à-vis the preoperational baseline.

The Ministry of Health's regulations deal with matters affecting both the natural environmental and human health. Even though Ibama's monitoring focuses on matters affecting the preservation of the natural environment, it has become involved in issues pertaining to public health, especially in uranium mining in Caetité (Bahia).

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231 Conama, Resolução Conama No. 237, de 19 de Dezembro de 1997, *Diário Oficial da União*, December 22, 1997, art. 4.

232 Conama, Resolução Conama No. 001, de 23 de Janeiro de 1986, *Diário Oficial da União*, February 17, 1986; Conama, Resolução Conama No. 11, de 18 de Março de 1986, *Diário Oficial da União*, May 2, 1986; Conama, Resolução Conama No. 5, de 5 de Agosto de 1993, *Diário Oficial da União*, August 31, 1993; Conama, Resolução Conama No. 237, de 19 de Dezembro de 1997, *Diário Oficial da União*, December 22, 1997.

233 Ibama, Instrução Normativa MMA/IBAMA No. 1 (2015).

COORDINATION AMONG REGULATORY AUTHORITIES

Brazil does not have a single authority with a final say over criteria for environmental protection in the nuclear sector. Ibama's documents show that it tried to coordinate field inspections with CNEN and reached out to the Commission for technical support and evaluation of uranium mining in Caetité in some occasions in the 2000s and 2010s. However, bureaucratic disputes and lack of coordination are reality between the two institutions. This is the case because CNEN oversees nuclear regulation on radiological protection and nuclear safety, while federal and state-level environmental agencies spearhead environmental regulation for ecosystems preservation. The differences between these bodies pertain not only to the criteria and procedures for licensing but also enforcement mechanisms.

> **CNEN and Ibama have in the past been at loggerheads on how to classify incidents, determine their scale, and set punitive and mitigating measures.**

CNEN and Ibama have in the past been at loggerheads on how to classify incidents, determine their scale, and set punitive and mitigating measures. In 2000, in Caetité, for instance, Ibama suspended INB's license due to the leakage of 5,000 cubic meters of uranium liquor when INB officials refused to acknowledge the problem. The state-level environmental agency fined INB for not communicating the event, and the prosecutor's office launched a civil lawsuit against the company. But CNEN moved in the opposite direction. Although CNEN officials acknowledged the leakage, they argued there was no environmental damage and decided to maintain INB's operating license while requesting a change to storage tanks to avoid similar incidents in the future. In the following years, CNEN issued temporary licenses to INB Caetité as a way of certifying that the company fully complied with CNEN's requirements, but the conflict over jurisdiction with Ibama and state-level agencies persisted.[234] Part of the problem lies in the fact that Ibama can impose fines on the nuclear operator, but CNEN can only suspend licenses. As a result, two oversight institutions struggle to find permanent solutions and are incentivized to provide temporary licenses only (as a way to force licensees to observe the rules).[235] This results in the sense of uneasiness and insecurity among the local communities who live in the vicinity of nuclear facilities.

Lack of coordination is also expressed in ineffective communication. In 2010, INB informed CNEN about the contamination of a monitoring well by an organic solvent. But neither INB nor CNEN informed Ibama about the event. Ibama only came to know

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[234] Lisboa, Zagallo, Mello, *Relatório da Missão Caetité*, 21-23; Duarte, Relatório do GT Fiscalização e Segurança Nuclear, at 94-99 (2007); Dalaqua, "Átomos e Democracia no Brasil", 117-125.

[235] Duarte, Relatório do GT Fiscalização e Segurança Nuclear, at 94-99 (2007); TCU, Acórdão No. 519/2009, Processo No. 017.897/2007-5, Relator: Min. Augusto Sherman, 23.03.2009, pp. 23-25, https://contas.tcu.gov.br/sagas/SvlVisualizarRelVotoAcRtf?codFiltro=SAGAS-SESSAO-ENCERRADA&seOcultaPagina=S&item0=5041.

about it in 2011, when CNEN issued a press release amid an unrelated political crisis affecting CNEN's presidency.[236]

Conflicts involving different types of regulatory norms similarly bring uneasiness to environmental and radiological protection. One example is a 2011 episode in which a cargo of yellowcake traveled from CTMSP to INB Caetité for redrumming. Even though INB complied with the *nuclear* regulation for transportation and security of the radioactive content, it violated the terms of Ibama's license of operation, which did not include redrumming activities at INB Caetité facilities.[237]

Similar tensions affect the assessment of the potability of water, which might respond to distinct measures set by health, environmental, and nuclear regulatory authorities. In practice, this means that Ibama is solely in charge of the monitoring of the chemical toxicity of radionuclides in interaction with the environment, while potability of water with respect to radioactivity is a responsibility of the Ministry of Health and CNEN. Still, Ibama is required to act in response to matters affecting the potability of waters in the Caetité region.[238]

CONFLICT OF INTERESTS

From 1989 to 2019, CNEN was INB's majority shareholder and sat on its board. Past clashes between CNEN and environmental authorities suggested that CNEN might be vulnerable to conflicting standards in nuclear environmental protection, especially in the assessment of damages and in government responses to them.[239] In the past, this led to divisions within CNEN, pitting the president's office against CNEN's permanent staff. In 2004, for instance, the retention basin of fine materials at INB Caetité overflowed and released liquid containing uranium-238 and radium-226, causing the death of fish in surrounding lagoons. The technical experts from CNEN's Coordination of Nuclear Facilities conducted inspections and identified 25 irregularities (three of which were deemed to be of "serious concern"). Their report recommended the suspension of the authorization for initial operation, but CNEN's president reached out to the IRD for a second opinion. The second report agreed with CNEN's original diagnosis but argued the license should be maintained. The president of CNEN followed IRD, while Ibama opted to fine INB. (See "Nuclear Regulation" in "2 - Governance and Accountability)[240]

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[236] See "Nota à Imprensa Sobre Denúncia / Resposta à Imprensa.", available at Nassif, "O Caso CNEN". Ibama – Coordenação de Mineração e Obas Civis, Vistoria à Área de Lavra Subterrânea da URA – Caetité/BA, Relatório de Vistoria No. 004/2011 (2011).

[237] Ibama – Coordenação de Mineração e Obras Civis, Transporte de Material Nuclear para Reentamboramento na URA – Caetité/BA, Informação No. 10/2011 (2011).

[238] Ibama – Coordenação de Mineração e Obras Civis, Manifestação das Indústrias Nucleares do Brasil S.A. sobre a suposta ocorrência de danos ambientais em Riacho da Vaca, localidade de Caetité, PAR. 139/2011 (2011).

[239] TCU, Acórdão No. 519/2009, Processo No. 017.897/2007-5, Relator: Min. Augusto Sherman, 23.03.2009, pp. 23-25, https://contas.tcu.gov.br/sagas/SvlVisualizarRelVotoAcRtf?codFiltro=SAGAS-SESSAO-ENCERRADA&seOcultaPagina=S&item0=5041.

[240] Greenpeace, *Ciclo do Perigo*, 20-21; Duarte, Relatório do GT Fiscalização e Segurança Nuclear, at 94-99 (2007); "Mina não Tem Autorização do Ibama," *Folha de São Paulo*, December 14, 2004, p.A9.

COMMUNICATION CHALLENGES

Ibama has repeatedly questioned the readiness of nuclear operators such as INB Caetité to communicate incidents to environmental authorities and the local population and to provide accurate and timely information about their activities and their impact on the environment.[241] This inefficiency in communication results in insecurity and misinformation among local communities who feel vulnerable in the face of unknown risks. On October 28, 2009, an estimated 700 liters of uranium-loaded solvent leaked into rainwater tanks. The tanks overflowed, leading to environmental contamination along the course of the water drainage system. Ibama did not find out about the incident until it received information from Greenpeace, more than 15 days after the incident. According to Ibama, the lack of communication resulted in alarm and misinformation in local communities who learned from the press that 30,000 liters (instead of the actual 700 liters) of radioactive solvent would have leaked. Ibama fined INB BRL 1 million.[242]

Ibama has repeatedly questioned the readiness of nuclear operators such as INB Caetité to communicate incidents to environmental authorities and the local population and to provide accurate and timely information about their activities and their impact on the environment.

In Caetité, in particular, the local community is mistrustful of INB. In 2011, the imminent arrival of a cargo of yellowcake shipped from the naval nuclear facility at Iperó – for the purposes of retreatment and redrumming – alarmed the local population, which did not know the content of the cargo and assumed that it was radioactive waste. Three thousand people blocked the roads, forcing INB to call in state police. Protesters allowed the cargo through only after INB, local authorities, social movements, Ibama, and CNEN signed a letter certifying the cargo's contents. On that occasion, Ibama fined INB for BRL 2 million for planning to carry out redrumming without Ibama's previous consent. The miners' union reported at the time that INB contracted external workers who lacked training and operated in

241 Ibama – Coordenação de Energia Elétrica, Nuclear e Dutos, Análise do Relatório "Evento de Transbordamento do Decantador DC – 1602" ocorrido em 28/10/09 na URA, Caetité/BA, PAR. No. 03/2010 (2010); Ibama – Coordenação de Mineração e Obas Civis, Vistoria à Área de Lavra Subterrânea da URA – Caetité/BA, Relatório de Vistoria No. 004/2011 (2011); Ibama – Coordenação de Mineração e Obras Civis, Denúncia de Lavagem de Veículos da Mina e Usina da URA – Caetité/BA, PAR. No. 40/2011 (2011);); Ibama – Coordenação de Mineração e Obras Civis, Vistoria à URA-Caetité, no período de 25 a 28 de março de 2013, PAR. 004362/2013 (2013); Ibama – Coordenação de Mineração e Obras Civis, Informações sobre Eventos não Usuais na URA-Caetité, Informação Técnica No. 008/2011 (2011).

242 "Ibama Multa Empresa que Explora Urânio em R$ 1 milhão," *Estadão*, November 22, 2009, https://sustentabilidade.estadao.com.br/noticias/geral,ibama-multa-empresa-que-explora-uranio-em-r-1-milhao,470391; "INB Esconde Vazamento de Urânio," Greenpeace, accessed on November 17, 2017, http://www.greenpeace.org/brasil/pt/Noticias/inb-esconde-vazamento-de-ur-ni/; Ibama – Coordenação de Energia Elétrica, Nuclear e Dutos, Análise do Relatório "Evento de Transbordamento do Decantador DC – 1602" ocorrido em 28/10/09 na URA, Caetité/BA, PAR. No. 03/2010 (2010).

unsuitable conditions to carry out redrumming. This process resulted in the release of radioactive uranium dust.[243]

Another recurrent problem is INB's communication with local residents when water contamination in wells in surrounding communities is reported by either the media or the local community itself. Locals claim that levels of radionuclides are higher than the reference parameters, while INB argues that this is the result of the geological profile of the region and the presence of natural radioactive elements.[244] Sometimes, complaints pertain to wells that are outside of INB's monitoring area.

SOCIAL MOVEMENTS

Social movements promoting environmental protection in the areas affected by nuclear industries are sparse, small, and usually weak. Their origins date back to the 1970s and the early 1980s when they focused mostly on opposition to the construction of the Angra nuclear site. By and large, these Brazilian movements are disconnected from transnational NGOs working in the nuclear field, such as Greenpeace. In the aftermath of the Fukushima accident in 2011, the antinuclear agenda gained some momentum with the creation of the Brazilian Antinuclear Network (*Articulação Antinuclear Brasileira*) and the Coalition for a Nuclear-Plant-Free Brazil (*Coalizão por um Brasil Livre de Usinas Nucleares*), which advocates, among other things, a constitutional amendment to prohibit construction, installation, and operation of nuclear power plants in the country. These antinuclear movements did not gain any significant traction.

Local communities have been more active in the uranium mining areas. These groups include Catholic Church leaders, *quilomba* communities (former freed-slave enclaves), local politicians, miners' and farmworkers' unions (*Sindicato dos Mineradores de Brumado e Micro Região e Sindicato dos Trabalhadores Rurais de Caetité e Pindaí*), rural regional organizations, and national human rights organizations (*Plataforma Dhesca*). As INB plans to expand uranium mining to the Santa Quitéria site, a new anti-uranium-mining coalition is actively trying to draw in social movements, research groups, and local communities – the Antinuclear Articulation of Ceará (*Articulação Antinuclear do Ceará*) – to resist uranium and phosphate mining. The initiative replicates similar actors in the antinuclear movement in Caetité: local grassroots organizations, rural groups such as the Landless Rural Workers' Movement (*Movimento dos Trabalhadores Rurais Sem Terra*), Catholic parish associations (*Comissão Pastoral*

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[243] *De Caetité (BA) a Santa Quitéria (CE) - As sagas da exploração do urânio no Brasil*, produced by Núcleo Tramas – UFC, 2013, 65 min, https://www.youtube.com/watch?v=4sA_-ClFaZA; Lisboa, Zagallo, and Mello, *Relatório da Missão de Caetité*, 59-63; Ibama – Coordenação de Mineração e Obras Civis, Transporte de Material Nuclear para Reentamboramento na URA – Caetité/BA, Informação No. 10/2011 (2011); Ibama – Coordenação de Mineração e Obras Civis, Vistoria à Área da URA – Caetité/BA, Relatório de Vistoria No. 016/2011 (2011); "Urânio entre o Caos e o Silêncio," Instituto Humanitas Unisinos, accessed http://www.ihu.unisinos.br/noticias/43456-uranio-entre-o-caos-e-o-silencio. For a narrative of the events of this episode, see Dalaqua, "Átomos e Democracia no Brasil," 155-58.

[244] Dalaqua, "Átomos e Democracia no Brasil," 159-63; Borges and Sampaio, "Urânio Contamina Água na Bahia"; André Borges, "Força-Tarefa Vai Apurar Contaminação por Urânio na Bahia," *Estadão*, August 24, 2015, https://brasil.estadao.com.br/noticias/geral,forca-tarefa-vai-apurar-contaminacao-por-uranio-no-sertao-da-bahia,1749480; Lisboa, Zagallo, and Mello, *Relatório da Missão Caetité*, 59-63.

da Terra, *Cáritas Diocesana de Sobral*), and human rights organizations (*Coletivo Flor de Urucum - Direitos Humanos, Comunicação e Justiça*). The *Núcleo Trabalho, Meio Ambiente, Saúde* (Tramas) of the Federal University of Ceará is also part of the coalition. In 2013, Tramas released a movie[245] to raise awareness about the environmental impact of uranium mining in Caetité and question the plans to expand mining to Santa Quitéria. Since 2016, the network has engaged public audiences and maintained contact with the national environmental authorities to denounce the environmental implications of the project (for example, water use, contamination, and waste). It remains unclear when (and if) mining at Santa Quitéria will begin, given that no operating license has been issued so far.

[245] De Caetité (BA) a Santa Quitéria (CE) - As sagas da exploração do urânio no Brasil, produced by Núcleo Tramas – UFC, 2013, 65 min, https://www.youtube.com/watch?v=4sA_-ClFaZA.

NUCLEAR SAFETY AND SECURITY

For the purposes of this report, the authors adopt the IAEA's definition of nuclear security as "the prevention of, detection of, and response to, criminal or intentional unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities, or associated activities" and "the prevention and detection of and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities."[246]

Nuclear and radioactive material present distinct challenges. The IAEA defines nuclear material as uranium-235, uranium-233, plutonium, and irradiated fuel.[247] Highly enriched uranium (HEU) and plutonium can be used directly in a nuclear device. A detonation of even a simple nuclear device would have far-reaching immediate and long-term consequences. The immediate consequences could include death and injuries, contamination of the environment, and disruption of economic activity, including interruption of trade and supply chains. A single nuclear incident could also have a serious long-term impact on entire industries. The nuclear industry would be the first victim since a nuclear incident would generate nuclear phobia and opposition to all nuclear-related activities, including peaceful nuclear power programs.

Radioactive material presents a different kind of risk. Some materials – for example, cobalt-60, cesium-137, iridium-192, strontium-90, americium-241, californium-258, plutonium-238, and radium-226 – present the risk that they could be used in a radiological dispersal device or "dirty bomb."[248] In scale and impact, a dirty bomb cannot be compared to a nuclear explosive device. The number of immediate victims and the size of the contaminated territory will be immensely lower. Nonetheless, an incident involving a dirty bomb would contaminate the immediate territory where it was used and might claim numerous victims. Such an incident would also have a psychological effect on society.

In addition to deliberate misuse of nuclear or radioactive material, there exists a safety risk – release of radioactivity due to an accident. For the purposes of this report, the authors use the IAEA's definition of nuclear safety as "the achievement of proper

[246] IAEA, *Nuclear Security Series Glossary Version 1.3* (November 2015), 18, http://www-ns.iaea.org/downloads/security/nuclear-security-series-glossary-v1-3.pdf.

[247] Ibid., 17.

[248] Charles D. Ferguson, Tahseen Kazi, and Judith Perera, *OP#11: Commercial Radioactive Sources: Surveying the Security Risks* (Monterey, CA: CNS, 2003).

operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation hazards."[249]

STATE OF THE FIELD IN BRAZIL

ANGRA NUCLEAR POWER PLANT

In May 2018, the IAEA conducted a review of long-term operational (LTO) safety of the Angra nuclear power plant at the request of Eletronuclear. The IAEA team focused on Angra-1, which began operation in 1985.[250] The plant has a standard operating license, which is valid for 40 years. To extend the plant's lifetime for another 20 years, to 2045, Eletronuclear needs to apply for a new license from CNEN. According to Eletronuclear, the preparations for the license application are underway and Eletronuclear expected to apply for it by October 2019.

The IAEA team concluded that the plant had implemented appropriate measures to address fatigue of safety-significant components. The IAEA team praised the plant's management for active support of educational activities. At the same time, it recommended several measures to improve safety, such as ensuring that aging of active and short-lived structures and components within the scope of the LTO review are appropriately assessed and managed, fully implementing a comprehensive environmental qualification program, and conducting comprehensive periodic safety reviews.[251] According to Eletronuclear, it carries out comprehensive periodic safety reviews every 10 years. The most recent one was conducted in 2014 and the next one is expected to take place in 2024.

The safety features of the unfinished third Angra unit have been the object of intense debates in Brazil.[252] Critics of Angra-3's safety design argue that since the project was developed in the 1970s, its safety features are obsolete.[253] Sidney Luiz Rabello, safety engineer at CNEN, has claimed that Angra-3 will not be equipped to deal with large-scale and complex accident sequences such as accidents that took place at the Three

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[249] IAEA, IAEA *Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection* (2007), p.133, https://www-pub.iaea.org/MTCD/publications/PDF/Pub1290_web.pdf.

[250] "IAEA Concludes Long-Term Operational Safety Review at Brazil's Angra Nuclear Power Plant," IAEA, accessed August 29, 2019, https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-at-brazils-angra-nuclear-power-plant.

[251] Ibid.

[252] Chico Whitaker, "Brumadinho, Flamengo, Angra: e o Bom Senso?," *Folha de São Paulo*, March 5, 2019, https://www1.folha.uol.com.br/opiniao/2019/03/brumadinho-flamengo-angra-e-o-bom-senso.shtml; Leonam dos Santos Guimarães, "Mais Luz na Questão Nuclear," *Folha de São Paulo*, March 19, 2019, https://www1.folha.uol.com.br/opiniao/2019/03/mais-luz-na-questao-nuclear.shtml; Chico Whitaker, "Angra 3, e o que Virá em 2018?," *Folha de São Paulo*, January 28, 2018, https://www1.folha.uol.com.br/opiniao/2018/01/1953760-angra-3-e-o-que-vira-em-2018.shtml; "O Dilema de Angra 3," *Folha de São Paulo*, November 24, 2018, https://www1.folha.uol.com.br/opiniao/2018/11/o-dilema-de-angra-3.shtml; Leonam dos Santos Guimarães, Lúcio Ferrari, and Jorge Mendes, "Segurança de Angra 3: Mitos e Verdades," Clube de Engenharia, accessed July 4, 2018, http://portalclubedeengenharia.org.br/2018/07/04/seguranca-de-angra-3-mitos-e-verdades/; Sidney Luiz Rabello, "Angra 3: uma Usina Obsoleta e Insegura," *Jornal do Brasil*, June 26, 2019, https://www.jb.com.br/index.php?id=/acervo/materia.php&cd_matia=923681&dinamico=1&preview=1.

[253] Whitaker, "Brumadinho, Flamengo, Angra"; Rabello, "Angra 3.

Usinas de Angra-1 e Angra-2 (Foto: Saulo Cruz, Ministério de Minas e Energia, CC BY-NC 2.0)

Mile Island, Chernobyl, and Fukushima Daiichi nuclear power plants.[254]

Eletronuclear managers object to this criticism. They note that CNEN granted licenses for Angra-3 and that the project is regularly reviewed in order to incorporate changes in regulations and lessons learned from the operation of Angra-2. They also point out that contingency plans exist for cases of severe accidents and that the lessons from the nuclear accidents at Three Mile Island, Chernobyl, and Fukushima Daiichi were integrated into safety planning for Angra-3.[255]

In 2011, for example, Eletronuclear formed a technical group and started developing a special plan to incorporate the lessons learned from the nuclear accident in Japan in March of that year. This plan lasted until 2015. First, it reassessed the safety risks and threats associated with natural disasters. In particular, it sought to improve the prevention of landslides in areas near the plant by building additional retaining walls on the hills and expanding the program that monitors the stability of the slopes. Eletronuclear's studies also considered the most critical scenarios involving earthquakes and flooding caused by heavy rains and concluded that the existing infrastructure was capable of responding to these events. The plan also considered scenarios of high waves caused by hurricanes and the occurrence of tornadoes and recommended specific measures to improve the existing infrastructure of protection and to update equipment.

Second, the plan established a package of updates of the existing structures, systems, and equipment to improve response measures in case of an accident, including the use of portable equipment such as electricity generators to cool the reactors in case of damage of safety mechanisms caused by a natural disaster and the adoption of systems to keep radioactive materials inside the plant in case of an accident. Finally, Eletronuclear decided to adopt measures to improve the infrastructure for carrying out its emergency plans, such as the creation of new routes for personnel's displacement and the transportation of equipment by land and sea.[256]

[254] Rabello, "Angra 3".

[255] Guimarães, Ferrari, and Mendes, "Segurança de Angra 3".

[256] "Informação sobre a Situação do Plano de Resposta à Fukushima da Eletronuclear (atualizada em março de 2014)", ABEN, accessed on October 24, 2019, http://www.aben.com.br/Arquivos/170/170.pdf; André Luiz Lopes Quadros, "Aprendizagem, Inovação e Comunicação: A Dinâmica Evolutiva de um Plano de Emergência Nuclear" (PhD diss., UFRJ, Rio de Janeiro, RJ, 2014), 192-195; Eletronuclear, *Relatório de Gestão do Exercício de 2014* (2015), 56; Eletronuclear, *Relatório de Gestão do Exercício de 2015* (2016), 29, 34.

In February 2018, Eletronuclear announced completion of a study that described the safety improvements adopted in the design of Angra-3. One key improvement was the digitalization of control room operations. (See "Nuclear Cybersecurity" in "2 - Governance and Accountability)[257]

In terms of physical protection, Angra faces a double set of vulnerabilities: risks typical for any nuclear facility and risks specific to the plant because of its location. The most significant potential risk any nuclear power plant faces is an attack that results in disruption of safe operations. For example, an attack on the reactor control room can prevent plant personnel from controlling reactor operation. In another example, the intentional cutting of electrical power can disrupt the cooling system and lead to a reactor meltdown.

The plant's location in Angra dos Reis poses some security vulnerabilities not faced by most nuclear installations. The region is prone to violent crime. In recent years, the security situation has deteriorated due to the availability of high-caliber weapons and the reorganization of the illegal drug markets in the area surrounding the plant.

In 2017-2018, on three occasions, armed criminals robbed cash machines in the residential areas affiliated with the plant (*Vila Residencial de Prata Brava* and *Vila Residencial de Mambucaba*). While the attacks happened away from the plant itself, which is better protected than the residential area, and the criminals were motivated by financial gain rather than terrorist or other motivations, the fact that the criminals could not be apprehended and that they escaped by sea points to general security vulnerabilities in the region that hosts a nuclear facility.[258]

In early 2018, drug lords who control nearby communities refused to grant the plant's maintenance personnel access to the emergency sirens located in the community of Frade, located in the vinicity of the Angra nuclear power station.[259] The sirens are indispensable in informing the public in case of an emergency. Eventually, the Angra maintenance crew received access to the sirens and performed the needed maintenance.

In February of 2018, Fernando Jordão, the mayor of Angra dos Reis, threatened to order a halt to the operation of the plant if the federal government failed to deploy the National Security Force and the Army for its protection.[260] In May a strike by truckers

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257 "Eletronuclear Divulga Estudo sobre Melhorias de Segurança Feitas em Angra 3," ABEN, accessed August 29, 2019, http://www.aben.com.br/noticias/eletronuclear-divulga-estudo-sobre-melhorias-de-seguranca-feitas-em-angra-3#noticia.

258 "Agência do Banco Santander É Assaltada na Vila Residencial de Mambucaba," Eletronuclear, accessed on April 25, 2018, http://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/Ag%C3%AAncia-do-banco-Santander-%C3%A9-assaltada-na-Vila-Residencial-de-Mambucaba.aspx; "Comunicado sobre Assalto a Agências Bancárias na Vila Residencial de Praia Brava," Eletronuclear, accessed on April 25, 2018, http://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/Comunicado-sobre-assalto-a-ag%C3%AAncias-banc%C3%A1rias-na-Vila-Residencial-de-Praia-Brava.aspx; "Bancos da Central Nuclear de Angra e das Vilas Residenciais Suspendem Movimentação de Dinheiro," Eletronuclear, accessed on April 25, 2018, http://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/Bancos-da-central-nuclear-de-Angra-e-das-vilas-residenciais-suspendem-movimenta%C3%A7%C3%A3o-de-dinheiro.aspx.

259 Giselle Ouchana, "Tráfico Impede o Acionamento de Sirenes de Usina de Angra," *O Globo*, January 3, 2018, accessed August 29, 2019, https://oglobo.globo.com/rio/trafico-impede-acionamento-de-sirenes-de-usina-de-angra-22248638.

260 "Prefeito de Angra Ameaça Pedir Desligamento de Usinas," *Angra News*, February 8, 2018, accessed August 29, 2019, http://angranews.com.br/prefeito-de-angra-ameaca-pedir-desligamento-de-usinas/.

prompted Jordão to declare a state of emergency in Angra dos Reis. In August the mayor declared a state of emergency again due to violence initiated by warring drug lords. Jordão demanded federal intervention and warned that the nuclear power plant might have to shut down.[261]

NUCLEAR AND RADIOACTIVE MATERIALS

Brazil possesses nuclear material at only a handful of facilities. Radioactive material, on the other hand, can be found in many facilities and sites since it is widely used in nuclear research, the medical field, the agricultural and food sectors, and other industries.

The transportation of valuable and hazardous substances such as nuclear and radioactive materials poses potential safety and security risks. Insufficient implementation of regulatory requirements and sloppy logistical procedures add vulnerabilities.

In Brazil, facilities that use or produce nuclear and/or radioactive material are operated by military (Navy) and civilian agencies. By design, Navy facilities have greater protection than civilian facilities. Public facilities, such as hospitals and universities, are designed to be freely accessible to the public.[262]

The Global Incidents and Trafficking Database maintained by the James Martin Center for Nonproliferation Studies lists four publicly reported incidents involving radioactive material in Brazil between 2013 and 2017. On December 4, 2013, police seized 22 drums with radioactive medical material stored at a shipping company in São Paulo. The company's manager was arrested and charged with illegal possession of toxic substances. On February 7, 2014, the Civil Defense Forces found a radioactive source (cesium-137) at an abandoned industrial building in Cuiabá. On June 9, 2014, CNEN was called to collect randomly discovered bottles with iridium-125 at the Inca-3 National Cancer Center. On May 19, 2015, a plastic package containing a radioactive (molybdenum) source was stolen near the city of Carazinho. The radioactive source, which is used for diagnosis in the medical field, was a product of IPEN bound for the Ijui Charity Hospital Association.[263]

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261 Ibid.

262 CNEN regulations for nuclear safety and security do not differentiate between civilian and military facilities. Its regulations differentiate between facilities that produce/use radiological material and facilities that produce/use nuclear material.

263 Shea Cotton, Sam Meyer, Anne Pellegrino, *CNS Global Incidents and Trafficking Database – 2017 Annual Report*, (Nuclear Threat Initiative – CNS, 2018), 14.

vulnerabilities. In 2004, on at least two occasions, ships with enriched uranium arriving from abroad tried to dock at the Port of Salvador to collect mined uranium from Caetité without the prior consent of regulatory authorities.

On the first occasion, in January 2004, the Danish ship *Jens Munk*, which was en route to the Port of Rio de Janeiro, anchored at the Port of Salvador with 40 tons of enriched uranium. While in Salvador, the ship was to be loaded with 113 tons of U_3O_8 from Caetité, which would then be sent to Canada for conversion into UF_6 and enrichment. Even though INB had the licenses for transporting enriched uranium from Canada to Rio and for transferring yellowcake from Caetité to Salvador,[264] the company did not have the documents authorizing a ship carrying enriched uranium to stop over at the Port of Salvador in order to carry out the so-called combined operation. According to the Report on Nuclear Monitoring and Safety elaborated by the rapporteur of the Environment Commission of the Brazilian House of Representatives in 2006, neither the Navy nor Ibama knew in advance that the ship anchored in Salvador was carrying such enriched uranium. When Ibama found out about it, it prohibited the ship from docking at the port. INB claimed that it had taken an exceptional action that it would not repeat. After negotiating with INB, Ibama allowed the ship to dock and be loaded with yellowcake. MPF urged Ibama to take action to curb the risks involved in the transportation of radioactive cargo in the Bay of Todos os Santos, where the Port of Salvador is located.[265]

Despite INB's commitments to Ibama, the company tried to carry out another combined operation six months later, in September 2004. On that occasion, Ibama issued to INB a fine of BRL 1 million that had been recommended by MPF. The executive manager of Ibama, Julio Rocha, said that cargo posed risks for the Bay of Todos os Santos, an environmental protection area under Brazilian law. In November 2004, the environmental authority prohibited any form of combined operation involving uranium cargo at the port of Salvador.[266]

The rapporteur of the Environment Commission expressed concern with those two events because the ships involved were proprieties of J. Poulsen Shipping A/S, a Danish company with a controversial record on safety and security. Earlier in February 2003, a ship similar to the *Jens Munk* had sunk in the Mediterranean. Furthermore, the company's ships had transported armaments to South Africa in violation of the UN embargo in force in the 1970s and 1980s.[267]

The mismanagement of logistics in the transportation of radioactive cargo was stark in at least two other events. In May 2008, a cargo of 175 tons of yellowcake from Caetité had to wait at an unsuitable storage facility for four days because the ship expected to transport it could not dock at the port of Salvador. Another ship had problems in the loading of cargo at Salvador and delayed operations at the port. For safety reasons, the

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264 Licenses of Operation 366/2004 and 368/2004, respectively. "Nota de Esclarecimento sobre o Transporte de Urânio em Território Brasileiro," Ministério do Meio Ambiente, accessed August 29, 2019, https://www.mma.gov.br/informma/item/1718-nota-de-esclarecimento-sobre-o-transporte-de-uranio-em-territorio-brasileiro.html.

265 Comissão de Meio Ambiente e Desenvolvimento Sustentável, Rapporteur: Edson Duarte, Relatório do Grupo de Trabalho Fiscalização e Segurança Nuclear, Câmara dos Deputados (2006), 129-30.

266 Duarte, Relatório do GT Fiscalização e Segurança Nuclear, 130.

267 Ibid., 131-32.

port operator did not receive the uranium cargo, which had to be transferred to the transportation company's facilities. These facilities did not have specific procedures to handle radioactive cargo. The local newspaper *A Tarde* reported that the uranium cargo was stored outdoors, not separated from other containers, and that the facility had only two security officers on each shift.[268] No incident or accident was reported and the cargo loading took place once the port operators allowed it. According to INB officials, the cargo was inspected and measured before being brought onboard the ship in order to verify that no material had been diverted. The Federal Police monitored the operation at the port.[269]

In the second incident, a cargo of 178 tons of uranium concentrate bound for France had to return to Caetité because transportation requirements were not met. The cargo left Caetité on July 12, 2012. In the middle of the trip to Salvador, INB found out that the transportation company had not provided notification at least 15 days in advance to France's Ministry of Ecology and Sustainable Development and Ministry of Energy, as required by French law. The company decided to stop the convoy in Feira de Santana, at a military police battalion, only 100 kilometers from Salvador, and then return to Caetité, 630 kilometers from Salvador, to wait for the proper authorization. By that time, the authorization to bring the uranium onboard was expected to be issued only on July 20, so the convoy returned to Caetité.[270] The Federal Highway Police followed the convoy on all the routes.[271]

The rise of criminality in Brazil is another pressing factor affecting the security of nuclear material during transportation. In March of 2019, a convoy of trucks carrying nuclear fuel from Resende to Angra nuclear power plant came under rifle fire when it was passing the Frade community. Located 12 kilometers away from the Angra nuclear power station, the community is now dominated by a drug gang. The Federal Highway Police that escorted the convoy exchanged shots with the gang members.[272] In its official statement, Electronuclear said that the convoy with nuclear fuel was not a target and that "some bandits, frightened by the strong police apparatus, shot at the Federal Highway Police vehicle. Police officers retaliated, but there were no injuries or material damage." Electronuclear reiterated that even if the metal containers holding nuclear fuel had been perforated by the bullets, there would not have been a radiological incident since the "uranium contained in the nuclear fuel is in natural state" and has "the same radioactivity level of that found in nature." [273]

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[268] Adilson Fonsêca, "Carga de Urânio É Armazenada sem Seguir Normas de Segurança," *Jornal A Tarde*, May 18, 2008, accessed August 29, 2019, https://atarde.uol.com.br/bahia/salvador/noticias/1249799-carga-de-uranio-e-armazenada-sem-seguir-normas-de-seguranca.

[269] Danile Rebouças, "Urânio Finalmente Deixa o Porto e Vai para o Canadá," *Jornal A Tarde*, May 18 2008, accessed August 29, 2019, https://atarde.uol.com.br/bahia/salvador/noticias/1289757-uranio-finalmente-deixa-o-porto-e-vai-para-o-canada.

[270] Celso Calheiros, "Carga de Urânio Vai e Volta pelas Estradas da Bahia," *O Eco*, July 18, 2012, accessed August 29, 2019, https://www.oeco.org.br/noticias/26257-carga-de-uranio-de-caitite-vai-e-volta-pelas-estradas-da-bahia/.

[271] "Cento e Setenta e Oito Toneladas de Urânio Ficam Retidas na Bahia," *G1*, July 13, 2012, accessed August 29, 2019, http://g1.globo.com/bahia/noticia/2012/07/cento-e-setenta-e-oito-toneladas-de-uranio-ficam-retidas-na-bahia.html.

[272] Dom Phillips, "Brazilian Drug Gang Opens Fire on Convoy of Trucks Carrying Nuclear Fuel," *The Guardian*, March 20, 2019, accessed August 29, 2019, https://www.theguardian.com/world/2019/mar/20/brazilian-drug-gang-opens-fire-on-convoy-of-trucks-carrying-nuclear-fuel.

[273] "Esclarecimento da Eletronuclear sobre Incidente Envolvendo Transporte de Combustível," Eletronuclear, accessed

In addition, Brazil faces vulnerabilities when it comes to the management for handling radioactive sealed sources. A recent example highlights specific challenges with safe disposal of disused radiological sources. The Evangelical Hospital in Dourados maintains several disused radiological sources containing Cs-137 which it must dispose of. Previously, the hospital had an agreement with the Cancer Treatment Center of Dourados. According to this agreement, the Center would handle the disposal of disused radiological sources for the hospital. The impasse arose after CTCD failed to obtain a license from the regulator – CNEN – to handle radioactive material. This happened because Brazilian legislation prohibits two companies located at the same address from handling radioactive material. Without CNEN's license, CTCD could not move disused radiological sources for safe disposal at another location. In 2017, MPF opened an investigation into the risk of a radiological incident at Dourados.[274] The fact that CNEN has neither the legal authority nor adequate infrastructure to carry out the collection of disused radioactive sources across Brazil, a continent-sized country, is another factor of concern. (See "Radioactive Waste and Spent Fuel Management" in "2 - Governance and Accountability.")

Both military and civilian facilities handling nuclear material, in theory, are vulnerable to a so-called insider threat.[275] All internationally known cases of theft of nuclear material (none of which involved Brazil) relied on either direct involvement of insiders or help from insiders. The motivation driving insiders might come from various sources. Nuclear custodians can be subject to blackmail and pressured to help with unauthorized access to material. Disgruntled nuclear custodians may attempt to divert nuclear material and may be motivated by profit.[276]

GOVERNING NUCLEAR SAFETY AND SECURITY

Brazil has an overarching legislative and regulatory framework for the management of nuclear and radioactive material. Traditionally, the regulators and nuclear custodians focused on safety aspects, but in recent years, Brazil has taken steps to strengthen its nuclear security capacity.

GSI

At the political level, Sipron under the GSI oversees the safety and security of Brazil's entire nuclear sector. The idea of "protection" that sets the legal baseline[277] for the

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August 29, 2019, https://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/Esclarecimento-da-Eletronuclear-sobre-incidente-envolvendo-transporte-de-combust%C3%ADvel.aspx.

[274] "Procuradoria Abre Inquérito sobre Depósito Radioativo em Dourados," IPEN, accessed August 29, 2019, https://www.ipen.br/portal_por/portal/interna.php?secao_id=40&campo=8112.

[275] Matthew Bunn and Scott Douglas Sagan, *Insider Threats* (Ithaca: Cornell University Press, 2016); Matthew Bunn and Scott D. Sagan, A *Worst Practices Guide to Insider Threats: Lessons from Past Mistakes* (Cambridge, Mass.: American Academy of Arts and Sciences, 2014).

[276] Matthew Bunn and Scott D. Sagan, A Worst Practices Guide to Insider Threats: Lessons from Past Mistakes, American Academy of Arts and Sciences, 2014.

[277] Presidência da República, Decreto no. 9.668, de 2 de janeiro de 2019. *Presidência da República*, January 2, 2019.

Chemical, biological, and radiological defense (Photo by the Brazilian Army / CC BY-NC-SA 2.0)

work of Sipron encompasses both security and safety provisions, which merge in the same institutional framework. In this regard, responsibilities are broadly defined, as Sipron is meant to "protect" a diverse set of targets, from information, technology, and nuclear facilities to people and the environment.

Within the Sipron structure, two decision-making bodies are dedicated only to nuclear security. The Committee for the Articulation of Security and Logistical Areas dates back to 2012[278] and is conceived as an instrument to coordinate the actions aimed at "mitigating and neutralizing activities that impede or hamper the functioning of nuclear facilities and the transportation of nuclear materials and sensitive equipment for the Brazilian Nuclear Program" and "preventing and avoiding the interference in the activities of the Brazilian Nuclear Program by institutions, organizations, and entities that do have the legal competence to interfere in the nuclear activities in the country."[279] In June 2019, GSI created a new committee especially focused on the coordination of response actions to nuclear-security-related incidents in Angra dos Reis, including the assessment of threats and risks affecting the security of the nuclear power station.[280]

Most of the threat assessments pertaining to nuclear security however fall outside the scope of the main mandate of Sipron and are carried out by another entity, the Brazilian Intelligence Agency (Abin), which is also involved in nonnuclear sectors. Currently, Abin is mainly dealing with export controls on sensitive goods (through the Interministerial Commission for the Export Control of Sensitive Goods), which adopts a nonproliferation mindset for assessment of threats and risks.[281] Moreover, Abin prepared a threat assessment report for the uranium mining complex in Caetité in 2010. Abin's methodology for its threat-based reports covers physical protection, protection of information systems and personnel management, and essential services. It also seeks to assess the existence of threats, vulnerabilities in the security systems, and

[278] GSI, Portaria No. 31, de 26 de Março de 2012, *Diário Oficial da União*, March 27, 2012.

[279] Presidência da República, Decreto no. 9.865, de 27 de junho de 2019. *Presidência da República*, June 27, 2019.

[280] Presidência da República, Decreto no. 9.865, de 27 de junho de 2019. *Presidência da República*, June 27, 2019.

[281] "Não-Proliferação," ABIN, accessed August 29, 2019, http://www.abin.gov.br/atuacao/areas-prioritarias/nao-proliferacao/.

their potential negative impacts.[282] Abin is also involved in counterterrorism actions. Senior officials at CNEN's nuclear security team have attempted to introduce new types of threats, such as cyber, aerial, and long-distance attacks, into such national assessments.[283]

The remainder of Sipron's structure, planning and activities deals with "emergency response.". Established over the years, it gives particular emphasis to "nuclear emergencies," especially those affecting facilities in Angra (nuclear power plants) and Resende (enrichment and fuel fabrication facilities). Both nuclear safety and nuclear security risks might fall into the category of "emergency response."[284]

CNEN

As the main regulator of the nuclear sector, CNEN sets the standard for both nuclear safety and nuclear security. Norms on safety are more numerous and are constantly revised by the commission.

The normative framework for nuclear security still requires substantial reforms, which are currently being carried out within CNEN. According to senior officials at the Commission's nuclear security divisions, nuclear security regulation has primarily focused on the nuclear power plants, which require more stringent and comprehensive prescriptions.

CNEN is carrying out a regulatory transformation towards a "graded" approach to nuclear security standards which are tailored to a facility or activity in accordance with its specific nuclear security needs.

In this context, CNEN is carrying out a regulatory transformation towards a "graded" approach to nuclear security standards which are tailored to a facility or activity in accordance with its specific nuclear security needs.[285] In November 2019, CNEN adopted a new set of regulation on nuclear security, which differentiates nuclear security norms in three areas: the security of operational facilities in the nuclear sector (NE 2.01), the security of nuclear materials and facilities (NN 2.01), and the security of radioactive sources and associated radiological facilities (NN 2.06). The new norm on the security of nuclear facilities includes provisions on mitigating the insider threat.

CNEN is also in charge of inspections in the nuclear sector, which verify whether nuclear operators have complied with the existing terms of reference for safety and

282 "Avaliação de Riscos," ABIN, accessed August 29, 2019, http://www.abin.gov.br/atuacao/produtos/avaliacoes-de-riscos/.

283 Renato L. A. Tavares, "Physical Protection of Brazilian Nuclear Material and Facilities: Challenges and Actions" (Power-point presentation, 60 Years of IEA-R1, International Workshop on Utilization of Research Reactors, IPEN, São Paulo, SP, November 30, 2017).

284 "Sistema de Proteção ao Programa Nuclear Brasileiro", GSI, accessed October 24, 2019, http://gsi.gov.br/sipron-1/sipron.

285 Tavares, "Physical Protection of Brazilian Nuclear Materials and Facilities".

security. Even though CNEN has managed to verify the required level of nuclear safety and security in recent years, there have been two pressing challenges that might affect the performance of such tasks: lack of human resources and insufficient budget allocation, in contrast with the continuously growing nuclear sector, which now includes nearly 2,300 facilities where nuclear and radioactive materials are present. (See “Human Resources and Education” in “2 - Governance and Accountability.”)

ADDITIONAL DEVELOPMENTS

Since the 1990s, Brazil has been strengthening nuclear safety and security procedures and practices and mitigating potential risks. It has, for instance, converted all its research reactors from highly enriched uranium (HEU) to low-enriched uranium (LEU), and it has repatriated all foreign-origin HEU fuel elements to the country of origin.[286]

In 2014, it passed new regulations for the transport of radioactive and nuclear sources, and in 2017, the Environment Commission in the Senate approved a bill for the monitoring of radioactive and nuclear cargo in the country.[287]

CNEN and Sipron are acting together with other partners to regularly offer seminars, workshops, and training events for facilities handling nuclear and radiological material and to promote nuclear security culture. According to CNEN, nearly 450 professionals were trained in nuclear security in the last 10 years.[288] These activities are aimed at mitigating a range of challenges related to nuclear safety and security, such as dealing with emergencies, accidents, and security breaches.

In emergency drills and actual emergencies, Sipron now coordinates the safety and security measures, integrating the work of nuclear and radioactive facilities with those of national and regional defense forces (such as municipal and state civil defenses). Emergency drills are conducted on at least an annual basis.[289]

Following the accident in the Fukushima Daiichi nuclear power station, Brazil decided to adapt the then existing emergency plans implemented by the federal and local authorities (for example, Sipron, the Armed Forces, civil defense) in the areas surrounding the Angra nuclear power complex. These simulations of accidents started considering a scenario of dispersion of a radioactive cloud. This type of scenario included new actions both outside and in the field such as the monitoring of the environment and the use of new techniques. One of such techniques involved the use of the ARGOS software for the measurement of the dispersion of the cloud

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[286] Sara Z. Kutchesfahani, Kelsey Davenport and Erin Connolly, *The Nuclear Security Summits: An Overview of State Actions to Curb Nuclear Terrorism 2010–2016* (Washington, D.C.: Arms Control Association, 2018); Linardi, *O IPEN e a Inovação Tecnológica*; Laércio Vinhas, Rajendra Saxena and Roberto Frajndlich, “60 Years of IEA-R1” (Roundtable presentation, 60 Years of IEA-R1, International Workshop on Utilization of Reasearch Reactors, IPEN, São Paulo, SP, November 11, 2017).

[287] Kuntchesfahani, Davenport and Connolly, *The Nuclear Security Summits*, 26.

[288] Tavares, “Physical Protection of Brazilian Nuclear Materials and Facilities”.

[289] Ibid.

based on meteorological data. The post-Fukushima plans also included the use of sea routes for evacuating the local population and the division of the surrounding areas into two parts, helping to divide responsibilities between the Army and the Navy in preparation for emergencies.[290]

At the regional level, Brazil cooperates with its partners in the Southern Common Market (Mercosur) to prevent, detect, and respond to the threat of illicit trafficking of nuclear and radioactive materials.[291]

According to CNEN, all nuclear facilities in Brazil have safety and security plans and procedures systems approved by the Commission.[292] Physical protection plans are part of the licensing process for all nuclear facilities in Brazil. Physical protection procedures follow the norms established by CNEN and the IAEA (in particular, INFCIRC/225). In addition, the nuclear operators regularly host facility-specific trainings and exercises and cooperate on nuclear safety and security with international partners such as the IAEA and foreign universities.

According to CNEN, all nuclear facilities in Brazil have safety and security plans and procedures systems approved by the Commission. Physical protection plans are part of the licensing process for all nuclear facilities in Brazil.

At INB facilities, for example, the system includes detection and intrusion alarms (along the perimeter and at the gates), monitoring of potential intrusion (video surveillance, electronic rounds, lights in isolated zones), access control (personnel, material, equipment, and vehicles). In addition, INB holds regular meetings at the managerial level to share information on incidents within the organization. Sharing of information on incidents also takes place on an online platform – INB Online – which allows any INB staff to ask interactive questions. INB also maintains a system of internal alerts. INB designed a manual on internal security culture and carries out mandatory annual training. Its employees participate in external seminars.

Similar physical protection measures and access control over personnel, material, equipment, and vehicles are implemented at the Angra nuclear power plant. The entire facility and surrounding premises are divided into different security zones, depending on the level of protection required. Eletronuclear holds daily meetings to discuss any operational issues.

Navy facilities have adopted similar measures.

In the nuclear R&D sector, Brazil's primary nuclear research institution, IPEN has

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[290] Quadros, "Aprendizagem, Inovação e Comunicação", 192-195; Dalaqua, "Átomos e Democracia", 305-311.

[291] "Argentina, Brasil, Paraguai e Uruguai se Reúnem para Tratar do Combate ao Tráfico Ilícito de Material Nuclear," CNEN, accessed August 29, 2019, http://www.cnen.gov.br/ultimas-noticias/344-argentina-brasil-paraguai-e-uruguai-se-reunem-para-tratar-do-combate-ao-trafico-ilicito-de-material-nuclear.

[292] Tavares, "Physical Protection of Brazilian Nuclear Materials and Facilities.

instituted the staff position of nuclear security officer and is actively engaged in training nuclear operators, researchers, and students from across Brazil. Finally, the universities training the next generation of nuclear personnel have begun including nuclear security in their curriculum, with the Federal University of Rio de Janeiro leading the way.

NUCLEAR CYBERSECURITY

STATE OF THE FIELD

The growth of cybercrime in Brazil is staggering. During this decade alone, cyber incidents soared from 399,515 in 2010 to 833,775 in 2017, with the highest activity recorded in 2014, when more than 1 million incidents were reported.[293] In 2018, the government's Computer Security and Incident Response Team dealt with approximately 15,300 notifications and 9,600 incidents.[294] Symantec, one of the world's largest cybersecurity companies, ranks Brazil as the 10th most affected country in the world for malicious online activity.[295] Most cybercrime in Brazil involves bank fraud and content-related offenses such as racism and child pornography on social media. Other cyber threats worldwide involve copyright and trademark violations, offenses against companies and businesses, cyberterrorism, cyber warfare, attacks against critical infrastructure, cyber espionage, and hacktivism.

While there have been no reports of cyberattacks on Brazilian nuclear facilities to date,[296] cybersecurity at nuclear installations should be taken seriously. Recent intentional cyberattacks against nuclear facilities worldwide have revealed the vulnerability of these facilities to digital threats.[297] Online attacks can cause confusion, create market instabilities, allow the theft of sensitive or valuable information, prepare for a future attack, or in extreme scenarios, cause direct disruption or sabotage in the operation of a nuclear facility.[298] Electronic data in the nuclear sector has become more vulnerable to hostile cyber actions as facilities digitalized their control systems, increased connectivity with external networks, and turned to commercial off-the-shelf systems. Cyber threats to the

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[293] CERT.br, Estatísticas dos Incidentes Reportados ao CERT.br (Total de Incidentes Reportados ao CERT.br por Ano), accessed August 29, 2019, https://www.cert.br/stats/incidentes/.

[294] CIRTGov, CTIRGov em Números, accessed October 29, 2019, https://emnumeros.ctir.gov.br/.

[295] Symantec, *Internet Security Threat Report – Government* (Mountain View, CA: Symantec Corporation, 2016).

[296] Gustavo Diniz, Robert Muggah, and Misha Glenny, *Deconstructing Cyber Security in Brazil: Threats and Responses* (Igarapé Institute, 2014).

[297] For a list of cyber incidents at nuclear facilities worldwide, see Alexandra Van Dine, Michael Assante, and Page Stoutland, *Outpacing Cyber Threats: Priorities for Cybersecurity at Nuclear Facilities* (Nuclear Threat Initiative, 2016), 31-32.

[298] Caroline Baylon, Roger Brunt, and David Livingstone, *Cyber Security at Civil Nuclear Facilities: Understanding the Risks* (London: Chatham House, 2015), 6-7.

nuclear sector may include hostile actions using automated cyberattack tools.[299]

Ironically, in Brazil, the greater age of older critical nuclear infrastructure might have protected it from cyber risks. The two operating nuclear power plants, Angra-1 and Angra-2, date back to the late 1970s and early 1980s, when plants relied mostly on analog systems – that is, hardwired systems that carried out computational tasks. Even though most systems were "insecure by design" back then, as they did not include cybersecurity features, any disruption would require a physical change in the arrangement of circuits instead of a programming alteration.[300]

The control room at Angra 1 in February 2018 (Photo by Saulo Cruz, Ministry of Mines and Energy, CC BY-NC 2.0)

But the cyber environment at nuclear power plants is changing rapidly. The control systems at both Angra reactors have undergone gradual digitalization in recent years.[301] Angra-3 is expected to be a fully digitalized nuclear plant.[302] Digitalized plant systems may be therefore susceptible to external modification and cyber disruptions. A more vulnerable environment for instrumentation and control (I&C) systems could result, for example, in interception and modification of electronic data and compromising of information integrity. Another scenario could involve a partial or complete blockage of data transmission lines, which could produce a shutdown of the systems at the nuclear plants.[303]

Industry experts argue that nuclear plants are protected by "isolation" because their I&C systems, the operational core of the facility, are air-gapped – that is, they are not connected to any external networks such as the Internet. However, other indirect Internet connection ports, which are increasingly used to share electronic data relating to areas such as finance, performance, and emergency procedures with off-site actors, might also be a pathway for external access by cyberattackers, despite the existence of firewalls protecting the operational core. Even if the air gap

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299 Baylon, Brunt, Livingstone, *Cyber Security at Civil Nuclear Facilities*, 8-10.

300 Ibid., 9, 23.

301 For more information on measures for the digitalization of Angra-1 and Angra-2, see Eletronuclear's annual reports (*Relatório de Gestão*) from 2010 to 2016, available at http://www.eletronuclear.gov.br/Canais-de-Negocios/Paginas/Processo-de-Contas.aspx.

302 Nacim M. Mod, "Brazilian Power Generation" (Eletronuclear, Angra dos Reis), April 2018.

303 IAEA, *Computer Security at Nuclear Facilities: Technical Guidance, Reference Manual,* (Vienna, IAEA: 2011), 39, 43.

of the I&C were entirely effective, there would still be a chance of an unauthorized, unnoticed connection set by an insider or in loco infection by hardware such as a USB drive. Moreover, systems connected to the Internet that are not involved in the direct operation of the plant (for example, access control, information management, and waste management) remain prone to cyberattacks, which can compromise the confidentiality, integrity or availability of electronic data.[304]

Another concern pertains to the protection of industrial data against cyber espionage by global competitors; this especially applies to national technologies used in the nuclear fuel cycle and naval nuclear reactor construction. A cybersecurity breach might result in the loss of confidential information. The integrity and availability of information must also be protected to avoid disruptions in industrial systems, which could compromise equipment and complex operations such as enrichment. Hostile actions such as these could not only compromise industrial secrecy and technology, but also jeopardize plant operation and therefore endanger nuclear safety. Moreover, any serious case of a cybersecurity breach and public exposure of vulnerability will likely further breed public distrust of nuclear activities.

GOVERNING CYBERSECURITY IN THE NUCLEAR SECTOR

Brazil still lacks laws and regulations for cybersecurity in its nuclear activities. The Nuclear Threat Initiative assigned Brazil a score of zero for nuclear cybersecurity in its Nuclear Security Index in 2016 and 2018.[305] The absence of a nuclear-specific framework of governance for cybersecurity is a vulnerability in its own right, as it prevents the government from developing an effective response capacity. However, it would be wrong to assume that government officials are desensitized to the dangers. Relevant rules are dispersed among a range of norms encompassing nuclear security, cybersecurity, information security, cyber defense, and security of critical information infrastructure. As a result, legislation and policies for the protection of electronic data in the nuclear sector do exist, but they are spread across multiple layers of governance with little if any coordination.

INFORMATION SECURITY AND CYBER SECURITY

According to the IAEA, information security in the nuclear sector concerns "the system, program or set of rules in place to ensure the confidentiality, integrity, and availability of information in any form,"[306] while cybersecurity applies the same to "electronic data or computer systems and processes."[307] In Brazil, nuclear

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[304] For "modes of cyber infection" of a nuclear facility, see Baylon, Brunt, Livingstone, *Cyber Security at Civil Nuclear Facilities*, 10-12.

[305] NTI, *Building a Framework for Assurance, Accountability, and Action* (Nuclear Threat Initiative, January 2016), 14; NTI, *Building a Framework for Assurance, Accountability, and Action* (Nuclear Threat Initiative, September 2018), 88.

[306] IAEA, *Computer Security at Nuclear Facilities*, 5.

[307] Ibid, 2.

Since the first Information Security Policy was adopted in 2000, the implementation of the information security policy by the federal administration has not been a smooth process, and the nuclear sector has been no exception. In 2008, the Federal Court of Accounts (TCU) published a report that identified technical and institutional gaps in the implementation of the information security policy across the government and issued a list of recommendations to all state bodies to modernize the system.

operators follow specific policies for *information* security, which includes, for instance, cybersecurity and cyber defense. The first Information Security Policy adopted in 2000,[308] has been recently revised. The new National Information Security Policy established in December 2018 sets the goal of "assur[ing] the availability, integrity, confidentiality and authenticity of information at the national level" and guides the implementation of actions to secure state and critical infrastructure information, to protect individuals' information, and to classify sensitive information.[309] The GSI's Department of Information Security, a division of the Secretariat for Systems Coordination, controls these activities. This secretariat also controls Sipron. The National Information Security Policy also established the Management Committee of Information Security as an advisory group to the GSI in matters of information security. Overall, the department is the main political body responsible for planning, guidance, coordination, and development of information security policies in the country.[310] Moreover, since 2009, the GSI runs the Government Center for Treatment and Response to Cyber Incidents (CTIR Gov), which monitors and responds to incidents affecting the government's networks. Brazil's intelligence agency, Abin, also plays a role by overseeing risk and threat assessment for the protection of sensitive knowledge.

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308 Decreto No. 3.505, de 13 de Junho de 2000, *Diário Oficial da União*, June 14, 2000.

309 Decreto No. 9.637, de 26 de Dezembro de 2018, *Diário Oficial da União*, December 12, 2018.

310 GSI, Portaria No. 91, de 26 de Julho de 2017, *Diário Oficial da União*, July 27, 2017.

311 Decreto No. 3.505, de 13 de Junho de 2000, *Diário Oficial da União*, June 14, 2000.

issued a list of recommendations to all state bodies to modernize the system.[312] The president's office also issued a regulatory guidance document for the management of information security in the public sector which served as the baseline for operators such as Eletronuclear[313] and CNEN[314] to develop their own information security systems. Since then, CNEN, CTMSP, and INB developed specific policies and established institutional structures to tackle the problem of information security. In accordance with the new National Information Security Policy (2018), state institutions must, for instance, develop internal policies and norms on the matter, establish an information security committee and nominate its manager, allocate a budget for information security, build capacity and expertise, create groups to respond to incidents, audit their actions, and punish violations of the information security policy.[315]

In recent years, cybersecurity has become part of the discourse within the federal government and references to cybersecurity appeared in the national legal framework. New laws and decrees were adopted to provide a legislative basis for the preservation of networks' integrity,[316] investigation of hostile cyber actions,[317] criminalization of[318] and law-enforcement[319] against cybercrimes, and cyberterrorism,[320] and handling of classified information.[321] Strengthening the legal provisions for implementing cybersecurity measures did not necessarily translate into effective governance; the excess of legal norms in the Brazilian law compromises the ability of the legal system to adapt in a timely way to the volatile environment of cyberspace.[322] The federal government is now drafting the cybersecurity component of the National Information Security Strategy. [323]

Even though the national policy on cybersecurity is still unfolding, the nuclear sector has taken actions to get educated in this area. For instance, Brazilian nuclear officials and experts participated in IAEA-sponsored training in cybersecurity in Argentina, Chile, and Mexico in 2012, 2014, and 2016. Brazil also hosted three IAEA courses on computer security between 2013 and 2017. Moreover, the Polytechnic School of the University of São Paulo is currently a member of the IAEA Coordinated Research Project for the implementation of three centers of the International Training Course on Computer Security. Figure 7 lists some of these capacity-

312 Levantamento de Auditoria, TC-008.380/2007-1, Rapporteur: Guilherme Palmeira, 13.08.2008.

313 Eletronuclear, *Política de Segurança da Informação* (2009).

314 CNEN, Portaria No. 4, de 9 de Janeiro de 2017, *Diário Oficial da União*, Januray 16, 2017.

315 Decreto No. 9.637, de 26 de Dezembro de 2018, *Diário Oficial da União*, December 12, 2018.

316 Lei No. 12.965, de Abril de 2014, *Diário Oficial da União*, April 24, 2014.

317 Ibid.

318 Lei No. 12.737, de 30 de Novembro de 2012, *Diário Oficial da União*, December 3, 2012.

319 Lei No. 12.735, de 30 de Novembro de 2012, *Diário Oficial da União*, December 3, 2012.

320 Lei No. 13.260, de 16 de Março de 2016, *Diário Oficial da União*, March 17, 2016.

321 Lei No. 12.527, de 18 de Novembro de 2011, *Diário Oficial da União*, November 18, 2011; Decreto No. 7845, de 14 de Novembro de 2012, *Diário Oficial da União*, November 16, 2012.

322 Diniz, Muggah, and Glenny, *Deconstructing Cyber Security in Brazil*, 21.

323 "Estratégia Nacional de Segurança da Informação (ENSI)", GSI, accessed on October 29, 2019, http://www.gsi.gov.br/noticias/2019/estrategia-nacional-de-seguranca-da-informacao-ensi.

building initiatives taken by Brazil in nuclear cybersecurity. In 2016, CNEN held conversations with the IAEA for the establishment of a regional e-learning platform in nuclear cybersecurity, but no further development has happened since then.[324]

Figure 7 – Training Courses on Nuclear Cybersecurity with the IAEA

TRAINING COURSES ON NUCLEAR CYBERSECURITY WITH THE IAEA

#	IAEA Primary Training Course	Brazilian officials and experts' participation (point of contact: CNEN)
1	Basic Information and Computer Security Awareness (2011)	Attended the course in Argentina (2012) Course held in Rio de Janeiro; Professorship (2013) Attended the course in Chile; Professorship (2014)
2	Conducting Computer Security Assessments (2013)	Attended the course in Mexico + Professorship (2016)
3	Advanced Course in Information and Computer Security (2014)	Course held in Rio de Janeiro; Professorship (2014)
4	Computer Security for Nuclear Industrial Control Security (ICS) and Instrumentation and Control (I&C) Systems (2016)	Course held in Rio de Janeiro; Professorship (2017) (This course served as reference baseline for the Training Course #5)
5	International Training Course on Computer Security (2 week ITC) (Proposed for 2018)	The Polytechnic School of the University of São Paulo is currently a member of the IAEA Coordinated Research Project for the implementation of three centers of the International Training Course on Computer Security (Austria/US/South Korea).

Source: Adapted from Rodney Busquim, "Segurança Cibernética em Instalações Nucleares: ações conjuntas com a Agência Internacional de Energia Atômica" (power-point presentation, IV Simpósio de Ciência, Tecnologia e Inovação da Marinha, October 31, 2017).

CYBER DEFENSE

In 2014, the government published a new Military Doctrine of Cyber Defense.[325]

The new Cyber Defense Command – a joint command with all three branches of the Armed Forces – oversees initiatives for cyber protection of critical infrastructure, with a special focus on the nuclear and financial sectors. In 2018, officials and information technology (IT) experts from the nuclear sector participated in their first Cyber Guardian Exercise, which involved a series of simulations of cyberattacks on critical infrastructure. The event combined tabletop exercises in which high-ranking officials simulated the decision-making response to emergencies resulting from a cyberattack with technical training for IT experts who were expected to respond to a diverse sample of attacks in cyberspace. The simulations were designed with the help of Simoc, a platform for cyber operations simulations developed by the Brazilian Army in

[324] CNEN, *Relatório de Gestão 2016*, 57.

[325] Ministério da Defesa, *Doutrina Militar de Defesa Cibernética* (Brasília, 2014).

partnership with the IT firm Decatron.[326]

Cyber defense (Photo by the Brazilian Army /CC BY-NC-SA 2.0)

The exercise provided stakeholders in critical infrastructures an opportunity to track down their system's vulnerabilities, identify best practices, and adapt current information security policies based on the results from the simulations. The event also included a debate on developing a cyber defense policy with a specific focus on the protection of nuclear (and financial) critical infrastructure. Operators of all critical infrastructure facilities in the nuclear sector - Eletronuclear, INB,[327] and CTMSP – participated in the first exercise.[328]

CRITICAL INFORMATION INFRASTRUCTURE

So far, capacity-building efforts have focused on the protection of critical nuclear infrastructure, but there is a growing emphasis on critical information infrastructure. A Reference Guide for Security of Critical Information Infrastructure adopted in 2010[329] provides tools for asset mapping, risk management, and issuance of safety alerts. The

326 "Exército Brasileiro Começa a Utilizar Simulador de Guerra Cibernética, o Simoc," Canaltech, January 25, 2013, accessed August 29, 2019, https://canaltech.com.br/seguranca/Exercito-brasileiro-apresenta-simulador-de-guerra-cibernetica-o-Simoc/.

327 Exército Brasileiro, "Brasil Cyber Defence - Maior Evento de Defesa Cibernética do País". Video. Youtube Video, 3m40s, https://www.youtube.com/watch?v=yd37sX8U3Gg.

328 "Edição de Evento Cibernético Estimula Trabalho Colaborativo entre Forças Armadas, Órgãos Públicos e Privados," Exército Brasileiro, accessed August 29, 2019, http://www.eb.mil.br/web/noticias/noticiario-do-exercito/-/asset_publisher/MjaG93KcunQI/content/id/9007697; "ComDCiber - 1º Exercício Guardião Cibernético," DefesaNet, accessed August 29, 2019, http://www.defesanet.com.br/cyberwar/noticia/29755/ComDCiber---1--Exercicio-Guardiao-Cibernetico-/1/6; "Exercício Guardião Cibernético Reúne Especialistas em TI, Gestores de Crise e Tomadores de Decisão," DefesaNet, accessed August 29, 2019, http://www.defesanet.com.br/cyberwar/noticia/29795/Exercicio-Guardiao-Cibernetico-reune-especialistas-em-TI--gestores-de-crise-e-tomadores-%E2%80%A63/7; *Estado e Iniciativa Privada se Unem para Combater os Ataques Cibernéticos*, Telebrasil, Youtube Video, 4m42s, May 28, 2018, https://www.youtube.com/watch?v=CYP5rTHCGpU; "Governos e Empresas Privadas Realizam Treinamento contra Ataques Cibernéticos," DefesaNet, accessed August 29, 2019, http://www.defesanet.com.br/cyberwar/noticia/29781/Governo-e-empresas-privadas-realizam-treinamento-contra-ataques-ciberneticos/; "Eletronuclear Participa de Exercício Guardião Cibernético em Brasília," Eletronuclear, accessed August 29, 2019, http://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/Eletronuclear-participa-de-Exerc%C3%ADcio-Guardi%C3%A3o-Cibern%C3%A9tico-em-Bras%C3%ADlia.aspx; "Exercício Guardião Cibernético Treina Especialistas na Proteção de Ataques Virtuais," Brasil – Ministério da Defesa, accessed August 29, 2019, https://www.defesa.gov.br/noticias/44716-exerc%C3%ADcio-guardi%C3%A3o-cibern%C3%A9tico-treina-especialistas-na-prote%C3%A7%C3%A3o-de-ataques-virtuais; "Marinha do Brasil Participa do I Exercício Guardião Cibernético," Marinha do Brasil, accessed August 29, 2019, https://www.marinha.mil.br/noticias/marinha-do-brasil-participa-do-i-exercicio-guardiao-cibernetico.

329 GSI, *Guia de Referência para a Segurança das Infraestruturas Críticas da Informação* (Brasília: GSIPR/SE/DSIC), 2010.

Department of Information Security at the GSI is in charge of policy making on the security of critical information, while a separate structure at the GSI, the Secretariat for National Defense and Security Affairs, is responsible for the actual monitoring of critical infrastructure. Abin is also involved in risk and threat evaluations concerning critical infrastructure.

COORDINATION AND INTEGRATION

No unified norms guide cybersecurity at Brazilian nuclear facilities, and no single institution is in charge of the overall policy. This makes Brazil vulnerable, as it is unclear how various bodies tasked with different parts of cybersecurity policy will coordinate their responses in the case of an attack to a nuclear facility.

Brazil's experience with integrating information security into the day-to-day operation of nuclear operators was not smooth. It required a push from political actors outside of the nuclear sector, such as the GSI and TCU, to make it happen. This suggests that similar challenges will likely be encountered with integrating cybersecurity norms into the nuclear sector.

RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT

The management of radioactive waste and spent fuel involves procedures to separate, treat, store, and provide final disposal for hazardous substances and materials. In the case of Brazil, the regulatory framework for management of these materials is ill-equipped to cope with the current levels of nuclear activity.

GOVERNING RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT

National legislation and norms still do not provide a sound framework for radioactive waste and spent fuel management. Specific regulations on radioactive waste management have been adopted only very recently, and the existing legal framework creates an unbalanced distribution of responsibilities among the actors involved in the process. For example, legal instruments assign conflicting responsibilities to different actors, which in the end undermines CNEN's effectiveness in fulfilling its legal responsibility to provide for final disposal of radioactive waste and supervise waste management. The national regulatory framework on radioactive waste management also fails to provide a coordinated framework for the actors involved, especially when it comes to data gathering; transfer of radioactive waste to intermediate and, eventually, final storage facilities; and control of disused sealed radioactive sources.

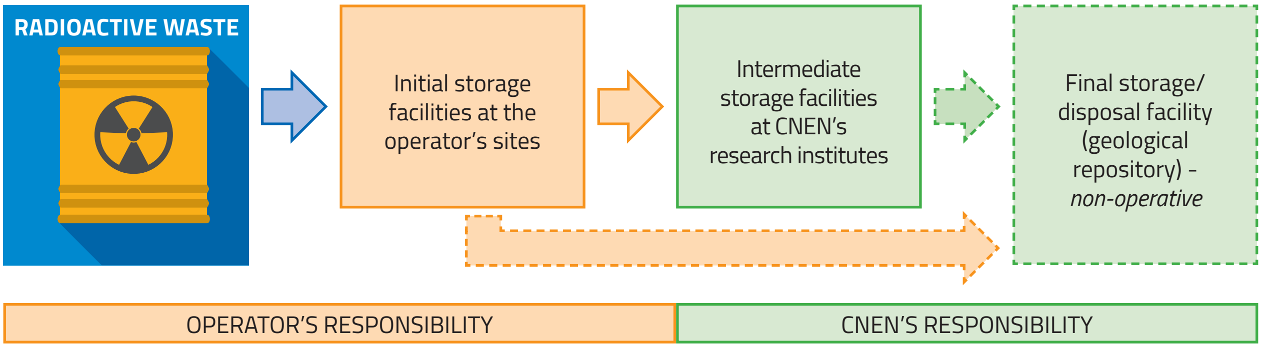
As a result, past environmental liabilities remain unresolved and radioactive waste accumulates at initial-storage facilities on the sites where it is generated and at intermediate facilities with limited capacity. Furthermore, the government has not reached a final decision on the permanent disposal of spent fuel in the country. Still, should Brazil elect to reprocess its spent nuclear fuel, it will need to deal with the remaining radioactive waste, including the high-level waste produced by reprocessing. Thus, the lack of an effective operational framework for the management of radioactive waste and spent fuel compromises the storage capacity of existing disposal facilities for such materials and could eventually jeopardize the operation of power plants and research reactors.

CNEN AND THE SYSTEM OF RADIOACTIVE WASTE MANAGEMENT

CNEN has primary responsibility for receiving and storing radioactive waste, while it also sets the regulations and norms on the safety and security of such material.[330] CNEN also holds the special authority to set the rules for the siting, construction, licensing, and monitoring of facilities for storing radioactive waste, both its own and those of the operators involved in the waste management system.[331] For all intents and purposes, CNEN acts as an operator and a regulator at the same time.

Existing regulations specify three types of radioactive waste storage in Brazil: initial, intermediate, and final. While CNEN has the legal authority and responsibility over design, construction, and operation of intermediate and final storage facilities, it is up to nuclear and radiological operators in the field to manage initial separation, treatment, and storage (including design and construction of related facilities) of their own waste, as well as the provision of transportation from initial to intermediate or final storage facilities.[332]

Figure 8: Brazil's system for radioactive waste and spent fuel management



In practice, however, the actual functioning of radioactive waste management is not as straightforward as it looks on paper.

First, the formal model applies only to low- and medium-level radioactive waste. Brazil does not classify spent fuel as high-level radioactive "waste" because no final political, economic or technical decision has been made on whether to reprocess it.[333] As a result, high-level radioactive waste is stored in loco at operating facilities outside of CNEN, as in the case of the Angra reactors. Unlike low- and medium-level radioactive waste, no specific legislation guides the initial storage of spent fuel in the country. Instead, CNEN publishes norms on the operation of nuclear facilities that define the technical requirements for the temporary protection of such radioactive waste at nuclear facilities.

330 Lei No. 7.781, de 27 de Junho de 1989, *Diário Oficial da União*, June 6, 1989.

331 Lei No. 10.308, de 20 de Novembro de 2001, *Diário Oficial da União*, November 21, 2001.

332 Lei No. 10.308, de 20 de Novembro de 2001, *Diário Oficial da União*, November 21, 2001; CNEN Norma NN 8.01; CNEN Norma NN 6.09; CNEN Norma NN 8.02.

333 CNEN, *National Report of Brazil 2017: for the 6th Review Meeting of the Joint on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*, (Rio de Janeiro, 2017), 16.

Second, transfers of low- and medium-level radioactive waste from initial- to intermediate-storage facilities have been minimal. As a result, public operators in the nuclear sector have kept most of their radioactive waste in loco at initial-storage facilities. What was first conceived as temporary storage has become in practice indefinite long-term storage since Brazil has yet to build a geological repository for the final disposal of radioactive waste. The only existing final repository today in Brazil is located in Abadia de Goiás, disposing of radioactive waste produced during the 1987 Goiânia radiological accident. The repository is closed and cannot receive any additional waste. Furthermore, CNEN's existing intermediate-storage facilities have limited storage capacity, as they are meant to serve only as temporary storage. Given such limitations, these facilities have for the most part received radioactive waste coming from private medical and industrial facilities and from CNEN's own research institutes, not from public nuclear facilities, which continue to accumulate such waste.

Third, existing legal instruments that could mitigate this problem are unclear. The national legislation prescribes one possible solution. Initial-storage facilities at mining and milling facilities could be converted into final-storage facilities if CNEN provides the necessary authorization. The same law, however, states that if CNEN delegates the operation of final-storage facilities to third parties, CNEN should remain legally responsible for any radiological damage caused by radioactive waste stored at these facilities.[334] This provision might add another layer of uncertainty to the radioactive waste management system; it does not specify what CNEN's legal responsibilities and authorities are in the case of a third party operating such final waste storage facilities.

Finally, the lack of coordination among norms and actors involved in the system of radioactive waste management creates vulnerabilities for the national nuclear policy. One particular concern is the management of disused sealed radioactive sources. CNEN itself acknowledges it as one of the "largest waste problems from the nonpower application," as this category comprises long-lived radionuclides such as radium-226 and americium-241 (in the case of radioactive disused lightning rods).[335]

Here details matter. Brazil's health authority, Anvisa, prohibits medical facilities from storing Co-60 sources used in radiotherapy that are below a certain level of radioactivity and requires that operators return them to either the manufacturer or CNEN. Likewise, CNEN limits the number of sources that operators can use for industrial gammagraphy: if companies want to import new sources, they must first return to the manufacturer those that that are no longer suitable or send them to one of CNEN's intermediate-storage facilities.[336] Overall, CNEN's norms prohibit operators from storing disused sealed radioactive sources at installations of any kind (in medicine, industry, research

[334] Lei No. 10.308, de 20 de Novembro de 2001, *Diário Oficial da União*, November 21, 2001.

[335] CNEN, *National Report of Brazil 2017*, 101. Relatório 2017, p. 101. CNEN stopped granting authorization for the use of lightning rods containing americium-241 only in 1989. For more information on radioactive lightning rods in Brazil, see Paulo de Oliveira Santos, Fábio Silva, "Management of Radioactive Disused Lightning Rods" (Paper, 2013 International Nuclear Atlantic Conference, Associação Brasileira de Energia Nuclear, Recife, PE, November 24-29, 2013).

[336] For more information, see Questions and Answers posted to Brazil for the Review Meeting of the Joint Convention 2015, http://www.cnen.gov.br/images/cnen/documentos/drs/relatorios-de-convencao/Questions_Answers_15.pdf, accessed on October 30, 2019.

and education, distribution, services, or production of radiopharmaceuticals).[337] In sum, disused sealed radioactive sources must not accumulate in loco. However, CNEN does not have a legal obligation to collect these sources (or any radioactive waste). The transportation of such hazardous material from the initial to the intermediate facilities is the responsibility of the licensee operator, not CNEN.[338]

To collect disused radiological sources, CNEN depends on formal requests made by the owners. After the Goiânia accident, CNEN tried to overcome this challenge on two occasions by conducting campaigns to collect disused radioactive sources in 1989 (in the northeastern part of the country) and 1998 (in southern Brazil). Since then, no other campaigns have taken place.[339] In the case of radioactive lightning rods (their production stopped in 1989), so far IPEN has collected 12,000 items, but an estimated 68,000 more remain to be transferred to the intermediate-storage facilities.[340] These radioactive sources are dispersed across civilian and private organizations throughout the territory of a country the size of a continent. If not handled properly, they could endanger public health and the environment or could be obtained and misused by criminals.[341] (See "Nuclear Safety and Security" in "2 - Governance and Accountability.")

The problem is further aggravated by the fact that CNEN does not have a national, unified database of radioactive waste. CNEN requires that all radiological and nuclear facilities have their own inventory of radioactive waste and that they submit it to CNEN, which collects and consolidates the list every month. The database templates, however, differ. CNEN is currently developing a unified national database for radioactive waste so that data can be uploaded with standard parameters to optimize the process.[342]

It is unclear whether Brazilian authorities will act upon these challenges. Some officials argue that the current system is fully compliant with the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management because it establishes a division of labor between CNEN's operational arm (the Directorate for Research and Development) and its regulatory arm (the Directorate for Radiation Protection and Nuclear Safety). But the quality of radioactive waste management in the country is clearly unsatisfactory. Although there have been calls for the creation of a state-owned Brazilian Radioactive Waste Company, no further development has occurred.

ENVIRONMENTAL LIABILITIES

CNEN published its first norms on radioactive waste management in 1985. It updated the norms in 2014 and for the first time, included provisions on the licensing of

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337 CNEN, *National Report of Brazil 2017*, 123.

338 Lei No. 7.781, de 27 de Junho de 1989, *Diário Oficial da União*, June 6, 1989; CNEN, *National Report of Brazil 2017*, 123-24.

339 CNEN, *National Report of Brazil 2017*, 124.

340 Ibid., 101.

341 Ibid., 101, 123-24.

342 CNEN, *National Report of Brazil 2014: for the 5th Review Meeting of the Joint on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* (Rio de Janeiro, 2014), 131.

radioactive waste facilities. The rules for the licensing of mines and milling projects were introduced only in 1989, with poorly specified requirements on radioactive waste management and decommissioning. New radiological safety requirements for mining projects were approved in 2004 and updated in 2016.

Failure to develop such norms in the past has left a legacy of persisting environmental liabilities, especially at old mining and milling projects in the country. Those projects started to operate before the norms were in place and did not follow a consistent normative framework on radioactive waste management or decommissioning. That was the case for radioactive waste disposed of at INB facilities in cities such as Caldas, São Paulo, and Itu.

Uranium mining in Caldas, in the state of Minas Gerais, was carried out between 1982 and 1995, but plans adopted ever since have failed to reverse the environmental impact of the mine. Radioactive waste there has been kept in a 29.2-hectare tailings dam system with a capacity of 1 million cubic meters, containing substances with U-238, Ra-226, and Ra-228 disposed of at the site, as described in Table 6. Inappropriate waste disposal during and after the operation of the Caldas mine led to contamination of the open-pit mining area, the waste rock piles, and the tailings dam. Radiological control has been carried out at the disposal areas of effluents coming from the dam and the waste rock piles, and chemical treatment is carried out to avoid further contamination by acid water.[343] Some amounts of waste were separated from the mine pit and are now kept at waste storage facilities (silos, ponds, and the like), together with the hazardous substances produced from the mining of monazite sands in other parts of the country. CNEN and the MPF in Minas Gerais described the infrastructure as precarious.[344] INB sees Caldas as the most critical environmental vulnerability under the company's responsibility.

Table 6 - Hazardous waste disposal at Caldas Ore Treatment Unity

HAZARDOUS SUBSTANCES	AMOUNT	STORAGE/ DISPOSAL	LOCATION
Mesothorium (Ra-226 and Ra-228)	1,300 tons	13,000 drums (50 liters each)	Waste dam
	280 tons	2,700 drums (50 liters each)	Silos at the slope of the waste dam; the silos are lined and covered with 3 m thick layer of clay and soil
	600 tons	5,750 drums (50 liters each)	Trench at the slope of the waste dam; trench is covered with 2 m thick layers of clay and soil

343 CNEN, *National Report of Brazil 2017*, 26, 97.

344 "Lixo Nuclear de Extinta Mina de Urânio Ocupa Área de Cem Maracanãs," *G1*, September 16, 2017, accessed August 29, 2019, http://g1.globo.com/jornal-nacional/noticia/2017/09/lixo-nuclear-de-extinta-mina-de-uranio-ocupa-area-de-cem-maracanas.html.

HAZARDOUS SUBSTANCES	AMOUNT	STORAGE/ DISPOSAL	LOCATION
Cake II (thorium hydroxide concentrate)	11,000 tons	19,400 drums (200 liters each) + 16,250 drums (100 liters each)	Sheds
	1,734 tons	Not applicable	Concrete silos (this material is now being treated)
	Unspecified	1,600 drums (200 liters each)	Sheds (Goianite Cake II, from experiments for the extraction of rare earths. The Goianite mineral contains a low thorium content)
	534 tons	3,560 drums (200 liters each)	Silos close to the waste dam
	124 tons	824 drums (200 liters each)	Unspecified Inaremo – very low thorium content; neutralized waste
Thorium (ThO_2)	32.9 tons	n/a	Disposed of in a pond
	46.6 tons	148 concrete containers	Concrete containers
Calcium Diuranate	217,000 tons (containing 308 tons of U_3O_8)	n/a	Acid mine drainage by adding hydrated lime; slurry resulting from the process – calcium diuranate – is pumped into the mine pit

Source: Based on CNEN, *National Report of Brazil 2017*, 97-98.

The collapse of tailings dams in areas where mining of iron ore was taking place in Mariana and Brumadinho, in the state of Minas Gerais, in 2015 and 2019 raised concerns among local authorities and population about the structural integrity of the INB's radioactive waste dam in Caldas.[345] Since then, INB has taken actions to provide information regarding the situation in Caldas through press releases, on-site visits, and public hearings in the region of the Poços de Caldas plateau.[346]

On September 25, 2018, an "unusual event" took place in INB's tailings dam in Caldas, causing the reduction of water flow from the drainage systems as well as the appearance of unexpected color alterations of the water. INB informed Ibama, CNEN, and the MPF about the event, which did not happen again. A technical report by the Federal University of Ouro Preto has identified grave damage to the drainage system

[345] "Comissão Vai Pedir Visita Técnica para Atestar Segurança de Barragem da INB, em Caldas, MG," G1, February 14, 2019, accessed August 29, 2019; "Representantes da Prefeitura Visitam Barragens sem Garantia de Segurança em Caldas," *G1*, February 5, 2019, accessed August 29, 2019, https://g1.globo.com/mg/sul-de-minas/noticia/2019/02/05/representantes-da-prefeitura-visitam-barragens-sem-garantia-de-seguranca-em-caldas.ghtml.

[346] See, for instance, the special section on "Barragem Caldas," INB, accessed August 29, 2019, http://www.inb.gov.br/Media-Center/Barragem-Caldas; "INB Garante que Irá Atender Todas as Recomendaçãoes do MPF," *Jornal da Cidade*, February 11, 2019; "INB Esclarece Dúvidas da População na Câmara Municipal de Poços de Caldas/MG," INB, accessed August 29, 2019, http://www.inb.gov.br/Detalhe/Conteudo/inb-esclarece-duvidas-da-populacao-na-camara-municipal-de-pocos-de-caldasmg/Origem/329.

and internal leakage.[347] The company started work to solve the problem and replace the drainage system in December 2018.[348] The work was completed in June 2019.[349]

In February 2019, the tailings dam did not hold a safety certificate from the National Agency of Mining due to the lack of technical documents and data.[350] Also in February 2019, the MPF in Pouso Alegre (MG) recommended that INB develop a plan for the emergency action concerning the tailings dam in Caldas; the plan was presented in March 2019.[351] In May 2019, CNEN established a plan of action for the regulation and monitoring of the tailings dam in Caldas. Under the plan, CNEN will update the existing norms for the safety of radioactive-tailings dams in order to adapt them to the National Policy for the Safety of Dams. It will also intensify the monitoring of the radioactive-tailings dams and follow closely the actions taken by INB to restructure the monitoring of the existing dams.[352]

Construction work at the tailings dam of INB Caldas, May 2019 (Photo by Acervo INB)

In terms of decommissioning, the MPF had demanded in 2015 that INB ensure the full recovery of the former mining areas.[353] In 2012, INB had presented a recovery plan, and in 2016 the environmental agency Ibama licensed it. But due to budgetary limitations, no progress has been made. The estimated cost of the decommissioning plan is

347 "MPF em Pouso Alegre (MG) Recomenda Implementação de Plano Emergencial em Barragem com Rejeitos Nucleares," Ministério Público Federal, accessed August 29, 2019, http://www.mpf.mp.br/mg/sala-de-imprensa/noticias-mg/mpf-em-pouso-alegre-mg-recomenda-implementacao-de-plano-emergencial-em-barragem-com-rejeitos-nucleares.

348 "Obras na Barragem Avançam em Caldas," INB, accessed August 29, 2019, http://www.inb.gov.br/Detalhe/Conteudo/obras-na-barragem-avancam-em-caldas/Origem/1634.

349 "Concluída a Obra na Barragem de Rejeitos da INB Caldas," INB, accessed August 29, 2019, http://www.inb.gov.br/Detalhe/Conteudo/concluida-a-obra-na-barragem-de-rejeitos-da-inb-caldas/Origem/395.

350 "Caldas Tem Duas Barragens sem Garantia de Segurança da Agência Nacional de Mineração", *G1*, January 28, 2019, accessed August 29, 2019, https://g1.globo.com/mg/sul-de-minas/noticia/2019/01/28/caldas-tem-duas-barragens-sem-garantia-de-seguranca-da-agencia-nacional-de-mineracao.ghtml.

351 "MPF em Pouso Alegre (MG) Recomenda Implementação de Plano Emergencial em Barragem com Rejeitos Nucleares," Ministério Público Federal, accessed August 29, 2019, http://www.mpf.mp.br/mg/sala-de-imprensa/noticias-mg/mpf-em-pouso-alegre-mg-recomenda-implementacao-de-plano-emergencial-em-barragem-com-rejeitos-nucleares; "INB Entrega Plano de Ação de Emergência ao MPF," INB, accessed August 29, 2019, http://www.inb.gov.br/Detalhe/Conteudo/inb-entrega-plano-de-acao-de-emergencia-ao-mpf/Origem/1634.

352 "CNEN Lança Plano para Aumentar Fiscalização de Barragens da INB," ABEN, accessed August 29, 2019, http://www.aben.com.br/noticias/cnen-lanca-plano-para-aumentar-fiscalizacao-de-barragens-da-inb.

353 "MPF em Pouso Alegre (MG) Recomenda Implementação de Plano Emergencial em Barragem com Rejeitos Nucleares," Ministério Público Federal, accessed August 29, 2019, http://www.mpf.mp.br/mg/sala-de-imprensa/noticias-mg/mpf-em-pouso-alegre-mg-recomenda-implementacao-de-plano-emergencial-em-barragem-com-rejeitos-nucleares.

US$450-500 million, which INB cannot afford to pay. Furthermore, there is no specific legislation in Brazil requiring the government to finance the decommissioning of mining facilities. Such legislation does exist for nuclear power plants.[354]

Similar problems persist at INB's facilities in the state of São Paulo (Interlargos, São Paulo, and Botuxim, Itu). The sheds and silos accumulate hazardous substances produced as a by-product of mining and milling rare-earth metals at the Interlagos and Santo Amaro facilities until the early 1990s. Such material is not officially defined as waste, but CNEN monitors it at INB storage facilities.[355] Inadequate management of waste during the operational period has caused leakage of material at the Interlagos unit. From 1998 to 2002 and from 2010 to 2013, INB partially (30%) decontaminated the terrain.[356]

Over the past few years, INB attempted to export Cake II – a substance containing thorium hydroxide concentrate, resulting from the mining of monazite sands – to China.[357] A special working group dedicated to this matter was created at INB. However, according to INB's 2016 annual report, the export could not take place because the importing company failed to obtain an import license; the partner could not indicate who would be the end user of the material.[358]

Unlike the former mining areas, uranium mines in Caetité have adopted distinct waste management procedures that allow decommissioning to take place alongside the operation of the mine instead of accumulating untreated waste for future decommissioning. Mine tailings and depleted ore in Caetité are piled up on the sides of a mine pit. The sludge resulting from liquid residue treatment is stored in ponds with drainage capacity. The process separates solid waste and allows liquid recycling. The solid waste is then stored at a solid-waste storage facility organized by modules covered by topsoil and vegetation.[359] Even though INB has conceived this adaptation as a way to avoid the same types of liabilities left by mining in Caldas and São Paulo, the new procedures cannot completely eliminate the environmental impact of uranium mining. (See "Environmental Regulation" in "2 - Governance and Accountability.")

NATIONAL REPOSITORY FOR LOW- AND MEDIUM-LEVEL RADIOACTIVE WASTE

CNEN plans to build a final geological repository for low- and medium-level radioactive waste. The construction of the National Repository for Low and Medium-Level

354 INB, *Relatório de Gestão 2016*, 55-56. "Como está a execução do Plano de Recuperação de Áreas Degradadas? Quanto a INB calcula gastar na recuperação da área e quanto tempo isso pode levar?" INB, accessed October 30, 2019, http://www.inb.gov.br/Media-Center/Barragem-Caldas.

355 CNEN, *National Report of Brazil 2017*, 27.

356 CNEN, *National Report of Brazil 2017*, 96; INB, *Relatório de Gestão 2016*, 55.

357 "Lixo Nuclear e Radioativo Será Exportado de Caldas para a China," *G1*, August 13, 2013, accessed August 29, 2019, http://g1.globo.com/mg/sul-de-minas/noticia/2013/08/lixo-nuclear-e-radioativo-sera-exportado-de-caldas-para-china.html.

358 INB, *Relatório de Gestão 2016*, 54.

359 CNEN, *National Report of Brazil 2017*, 28-29.

Radioactive Waste will cost an estimated BRL 156 million, as of 2019. [360] The project is still in its early stages and there is no consensus on a site for the final repository or compensation for the municipality that would host it.[361]

Without a more permanent solution for the final disposal of radioactive waste, initial and intermediate facilities with their limited and temporary storage capacity are filling up. Some nuclear and radiological facilities are reaching their capacity. The most pressing case is the Angra nuclear power complex. At the site's Radioactive Waste Management Center, one section is full, and four out of the remaining seven are more than 70% full (see Table 7). Eletronuclear estimates that by 2025 the Angra nuclear power complex will no longer be able to store waste.[362]

Table 7: Status of initial-storage facilities at Angra nuclear power station

WASTE MANAGEMENT CENTER	STORAGE FACILITY	CAPACITY	OCCUPANCY	RATE
Radioactive Waste Management Center (Angra-1 + Angra-2)	*Storage Facility 1 (1981; 2016)*	2,368 drums (low-level)	1,712 drums (or drum-equivalents)	**72.3%**
		1,696 drums (medium level)	1,204 drums (or drum-equivalents)	**71%**
	Storage Facility 2A (1992; 2011)	783 liners	743 liners + 28 liner-equivalents (19 concrete cylinders with 1.3 m^3)	**98.5%**
	Storage Facility 2B (2008)	2,296 drums	2,296 drums	**100%**
		252 liners	85 liners	**33.7%**
	Storage Facility 3 (2008)	5,612 drums	1,868 drums	**33.3%**
		300 metallic boxes	268 metallic boxes	**89.3%**
Angra 2 In-Plant Waste Management	*In-Plant Storage Facility (UKA Building)*	1,644 drums	809 drums	**54.1%**

Source: Based on CNEN, *National Report of Brazil 2017*, 93-95

Legal disputes involving CNEN, Eletronuclear, the prosecutor's office in Angra dos Reis, the TCU, and Ibama made finding a solution even more difficult. [363]

INB's Nuclear Fuel Fabrication Facility in Resende has reached 70% of its capacity

[360] SIOP – Sistema Integrado de Planejamento e Orçamento (Ação 10.24204.19.572.2059.13CM - Implantação Do Repositório de Rejeitos de Baixo e Médio Nível – RBMN, accessed October 30, 2019, http://www1.siop.planejamento.gov.br/acessopublico/?pp=acessopublico&rvn=1.

[361] CNEN, *Relatório de Gestão 2016*, 117-18, 127. CNEN, *Relatório de Gestão 2018*, 117.

[362] CNEN, *Relatório de Gestão 2016*, 126.

[363] CNEN, *Relatório de Gestão 2016*, 126; TCU, *Fiscalização do Setor Nuclear – Acompanhamento do Projeto do Repositório Nacional de Rejeitos Radioativos de Baixo e Médio Níveis de Radiação (RBMN) da CNEN*, (January, 2014); TCU, Acórdão 2587/2014, Processo TC 010.677/2014-3, Relator: Min. André de Carvalho, 01.10.2014, 7-8, 29-30;; TRF-2, Processo nº 0000121-82.2007.4.02.5111, 07.03.2017, Judicial - TRF do Tribunal Regional Federal da 2ª Região (TRF-2), 15.12.2015.

for initial waste storage, but CNEN reports that the volume of waste production is lower than at other installations. At the Navy's Aramar Experimental Center, the existing storage facility for contaminated material is at 64.3% of capacity, and a new initial-storage facility for waste resulting from the fuel cycle has been built. CNEN's intermediate facilities for disused radiological sources are at levels between 21% and 51% of capacity.

Table 8: Status of initial-storage facilities at INB's Nuclear Fuel Fabrication Facility

AREA	CAPACITY	OCCUPANCY	RATE
Area 1 – Solid wastes	444 drums (200 l each)	405 drums	71.8%
Area 2 – Liquid wastes	120 drums (200 l each)		

Source: Based on CNEN, *National Report of Brazil 2017*, 27, 95.

Table 9: Status of initial-storage facilities at Aramar Experimental Center

AREA	CAPACITY	OCCUPANCY	RATE
Radioactive Waste (Initial) Storage Facility (contaminated material)	336 drums (200 l each) 165.6 m^2	216 drums (200 l each)	64.3%
Radioactive Waste (Initial) Storage Facility (2) (planned) (only for wastes from the fuel cycle)	780 m^2	(new)	(new)

Source: Based on CNEN, *National Report of Brazil 2017*, 99-100, 29.

Table 10: Status of intermediate-storage facilities for disused sealed sources at CNEN's institutes

INSTITUTE	NUMBER OF SOURCES	TOTAL VOLUME	OCCUPANCY RATE
IPEN	152,530	100.4 m^3	25%
CDTN	11,864	52 m^3	22%
IEN	20,085	190 m^3	51%
CRCN-NE	1,068	32 m^3	21%

Source: Adapted from CNEN, *National Report of Brazil 2017*, 123

SPENT FUEL

The 2018 presidential decree "Brazilian Nuclear Policy," which sets out the principles, guidelines, and goals for the sector, does not exclude reprocessing as a potential future method of spent fuel management. Worldwide, the nuclear industry considers that the residual nuclear materials in spent fuel – plutonium and uranium – are resources that may be recovered by reprocessing and then used to make new reactor fuel. Some countries, mostly in Europe, have reprocessed spent fuel, but most nuclear programs so far have elected to store their spent fuel, at least for an interim period. A few have made programmatic decisions not to reprocess their spent fuel. With these considerations in view, the 2018 decree states that "spent nuclear fuel will be stored at the appropriate site for future utilization of reusable material."[364] In practice, Brazil has not yet developed the capacity to reprocess spent fuel, and most officials the authors met pointed out that choosing reprocessing would entail a high political cost since it would raise nonproliferation concerns. Reprocessing separates the plutonium that is generated by the burning of UO_2 fuels at power reactors from depleted uranium. The plutonium obtained from reprocessing can be used in a specific type of fuel for nuclear power reactors, but it is also considered weapon-usable and therefore might pose proliferation risks. Officials also pointed out the high economic costs involved in reprocessing spent fuel. In contrast to radioactive waste, there is no specific regulatory framework for the management of spent fuel that is kept at on-site storage facilities alongside the operating reactors, in accordance with general norms on radiological safety and security of nuclear facilities.

At Angra, spent fuel is kept in cooling pools, but available storage capacity is reaching critical levels. Eletronuclear estimates that Angra-1 and Angra-2 will run out of storage capacity for spent fuel by July 2021.[365] In the case of Angra-1, the capacity has been expanded, with the goal of accommodating all spent fuel that will be generated for the expected remaining operational life of the reactor.[366] At Angra-2, one part of initial-storage facilities (Region B) can accommodate spent fuel produced through the equivalent of 15 years of operation of the reactor at full capacity, but it will be full soon.[367] In order to overcome these limitations, in July of 2017, the company started developing plans to build a dry-storage facility for spent fuel. Initially, the new unit would alleviate for five years the storage challenges at Angra-1 and Angra-2, but in November 2018, Eletronuclear revised its estimates for the project and sent the new estimates to Ibama. According to the new estimates, the dry-storage facility can accommodate spent nuclear fuel that would be generated in 25 years of operation of the two reactors.[368] The new facility would store spent nuclear fuel once the existing storage facilities ran out of capacity. The estimated cost is US$50-60 million, and the facility is projected to start receiving spent fuel as early as 2020.[369]

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364 Decreto No. 9600, de 5 de Dezembro de 2018, *Diário Oficial da União*, December 6, 2018, art. 14.

365 Eletronuclear, *Relatório de Gestão 2016*, 16.

366 CNEN, *National Report of Brazil 2017*, 17-21.

367 Ibid.

368 Eletronuclear, *Unidade de Armazenamento Complementar a Seco (UAS) de Combustível Irradiado da Central Nuclear Almirante Álvaro Alberto (CNAAA) – Angra dos Reis/RJ*, (2018).

369 "Eletronuclear Dá Largada para UAS," Eletronuclear, accessed August 29, 2019, http://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/Eletronuclear-d%C3%A1-largada-para-UAS.aspx; "Implantação da Unidade de Armazenamento Complementar a Seco de Combustíveis Irradiados," Eletronuclear, accessed August 29, 2019, http://www.aben.com.br/Arquivos/468/468.pdf.

Table 11: Spent fuel assemblies stored at Angra-1

AREA	CAPACITY	STORED ASSEMBLIES	RATE
New fuel storage room	45	9	20%
Region 1 spent fuel pool	252	178	70.6%
Region 2 spent fuel pool	1,000	791	79.1%
Reactor core	121	121	100%

Source: Adapted from CNEN, *National Report of Brazil 2017*, 18

Table 12: Spent fuel assemblies stored at Angra-2

AREA	CAPACITY	STORED ASSEMBLIES	RATE
New fuel storage room	75	0	0%
Region 1 spent fuel pool	264	34	12.9%
Region 2 spent fuel pool	820	670	81.7%
Reactor core	193	193	100%

Source: Adapted from CNEN, *National Report of Brazil 2017*, 19

The capacity limitations at initial-storage facilities also present challenges for the operation of the IEA-R1 research reactor at IPEN over the next decade. In 2014, CNEN estimated that by keeping the reactor in operation for 64 hours per week at a power level of 4.5-5 MWth, facilities would run out of storage capacity in four to five years.[370] In 2017, this scenario changed. Due to modifications in the legislation regulating the work of personnel in the nuclear sector, reactor operation time per day had to be reduced. It is now expected that IEA-R1 will operate only 32 hours per week at 4.5-5 MW power. At this pace, the reactor's wet-storage facility will reach its capacity in six to seven years, as from 2017. To overcome this problem, IPEN is working on a technical solution: using a metal matrix composite in the construction of new high-density storage racks, which would increase the lifetime of the reactor by 25 years.[371]

In the past, removing spent fuel from IEA-R1 helped to minimize the amount of HEU available in the country. Currently, no reactor in Brazil operates with HEU. In the 1990s and 2000s, CNEN, in coordination with the US government and the IAEA, facilitated the return of all research reactor spent fuel to the United States, including HEU fuel.

In the military sector, spent fuel will become an issue after the Labgene prototype reactor starts operation in 2021 and once the nuclear-powered submarine is commissioned, which will be in 2029, according to current estimates.

Although no decision has been made on how to manage its spent fuel, the Brazilian Navy will likely be responsible for all spent fuel from the operation of the prototype

[370] CNEN, *National Report of Brazil 2014*, 25.

[371] CNEN, *National Report of Brazil 2017*, 25-26.

reactor and the nuclear-powered submarine. At Aramar, Labgene already has launched construction of the initial-storage facility for spent fuel. At the shipyard facilities in Itaguaí, a radiological complex will handle all fuel-related operations for the nuclear-powered submarine, including spent fuel management.

In terms of licensing and monitoring, CNEN and the new Naval Agency for Nuclear Safety and Quality have agreed on terms of collaboration and are likely dividing their regulatory work according to their respective expertise. Over the years, CNEN has accumulated regulatory expertise on land-based nuclear installations; therefore, CNEN will be in charge of licensing and monitoring spent fuel management at Labgene facilities at CTMSP Aramar and the radiological complex of the submarine site in Itaguaí. In turn, the Naval Agency will oversee norms and protocols concerning construction, commissioning, operation, and decommissioning of vessels carrying nuclear reactors – that is, the nuclear-powered submarine. It remains unclear whether the agency will carry out additional monitoring of the spent fuel involved in the operation of the submarine alongside CNEN.

NUCLEAR SAFEGUARDS

Within the next 10 years, the Brazilian government will need to make decisions on three critical issues concerning nuclear safeguards: whether or not to conclude an additional protocol to its safeguards agreement with the IAEA; how to safeguard naval nuclear fuel; and whether and how to introduce changes to ABACC.

GOVERNING NUCLEAR SAFEGUARDS

Two IAEA documents govern the international nuclear safeguards regime under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT): INFCIRC/153 (Corrected) and INFCIRC/540 (Corrected).

INFCIRC/153 (Corrected) describes the structure and content of comprehensive safeguards agreements, which the IAEA concludes with NPT non-nuclear-weapon states. The main feature of a comprehensive safeguards agreement is "an undertaking by the State to accept safeguards, in accordance with the terms of the Agreement, on all source or special fissionable material in all peaceful nuclear activities within its territory, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices."[372] For its part, the IAEA has, under such agreements, "the right and obligation to ensure that safeguards will be applied, in accordance with the terms of the Agreement, on *all* source or special fissionable material in all peaceful nuclear activities within the territory of the State, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices" (emphasis added).[373]

INFCIRC/540 (Corrected) contains a model protocol that serves as the standard for additional protocols concluded in conjunction with comprehensive safeguards agreements.[374] While it us up to the country to decide to conclude an additional protocol since this commitment is voluntary, the IAEA Board of Governors has directed that protocols to comprehensive safeguards agreements are to contain all of the measures provided for in the Model Additional Protocol; the State cannot pick and

[372] IAEA, *The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*, INFCIRC/153 (Corrected) (June 1972), para. 1.

[373] Ibid., para. 2.

[374] "Additional Protocol", IAEA, accessed August 29, 2019, https://www.iaea.org/topics/additional-protocol; IAEA, *Model Protocol Additional to the Agreement(s) between state(s) and the International Atomic Energy Agency for the Application of Safeguards*, INFCIRC/540 (Corrected) (May 1997).

choose from among those measures. Additional protocols to safeguards agreements grant the IAEA expanded rights and tools to gain access to information and locations in a given state. Commitments that states make under such protocols not only allow the IAEA to strengthen its verification of declared nuclear material and activities, but also greatly enhance the IAEA's ability to provide assurances about the absence of *undeclared* nuclear material and activities in a state.

In Brazil, nuclear safeguards are implemented at two levels: at the bilateral level with Argentina, by the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC); and at the multilateral level, by the IAEA.

ABACC implements its safeguards based on a bilateral agreement signed in 1991.[375] ABACC employs nuclear inspectors from Brazil and Argentina, with Brazilian inspectors inspecting Argentinian facilities and Argentinian inspectors inspecting Brazilian facilities.

Multilateral safeguards on Brazil's nuclear facilities and material follow from Brazil's participation in the NPT and are guided by the comprehensive safeguards agreement that Brazil, Argentina, and ABACC concluded with the IAEA (INFCIRC/435). This agreement, commonly known as the Quadripartite Agreement,[376] entered into force in 1994.

ABACC cooperates with the IAEA during the IAEA's safeguards activities in Brazil and Argentina. ABACC and the IAEA draw their own independent conclusions but coordinate their inspections to the extent possible to avoid duplication of verification efforts.

PROSPECTS FOR NUCLEAR SAFEGUARDS IN BRAZIL

THE IAEA ADDITIONAL PROTOCOL

Brazil's official position remains that it will not conclude an additional protocol with the IAEA in the short term, but officials also say publicly that they do not exclude the possibility of discussing the issue at some undetermined time in the future. As a matter of principle, Brazil is reluctant to accept additional nonproliferation obligations as long as nuclear-weapon states do not make sufficient progress toward nuclear disarmament. As a more practical matter, Brazil maintains that opening its facilities to more-intrusive inspections under an additional protocol would make it vulnerable to industrial espionage. International safeguards experts push back against this premise,

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375 Acordo para Usos Exclusivamente Pacífico da Energia Nuclear, Argentina-Brazil, July 18, 1991, Concórdia (Acervo de atos internacionais do Brasil), https://concordia.itamaraty.gov.br/detalhamento-acordo/3794?IdEnvolvido=19&page=18&tipoPesquisa=2.

376 Agreement of 13 December 1991 Between the Republic of Argentina, the Federative Republic of Brazil, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/435, Brazil –Argentina, December 13, 1991, IAEA, https://www.iaea.org/publications/documents/infcircs/agreement-13-december-1991-between-republic-argentina-federative-republic-brazil-brazilian-argentine-agency-accounting-and-control-nuclear-materials-and-international-atomic-energy-agency-application-safeguards.

asserting that there have been no cases of leaking of proprietary information by IAEA inspectors.[377]

Brazilian nuclear officials explain that Brazil's technology for enriching uranium was indigenously developed and represents technological know-how that Brazil would like to protect. According to some Brazilian interviewees, the technology is based on a mechanism that differs from that used in other centrifuge enrichment facilities (that is, levitation rather than electromagnetic fields). Whether Brazil's enrichment technology is truly indigenous is disputed by some international experts.

Leaving aside the discourse on the fairness of expecting non-nuclear-weapon states to accept additional safeguards obligations and Brazil's motivations to keep its enrichment technology as shielded as possible, Brazil is facing mounting pressure to conclude an additional protocol.

> **Brazil's official position remains that it will not conclude an additional protocol with the IAEA in the short term, but officials also say publicly that they do not exclude the possibility of discussing the issue at some undetermined time in the future.**

While the conclusion of an additional protocol by a state is formally a voluntary commitment, over the last decade it has become a norm. As of 2019, 150 states plus Euratom[378] have signed additional protocols, out of which 136 protocols are in force. Only a small minority of countries – which includes Argentina, Egypt, Syria, and Venezuela – have yet to bring an additional protocol into force.[379]

Even more consequential for Brazil than the growing international norm is the changing discourse in Argentina. Starting from 2015, voices within Argentina in support of concluding an additional protocol have become more prominent. The administration of President Mauricio Macri appeared to be more open to concluding an additional protocol than the previous administration of President Cristina Kirchner. Some of President Macri's foreign policy advisers openly supported the conclusion of an additional protocol.[380]

Unlike Brazil, Argentina's nuclear industry is export oriented. While an additional protocol will not make any practical difference to Argentina's ability to export its reactor technology, it will add political capital to a country that has an advanced nuclear

[377] Pierre Goldschmidt, "The Future of the NPT: Should It Be Enhanced, Changed or Replaced?" (Conference presentation, Nuclear Disarmament and Nonproliferation – The Future of the NPT, Rio de Janeiro, October 29-30, 2009).

[378] Euratom is an international organization engaged in a broad array of nuclear activities on behalf of its European members - promoting and distributing nuclear power, enhancing nuclear safety, and implementing nuclear safeguards.

[379] "Status List – Conclusion of Additional Protocols, Status as of 31 December 2019", IAEA, accessed on January 18, 2020, https://www.iaea.org/sites/default/files/20/01/sg-ap-status.pdf.

[380] Eduardo Diez, "National Development and Argentina's Nuclear Policy" in *Perspectives on the Evolving Nuclear Order*, ed. Toby Dalton; Togzhan Kassenova, and Lauryn Williams (Washington, DC: Carnegie Endowment for International Peace, 2016), 31.

industry and positions itself as a responsible stakeholder in the global nuclear regime.

Historically, Argentina has positioned itself as more aligned with the United States, as compared to Brazil, which has generally aligned itself with the developing world. The desire to be seen as part of the West and as an adherent to the global nonproliferation regime largely explains Argentina's willingness to conclude an additional protocol.

Argentina also enjoys high-profile representation on the global nuclear scene. It benefits from having a high-ranking diplomat with deep nuclear diplomatic expertise and an international reputation. In October 2019, the IAEA Board of Governors elected Ambassador Rafael Grossi, formerly the Assistant Director General for Policy and Chief of Cabinet at the IAEA (2010-2013), as the new IAEA's Director General, following the untimely death of its former director general Yukiya Amano, in July 2019. With Grossi at command of the IAEA, there will likely be even greater expectation for Argentina to conclude an additional protocol, but further developments on this matter will depend on the foreign policy of the newly elected president of Argentina, Alberto Fernández.

That is not to say that opinion is unified on this issue within Argentina. Many Argentine nuclear scientists and technical experts, especially those working closely with ABACC, support Brazil's stance and argue that ABACC safeguards suffice to verify Brazil`s nuclear peaceful-use commitments.

In light of the above, Brazil should be prepared for changes in Argentina's views on this issue. Argentina would undoubtedly prefer to act on an additional protocol in tandem with Brazil, but Brasília cannot expect that Buenos Aires will wait indefinitely for Brazil's decision. While the Brazilian government might currently perceive the conclusion of an additional protocol as contrary to its national interests, a scenario in which Argentina concludes an additional protocol on its own, leaving Brazil behind in an isolated minority, might be more damaging to Brazil's interests.

SAFEGUARDS IN CONNECTION WITH NAVAL NUCLEAR FUEL

Another pressing issue for Brazil is the question of safeguards for naval nuclear fuel. Brazil's nuclear-powered submarine is at least a decade away from being launched, but that amount of time may be needed to work out a satisfactory safeguards arrangement with the IAEA.

INFCIRC/153 (Corrected), the IAEA document that provides a model for comprehensive safeguards agreements, includes a provision for the "non-application of safeguards to nuclear material to be used in non-peaceful activities." That provision, in paragraph 14, allows a state to withdraw nuclear material from safeguards upon conclusion of an appropriate arrangement with the IAEA for the nonapplication of safeguards if the material is to be used in naval nuclear propulsion. Many international experts argue that this provides a "loophole" in applying safeguards to naval nuclear fuel.

Brazilian officials confirm that the country intends to apply safeguards to naval nuclear fuel in line with the Quadripartite Agreement. The corresponding provision in the

Quadripartite Agreement is Article 13. It differs from the INFCIRC/153 (Corrected) to the extent that, rather than speaking of the nonapplication of safeguards to such material, it speaks of the application of "special procedures" to nuclear material used for nuclear propulsion, including for submarines and prototypes. This reflects the undertaking by both Brazil and Argentina under the Tlatelolco Treaty to accept safeguards on all of their nuclear activities.

It appears that, for the Brazilian Navy, a principal motivation for safeguarding naval nuclear fuel comes from the desire to legitimize the nuclear submarine program in the eyes of the international community. To do that, Brazil would need to work out an arrangement with the IAEA that would satisfy both the Navy and the international community.

> **The challenge that Brazil faces is how to reconcile its legitimate concerns about protecting sensitive national security information with the need to provide enough access to ensure the credibility of safeguards.**

The challenge that Brazil faces is how to reconcile its legitimate concerns about protecting sensitive national security information with the need to provide enough access to ensure the credibility of safeguards. Among the practical concerns are how to protect information on the radioisotopic composition of nuclear fuel, protect data on the amount of fuel required for a core (since this information can indicate the length of time that the submarine can spend at sea), and avoid disclosing the movement patterns and location of the submarine. No precedent exists for the application of safeguards to naval nuclear fuel in a non-nuclear-weapon state. Therefore, no blueprint exists for how to do it. Some publicly available studies have started addressing this issue by proposing technical solutions.[381] The fundamental question that Brazil and the IAEA would have to resolve would be on where exactly "military application" starts and ends.

Since the IAEA Board of Governors obliges the director general to use the Model Additional Protocol as the standard for all states with comprehensive safeguards agreements, the IAEA is unlikely to be in a position to offer Brazil an additional protocol that substantially differs from the model. However, Brazil and the IAEA might negotiate special arrangements under the Quadripartite Agreement that already take into account the provisions of the additional protocol so that if and when Brazil chooses to conclude one, the special procedures (which likely will have to be approved by the Board of Governors) will already be in place. This would avoid an unnecessary and likely protracted debate in the board about an additional protocol that contains qualifications and conditions that do not exist in the model.

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[381] See, for example, Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle."

ABACC AND THE IAEA

Since its inception in 1991, ABACC has contributed immensely to increasing the trust between Argentina and Brazil in the nuclear field. The bilateral nuclear safeguards regime reassured the international community that the two countries were not on the path to a nuclear technology race. Importantly, ABACC also eased the process for both states to join the NPT as non-nuclear-weapon states, become members of the Nuclear Suppliers Group, and sign on to other nonproliferation commitments such as the Comprehensive Nuclear-Test-Ban Treaty and the Missile Technology Control Regime.

ABACC achieved this by establishing a network of bilateral agreements on the peaceful use of nuclear energy, a common system of accounting and control of nuclear materials, and a regime for carrying out nuclear safeguards. ABACC's model relies on a functionally independent verification system, a roster of qualified technical officers, safeguards criteria compatible with international safeguards, and a joint decision of two states to protect technology secrecy while making extensive use of unannounced verification visits, including visits to nuclear facilities controlled by the other country's military.

Three decades on, however, staff at ABACC and officials in Brasília and Buenos Aires seem to agree that the organization finds itself at a crossroads. Its terms of reference are narrow, and its inspectors often duplicate the work done by the IAEA inspectors. Furthermore, technical cooperation between the two agencies has remained, by and large, the same since the publication in 1998 of the cooperation agreement between IAEA and ABACC.[382]

What, if anything, should ABACC aspire to do differently?

The answers are elusive because the two agencies diverge on how they define the balance between cooperation and independence between them. IAEA officials often see ABACC as a spokesperson for the national nuclear sectors of Argentina and Brazil rather than as an independent agency in its own right. Some go as far as suggesting that ABACC is used as a shield to protect national sovereignty rather than an international body with actual authority over national programs.

In their turn, ABACC officials reject the claim by pointing out instances in which ABACC identified outstanding issues at national nuclear facilities before the IAEA did. These officials add that Vienna pays little if any attention to the reports they send and that the IAEA inspectors mistrust ABACC because there is no additional protocol binding Argentina or Brazil to more-intrusive inspections. They also complain that IAEA officials approach safeguards with a one-size-fits-all mind-set, whereas they think of safeguards as context dependent. As a result, after more than 25 years of existence, ABACC is still not treated by the international community as a full inspector in its own right. This is particularly frustrating for ABACC staff, who are eager to take on more responsibilities.

Divisions between ABACC and the IAEA have also undermined the potential for

[382] Agreement for the Application of Safeguards (Quadripartite Agreement), Argentina-Brazil-ABACC-IAEA, December 13, 1991, IAEA INFCIRC/435, https://www.abacc.org.br/wp-content/uploads/2016/09/1998-Acordo-de-cooperação-entre-a-ABACC-e-a-AIEA-espanhol-assinado.pdf.

synergy in areas where cooperation could, in practice, reduce costs on both sides. The most obvious candidates for such cooperation would be the integration of safeguards into the design of installations, a peer-review system, and an auditing system based on international benchmarks. The IAEA can also make use of an extensive sample collection that ABACC collects and analyzes. These kinds of joint activities could be particularly useful for the two organizations as nuclear programs in Argentina and Brazil expand and become more complex and more expensive to inspect. In addition, there is likely to be a growing demand for adapting existing safeguards procedures and methods for compliance with the new technologies that the organizations acquire. As Brazil makes progress in the construction of its nuclear-powered submarine, there will be growing demand for proof that it is not falling short on its international commitments by diverting naval nuclear fuel for unauthorized purposes, a gap that ABACC is in a unique position to help close.

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Another issue affecting ABACC is the tight financial environment in which it operates. For several years now, ABACC officials have argued that Argentina and Brazil should improve their support and funding for the organization. Yet, the quest for better budgets is a hard sell domestically in both Argentina and Brazil. One potential way out would be for ABACC to expand its remit to do more than simply carry out bilateral safeguards and assist the IAEA in verifying the correctness and completeness of national reports. Some have argued for expanding ABACC's mandate in the region by allowing it to provide technical assistance and cooperation, as well as education and training, to other countries in South America who voluntarily extend a request for help.

As Argentina and Brazil confront the hard questions on the future of ABACC, they should draw on the experience of Euratom. In particular, officials in Buenos Aires and Brasília should revisit the previous disputes between Euratom and the IAEA to learn how those two organizations eventually found a durable solution and adopted the nuclear partnership agreement that untangled many contentious issues. There is every reason to believe that ABACC and the IAEA should be able to make similar progress in their own relationship.

There is another set of issues pertaining to ABACC that should draw the attention of Brazilian officials. As construction on the nuclear-powered submarine progresses, there will be a growing demand for clear diplomatic communication of Brazilian intentions. This is bound to happen because the acquisition of new nuclear technology capabilities always brings with it uncertainties on the part of external observers. In this scenario, ABACC gains additional value to Brazil because of its potential to facilitate the challenging task of communicating intentions. This matters because the way

Brazil communicates its nuclear intentions and future plans once the submarine is operational will have long-term effects on how the international community perceives and responds to Brazil's nuclear program. ABACC can be instrumental in resolving the issues that are bound to emerge in the process and assist in the creation of a productive external environment.

PRIVATE INVESTMENT

Since 2016, Brazil has sought to sell billions of dollars in state-owned assets in energy generation and distribution to curb the country's massive deficit and attract much-needed investment to the sector. Despite the substantial transfer of assets to the private sector, there are no plans to privatize Eletronuclear with its Angra-1 and Angra-2 nuclear power plants. Instead, the government is actively seeking one or more international partners who would inject the financial resources into the completion of Angra-3. The Brazilian government is also developing a new framework to facilitate the participation of private capital in the future expansion of uranium mining and milling activities as well as expand its presence in the radioisotopes market. The details of these endeavors have yet to be defined. This chapter describes the current situation of private investment in the Brazilian nuclear sector, maps concerns that are likely to arise about diminished accountability and oversight, and offers an overview of opportunities and challenges that are likely to emerge in the process.

NUCLEAR POWER AND ANGRA-3

Site preparation for Angra-3 started in 1984, but was interrupted two years later due to budgetary problems. In 2010, works restarted thanks to loans from the National Development Bank (BNDES) and a state-owned savings bank, Caixa Econômica Federal, worth BRL 10 billion. At the time, the 35-year contract fixed the tariff at BRL 240/MWh. By 2015, however, TCU suspended all work as scandals involving major private conglomerates and Eletronuclear broke out as a result of the Lava Jato anticorruption probe. At the time of the suspension, construction work was well advanced. The overall completion rate reached 67%, including 88% of the engineering work, 78% for the provision or equipment and materials, 82% of the construction work, and 19% of the electromechanical assembly. All contracts allocated to companies investigated for corruption were canceled.

According to Eletronuclear, resumption of construction would involve an immediate cost of BRL 13.8 billion and require 55 months to complete. Electronuclear officials estimate that abandoning the project would require about BRL 11.9 billion in liquidation costs, including penalties, dismantlement, contract cancellation with Framatome (formerly Areva), environmental compensation, reimbursement of tax exemptions, and the construction of protection systems for the structures that already have been built. They argue that the difference in cost between completing the construction and dismantling it creates a powerful incentive for Brazil to complete and connect Angra-3 to the grid.[383]

Angra 3 construction site in 2017 (Photo by Divulgação PAC/Agência Brasil)

To make this happen, however, the company estimates that an international partner or a consortium of partners will have to be included to finance the remaining operations. Although the precise details of such a partnership remain unspecified, Eletronuclear would likely retain its obligation to apply for licenses (both nuclear and environmental), obtain the nuclear fuel, and operate Angra-3. The foreign partner would have to find a financial solution for the loans with Caixa Econômica Federal and BNDES. No official document specifies the division of shares in the new enterprise between Eletronuclear and the potential international partner, but in informal conversations with the authors, relevant officials mentioned a distribution in the range from 25-75 to 40-60, divided between the foreign partner and Eletronuclear, respectively. Furthermore, Eletrobras asserts that some private actors would not be interested in investing in just Angra-3 and therefore advocates offering a package of up to four new nuclear reactors, besides Angra-3. In conversations with the authors, Eletronuclear officials said that the selection of partners would involve a public call for proposals for Angra-3. Any joint work on additional reactors in the future will probably require a separate government-to-government agreement and will not be covered by this call for proposals.

To attract foreign investors, in late 2018 the National Council for Energy Policy, the federal advisory body on energy policy and strategy, lifted the cap on the BRL 240/MWh rate for offtake of the electric power produced. As of writing, the new estimated rate is BRL 480/MWh. Several potential partners, including EDF (France), Mitsubishi (Japan), CNNC (China), and Rosatom (Russia) have expressed interest.

[383] Nacim M. Mod, "Brazilian Power Generation" (Eletronuclear, Angra dos Reis), April 2018.; Consultations with Eletronuclear officials and staff in Angra dos Reis, Rio de Janeiro, April 12, 2018.

THE DEBATE OVER ANGRA-3 AND THE FUTURE OF NUCLEAR POWER IN BRAZIL

FGV Energia[384] mapped out the debate on whether Brazil should restart the construction of Angra-3 and continue to invest in nuclear power. The most important issue is the economic feasibility of the tariff of energy produced by Angra-3 and the methodologies for estimating the total cost of it. In particular, the National Council for Energy Policy has recently approved a new energy tariff for Angra-3. The proponents of nuclear power argue that this new tariff is the approved *limit* and not the actual price to be implemented, which is likely to decrease as nuclear power expands and is produced on a large scale. The final price also depends on the conditions set out in the expected public call for proposals for Angra-3 construction, which could decrease the cap. Angra-3 supporters emphasize that the rise of the tariff is not a given and is aimed at making investment in Angra-3 attractive to international partners at the initial stage. They also point out that the current tariff is aligned to the international benchmarks set by the International Energy Agency (US$40-100/MWh) and is competitive on the national market in the context of thermal baseload generation. They argue, for instance, that nuclear energy could replace more expensive thermal sources on which the country now relies. The price of the nuclear fuel is also considered to be less susceptible to international volatilities.[385]

On the other side of the debate, some experts on energy planning point out that the price of nuclear energy is actually *higher* than the tariff of other energy sources in the same "reserve energy" category (for example, biomass, wind, and photovoltaics) and when compared to thermal sources, even when other associated costs such as energy transmission are taken into account. For example, natural gas could be a potential economic competitor to nuclear energy, given the large offshore reserves near the coast of Brazil.[386] They also argue that the calculus of the proposed tariff takes into account only the production itself under perfectly safe conditions and disregards the costs involved with waste management and insurance for accidents.[387] Alternative methodologies point out that the current tariff ignores the costs of BNDES and Caixa Econômica Federal loans too.[388]

The impasse goes beyond the economic dimension. The debate also concerns the benefits and disadvantages of nuclear power for the security and sustainability of the Brazilian energy matrix. Currently, Brazil has to turn on

[384] FGV Energia, *Boletim de Conjuntura do Setor Energético*, (FGV Energia, 2019), https://fgvenergia.fgv.br/sites/fgvenergia.fgv.br/files/fevereiro-2019_final.pdf.

[385] FGV Energia, "Opinião: Entrevistas com especialistas: as diferentes visões a respeito da energia nuclear no Brasil" in FGV Energia, *Boletim de Conjuntura do Setor Energético* (2019), 15-17; FGV Energia, "Opinião" in FGV Energia, *Boletim de Conjuntura do Setor Energético* (2019), 17-18.

[386] Ibid., 9, 18-19, 22, 23.

[387] Ibid, 29.

[388] Instituto Escolhas, *Custos e Benefícios da Termelétrica Angra 3* (December, 2018).

thermal power stations in order to balance the energy input and provide the required amount of electricity when there is a shortage of hydropower – Brazil's major energy source – and other seasonal sources. Proponents of nuclear power claim that, as a nonseasonal thermal option, it could provide energy security at reasonable costs and with minor greenhouse gas emissions during energy production, compared to other thermal pollutant options.[389]

The opponents claim that, despite offering a continuous source of energy, nuclear power generation is too inflexible to balance the constant variations in a flexible energy system like the one in Brazil. They note that nuclear plants cannot be easily turned off to accommodate the variations in the amount of energy produced by other sources. Even when seasonal sources such as hydropower are used at full capacity, nuclear power plants would continue to operate. Therefore, if the government decides to expand nuclear power, this could create an oversized supply and make the system lose expensive energy.[390]

Energy experts also debate the levels of greenhouse gas emissions of nuclear power plants. Even though power production itself might require relatively small amounts of energy, the construction of nuclear power plants depends on energy-intensive processes, which increase the total carbon footprint.[391]

The decision to restart the construction of Angra-3 and to expand nuclear power is inter-connected with the operation of the nuclear sector as a whole, especially in terms of the nuclear fuel cycle. In this regard, the promoters of nuclear power argue that Angra-3 and the addition of new power plants could be an incentive to raise the industrial scale of the nuclear fuel cycle and stimulate new technological development in the nuclear sector such as production and operation of small modular reactors.[392] The critics counter by pointing out that no solution for the final disposal of radioactive waste has been found yet and that, even though the probability of accidents is low, their potential effects are incalculable and not worth risking.[393]

CHALLENGES AND OPPORTUNITIES

The recent evolution of public debate in Brazil on the role of the private sector in the production of nuclear energy points to several challenges, but also offers a window into potential opportunities.

First, the pursuit of a public-private partnership for the completion of Angra-3 is going to revive concerns about rent seeking in the nuclear sector. Rent seeking occurs when payments for resources are higher than if these resources are used in an alternative way. Rents occur when an economic player manipulates prices and forces

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[389] FGV Energia, "Opinião" in FGV Energia, *Boletim de Conjuntura do Setor Energético* (2019), 7, 10-11, 13-14, 17.

[390] Ibid., 18, 27-28.

[391] Ibid., 9-10.

[392] Ibid., 12-16, 25-27.

[393] Ibid.,22-23, 29.

them to diverge from competitive levels. The fact that state intervention in price setting can generate rents creates incentives for private-sector investors to influence policy decisions through personal connections. As the international experience shows, in rent-seeking societies, powerful groups overwhelm the state's ability to contain and channel their demands. Curbing such dynamics in the nuclear sector is particularly difficult because it often operates in a noncompetitive market with only a few qualified players. In such a context, it is not apparent that private involvement will effectively reduce operational costs or enhance the quality of services. Critics will contend that private ownership may make services unaffordable or unavailable to large parts of the population.

Second, some might argue that the increasing role of the private sector in the public provision of services will remove governmental action from the direct control of government officials. This would make standard practices of democratic accountability more difficult to implement.

The discussions of Angra-3 provide a welcome opportunity to debate the proper role of government in crafting a sound policy environment for nuclear energy use. The key priority should be the creation of conditions in which state and private actors will be more likely to act in the public's interest. Focusing on the impact of private investment on managerial control will highlight the pros and cons of privatization measured against the standards of good management and accountability. Such a debate will hopefully occur in a broader context of resolving enduring dilemmas that nuclear policy making is facing in this country, as this report highlights.

If Brazil is to retain (and expand) a viable nuclear industry, policy makers will have to reconcile the quest for profit by private partners with the core principles of safety, security, transparency, and accountability in a sector that has suffered from shortcomings on all these fronts. Requirements for increased transparency will help maintain democratic controls, and contractual terms that incorporate accountability and monitoring requirements for both government and third parties will contribute to a culture of compliance. This type of approach to accountability by private firms will be especially crucial as Brazil seeks to transition from the old system of endemic corruption to one of cleaner government.

THE NUCLEAR FUEL CYCLE AND INB

Attracting private investors is also one of the government's strategies to boost the nuclear industrial fuel cycle. The government sees the entrance of private actors in this segment as a means of curbing the industry's dependence on the financial resources coming from the federal budget. Today, the sole state company in charge of the industrial fuel cycle (INB) still depends on the federal budget to execute the government's monopoly in that area. For the government, the participation of private investors could not only increase the scale but also ensure the economic feasibility of the Brazilian nuclear fuel cycle as a whole, making the operation of the nuclear program sustainable in the long term.

Under the existing conditions, INB has not been able to fulfill the national demand for nuclear fuel without resorting to foreign suppliers. In the mining sector, activities stopped in 2014, and the plans to expand production at the existing mining complex in Caetité (that is, opening of a new mining pit and a new mine underground and doubling the milling capacity) are still underway. In addition, the joint project for uranium and phosphate mining in Santa Quitéria, a partnership with the private company Galvani, is on hold as INB waits for a license.

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The plans to introduce private investors are now focused on uranium mining, keeping enrichment and fuel production under state control.[394] The GSI's Nuclear Committee has been discussing the models for attracting private investors to the uranium mining sector since 2018. The Ministry of Mines and Energy, under Admiral Bento's command, is also considering the options. The main issue affecting the debate is whether changes to the Constitution are necessary to allow the participation of private investors.

As of 2019, the government has signaled that it would not propose any legal reform for lifting the state monopoly over uranium mining. Instead, the entrance of private companies would depend only on additional new guidelines on the matter, which do not require passing a law in the National Congress.[395] In this regard, there are at least two options on the table. The first one involves expansion of the model applied in Santa Quitéria to other prospecting areas for uranium mining. According to this model, the private partner (Galvani) is responsible for the establishment of the uranium mining project and mining of associated minerals, while INB remains in charge of all nuclear and environmental licensing, safety and radiological protection, and all remaining operations involving uranium.[396] Another option is to hire a private company to carry out the mining itself, with the federal government maintaining oversight and control over the processes.[397]

In addition to attracting private investors into uranium mining, the government sees the search for INB's financial independence as a way to boost the industrial

[394] Goés, Polito and Souza, "Governo Vai Estimular Parcerias para Ampliar a Produção de Urânio," *Valor Econômico*.

[395] Manoel Ventura, "Governo Quer Liberar Mineração de Urânio para Empresas Privadas sem Alterar a Constituição," *O Globo*, April 11, 2019, accessed August 29, 2019, https://oglobo.globo.com/economia/governo-quer-liberar-mineracao-de-uranio-para-empresas-privadas-sem-alterar-constituicao-23591104.

[396] INB, *Plano Estratégico INB 2017-2026* (2017), 36-37.

[397] Goés, Polito and Souza, "Governo Vai Estimular Parcerias para Ampliar a Produção de Urânio," *Valor Econômico*.

Uranium ore (Photo by Marcelo Corrêa/Acervo INB)

INB Santa Quitéria (Photo by Acervo INB)

scale of the fuel cycle, especially in uranium enrichment. In the current model, INB is a dependent state company, meaning that all revenues obtained from its products and services are transferred to the Treasury, which is in charge of allocating resources from the federal budget. In practice, the government sees this as an impediment to the company's further investments as it remains vulnerable to the volatility of the federal budget.[398] The project for an industrial-scale plant for uranium conversion is on hold and the company has been unable to fulfill the national demand for enrichment. The most recent indicators show that INB is fulfilling only the equivalent of 60% of the demand of Angra-1 for enriched uranium.[399]

Currently, INB has reached a 71% rate of financial self-sufficiency, but the company still depends on the Treasury to pay the staff's salaries, make large investments, and develop the project for the decommissioning of the Caldas mine.[400] According to its most recent strategic plan, INB expects to reach full financial autonomy – that is, "operational profit" – by 2026. In order to accomplish this goal, the company has identified several avenues for action: (1) resuming uranium mining; (2) increasing the installed enrichment capacity; (3) obtaining and exporting the excess volume of mined uranium; and (4) increasing the provision of products and services.[401] The minister of mines and energy, Admiral Bento, indicates that INB could also be split, separating mining activities from fuel fabrication.[402] There has been no further explanation of this idea, but it could be read as another signal that the government will most likely push for privatization of uranium

[398] Julio Wiziack, "'Minha Orientação É não Fazer Nomeação Política', Diz Futuro Ministro de Minas e Energia," *Folha de São Paulo*, December 7, 2018, accessed August 29, 2019, https://www1.folha.uol.com.br/mercado/2018/12/minha-orientacao-e-nao-fazer-nomeacao-politica-diz-futuro-ministro.shtml.

[399] "Presidente da República visita INB e inaugura cascata de enriquecimento de urânio" INB, 29 de novembro de 2019, https://www.inb.gov.br/Detalhe/Conteudo/presidente-da-republica-visita-inb-e-inaugura-cascata-de-enriquecimento-de-urani/Origem/395.

[400] INB, *Relatório de Gestão 2017*, 14-15; Pedro Aurélio Teixeira, "INB Quer Independência Financeira até 2026," CanalEnergia, July 25, 2018, https://canalenergia.com.br/noticias/53069425/inb-quer-independencia-financeira-ate-2026; Ministério da Economia, *Boletim das Empresas Estatais Federais*, no. 11, 2019, accessed on November 1, 2019, http://www.economia.gov.br/central-de-conteudos/publicacoes/boletim-das-empresas-estatais-federais/arquivos/boletim-das-empresas-estatais-federais-2013-11a-edicao, 58.

[401] INB, *Plano Estratégico INB 2017-2026*, 7, 31, 37.

[402] Wiziack, "'Minha Orientação É não Fazer Nomeação Política', Diz Futuro Ministro de Minas e Energia," *Folha de São Paulo*.

mining. INB would keep only enrichment and fuel fabrication, given their strategic value and sensitive implications for nonproliferation, safety, and security.

THE RADIOISOTOPES MARKET, IPEN, AND THE RMB

The Brazilian government is also debating how to expand the participation of private companies in the radioisotopes market. Constitutional Amendment n. 49 (2006) allows the federal government to grant special permission to private actors to produce, trade, and use radioisotopes that have a half-life of less than two hours.[403] The reference benchmark for such legal modifications was fludeoxyglucose (FDG), a 109-minute half-life radiopharmaceutical produced in cyclotrons. As of 2016, six companies and two nonprofit organizations were participating in the production and trade of this type of radioisotope.[404] Since 2010, Congress has been debating a new constitutional amendment to lift completely the state's monopoly over the radioisotopes market, but there has been no progress since at least 2013.[405] In 2018, the GSI established a special working group in the Nuclear Committee to discuss legal modifications that could loosen the state monopoly further, but no concrete results have come out of this effort. As of 2019, a new group within the GSI is debating a new strategy for the expansion of the nuclear medicine market in Brazil.

A larger presence of private companies in the radioisotopes market might affect the current actors and projects involved in isotope production under CNEN's oversight. Given the monopoly that the federal government still enjoys over radioisotopes with a half-life of more than two hours, CNEN's own research institutes (especially IPEN) are still the exclusive providers of most radioisotopes used in the country. As state-run institutions, they struggle to keep up with the national demand due to budget limitations as well as specific labor legislation. (See "Human Resources and Education" in "2 - Governance and Accountability.") At the same time, CNEN (in partnership with Amazul and the Argentine company Invap), is building the RMB, which is expected to increase the country's scale of production and free Brazil from reliance on imports of radioisotopes (especially radiopharmaceuticals).

The impact on these actors and projects depends on the model that Brazil adopts. The debate over the future of the radioisotopes market revolves around several key themes. Those who are wary about opening the field to private actors emphasize the need to protect the national supply of radioisotopes (especially radiopharmaceuticals) from market fluctuations. In their view, the market might not create the necessary incentives for private companies' investments and production in it. In this regard, they propose that IPEN remain the sole provider of radioisotopes for Brazil's national public health system and a backup provider in case of a shortage of products in the private

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[403] Such short half-life imposes a logistical challenge to producers (back then, only CNEN); since radioactive activity decays fast, production sites must be located close to the centers that apply these materials.

[404] Vitor da Silva Pereira, Maria Eveline de Castro Pereira, and Luiz Perez Zotes, "A Indústria de Radiofármacos no Brasil: O caso da Fluordesoxiflicose" (XII Congresso Nacional de Excelência em Gestão, Rio de Janeiro, 2016).

[405] Senado Federal, PEC 517/2010, Author: Senator Álvaro Dias (August 10, 2010).

Production of radiopharmaceuticals at IPEN (Photo by Marcello Vitorino/ Fullpress)

sector. For them, keeping IPEN as a key actor in the national production of radioisotopes is essential to preserving not just the supply of products such as nuclear medicine that are essential to social services, but also the institute itself. Radioisotope production is a key stream of funding from the federal budget and keeps IPEN running.

On the other hand, some representatives of the nuclear sector do not foresee any major implications for the national market. In their view, the domestic market will continue to have high demand for such products, making it profitable and continuously attractive for private actors that have the incentive to keep production running. For example, IPEN as the major processing center of radiopharmaceuticals in the country, is a large consumer of radioisotopes and therefore would keep the demand for such inputs at a high level. So those defending the expansion of private actors' participation in this market argue that letting private companies enter the radioisotope production market would diminish the country's dependence on imports and actually make this market more stable and secure.

Another issue concerns the business model currently in place. In interviews with the authors, nuclear sector officials and experts argued that the weaknesses from the current model stem less from the statist approach itself than the way the federal administration allocates resources. As in the case of INB with the profit generated from nuclear production, the revenue obtained from the commercialization of radioisotopes does not return to IPEN and CNEN's other institutes. Instead, it goes to the Treasury, and then the total sum is distributed among all entities in the federal government regardless of their productivity or profits. CNEN officials note that exactly for this reason, the revenue distribution model to be adopted for the RMB will be critical for making the project profitable in the future, especially in the context of a more open radioisotopes market. Radioisotopes produced in nuclear research reactors such as the RMB and IEA-R1 will remain a state monopoly.

CORRUPTION

This section presents an overview of the role of political corruption in Brazil's contemporary nuclear policies. The Lava Jato anticorruption probe launched in 2014 unveiled a massive corruption scheme in various industries: oil and gas, hydropower generation, meatpacking, and transportation, as well as in contracts for the World Cup (2014) and the Olympic Games (2016). The authors draw on the judicial findings of Lava Jato to describe the mechanisms through which government officials colluded with private business conglomerates to generate kickbacks worth several million dollars in the nuclear sector.

WHAT KIND OF CORRUPTION?

The pattern of corruption in the nuclear sector unveiled by Lava Jato is different from corruption by individuals exemplified by bribery and similar types of offenses. The investigation showed that corrupt activity in the nuclear sector was more institutionalized. The model adopted across various sectors involved business and political elites exchanging public contracts for funds – both legal and illegal – to pay for political parties and their campaigns. Although the prevalence of money politics in Brazil was an open secret for a long time, there was a limited understanding of why and how corruption plays such a central role in political fundraising.

Lava Jato unveiled a common mechanism employed by private actors and politicians. A company pays bribes to public officials for benefits such as contracts. These transactions eventually benefit the company by increasing its profits. They are worthwhile to a company even if detected as long as expected penalties are sufficiently low. A company can also collude with other companies to win contracts by forming a cartel and building barriers to entry and other mechanisms to protect their income. These businesses normally operate through brokers. Brokers are private middlemen with connections who promise business conglomerates a smooth passage through the bureaucracy for a price. The funds they extract from businesses are used to pay them for their work and bribe public officials. These officials may include professional politicians, associates from their personal patronage networks whom they appoint to managerial public-sector positions, and career personnel in state companies and agencies. In such a system, personal connections and influence peddling are the currency.

While traditional individual corruption must typically be kept secret, much of the

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more institutional, political corruption that Lava Jato unearthed takes place in the open. Crucially, the investigations also exposed the degree to which some policies make no economic sense but are implemented regardless because doing so is in the interest of a small number of business and political groups. As a result, public goods are sometimes delivered not because they are the main purpose of policy but because they are the by-product of actors competing to gain the private benefits of state resources.

This type of corruption is particularly damaging for policies that demand high regulatory standards. After all, the endemic trading of public contracts for campaign funding can lead to the lowering of requirements for licensing and other policy decisions. When kickbacks are normalized, policymakers reward political relationships at the expense of performance standards and seek political advantage in lieu of economic efficiency considerations. Such a system also privileges large conglomerates that enjoy easy access to the corridors of power while pushing out competitors that might instill dynamism in fields such as technology development. The outsized role of external influences such as vast private conglomerates can distort the decision-making process and impair the government's capacity to function in accordance with its fundamental values.

The prevalence of corruption in Brazil did not necessarily swamp development in the various sectors it involved. Corruption did not spin out of control to the point of making policies inviable, and the siphoning of funds did not prevent the state from providing goods. Even when there was a transfer of wealth from businesspeople to politicians, and from the state to the private sector, productive investment often occurred. Indeed, as the expert literature shows, machine-style politics has never stopped nations from developing.[406]

The institutional type of corrupt activities that Lava Jato exposed is particularly hard to eradicate because, unlike the payment of bribes to individuals, there are political gains involved. This should give pause to policy makers, given extensive evidence

[406] See, for instance, Mushtaq H. Khan, Jomo K.S., eds., *Rents, Rent-Seeking and Economic Development: Theory and Evidence in Asia*. (Cambridge: Cambridge University Press, 2000).

in the expert literature[407] that opportunities for corruption tend to expand during times of economic boom or privatization of state firms. Deterrence in these cases is difficult because corruption involves high-level political players with significant power resources at their disposal. Another critical implication from the revelations thus far is that the problem at hand goes beyond the odd "rotten apple." That is to say that replacing individuals will not necessarily change the underlying dynamics that generate demand for corruption in the first place.

WHAT IS KNOWN

This section reviews publicly available information on corruption in Brazil's nuclear sector.

ANGRA-3

Currently, judicial proceedings on corrupt practices in Angra-3 are unfolding at the Federal Court of Rio de Janeiro. In some cases, some defendants have already been tried, while in others, investigations and indictments by the MPF of Rio de Janeiro resulted in temporary and preventive detentions.[408] The corrupt practices and frauds at Angra-3 are also mentioned by decisions of the TCU[409] and plea bargain testimonials taken at different federal courts in Brazil.[410]

The investigations have brought to light a narrative of events and illegal practices affecting three separate sets of contracts for the construction of Angra-3, namely engineering, construction, and electromechanical-assembly contracts. They depict the functioning of a corruption mechanism of bribe trading, fraudulent bidding processes, and complex money laundering involving businessmen from firms involved in the Angra-3 project, brokers, public officials at Eletronuclear, and political parties and politicians, including former president Michel Temer, as illustrated in Figure 9.

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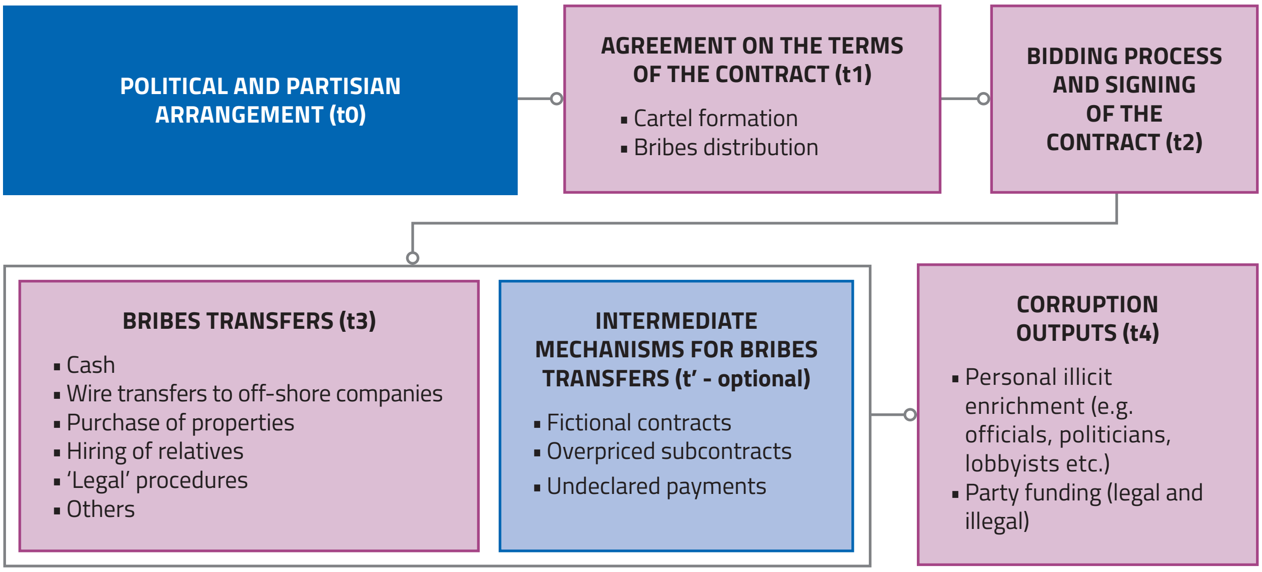
407 See, for instance, Dennis F. Thompson, "Theories of Institutional Corruption" in *Annual Review of Political Science*, 21 (2018), 495-513.

408 J.F.-7, Rio de Janeiro. Sentença D1, Processo No. 0510926-86.2015.4.02.5101, Judge: Marcelo da Costa Bretas, 03.08.2016; J.F.-7, Rio de Janeiro, Processo No. 0500591-66.2019.4.02.5101 (2019.51.01.500591-0), Judge: Marcelo da Costa Bretas, 18.03.2019; MPF, PRE-RJ, Rio de Janeiro, Alegações Finais, Processo N° 0510926-86.2015.4.02.5101, 02.06.2016; MPF, PRE-RJ, Rio de Janeiro, Denúncia, Processo No. 0100511-75.2016.4.02.5101, 20.02.2017; J.F.-7, Rio de Janeiro, Sentença D1, Processo No. 0106644-36.2016.4.02.5101 (2016.51.01.106644-6), Judge: Marcelo da Costa Bretas, 13.12.2017; MPF, PRE-RJ, Rio de Janeiro, Denúncia, Processo 0502834-85.2016.4.02.5101, 03.08.2016; MPF, PRE-RJ, Rio de Janeiro, Denúncia, Processo No. 0510926-86.2015.4.02.5101 (ação penal), 27.07.2016; J.F.-7, Rio de Janeiro, Sentença, Processo No. 0100511-75.2016.4.02.5101 (2016.51.01.100511-1), Judge: Marcelo da Costa Bretas, 27.10.2017.

409 TCU, Acórdão, Processo TC 002.651/2015-7, Relator: Min. Bruno Dantas; TCU, Voto, Processo TC 002.651/2015-7, Relator: Min. Bruno Dantas, 25.04.2018; TCU, Acompanhamento, Processo TC 016.991/2015-0, Relator: Min. Bruno Dantas.

410 *Petição 6683 – Benedicto Junior – Eletronuclear*, G1, Video, 24m25s, April 12, 2017, http://g1.globo.com/politica/operacao-lava-jato/videos/t/todos-os-videos/v/delacoes-da-odebrecht/5797325/; Petição 6683 – *Fabio Gandolfo – Eletronuclear*, G1, Video, 21m42s, April 12, 2017, http://g1.globo.com/politica/operacao-lava-jato/videos/t/delacoes-da-odebrecht/v/peticao-6683-fabio-gandolfo-eletronuclear/5797350/.

Figure 9: The mechanism of political corruption in Angra-3



At their initial stages, investigations have shown that the president of Eletronuclear, Othon Pinheiro da Silva, traded bribes with the major companies involved in the contracts for the construction and engineering services of the Angra-3 project. Most of them pertained to contracts signed in the 1980s, in the early stages of the Angra-3 project. The judicial proceedings describe at least three occasions (in 2006, 2008, and 2014) when Othon negotiated with Andrade Gutierrez - one of Brazil's major companies in civil engineering at that moment - bribes worth 1% of contracts[411] for the construction of Angra-3. The investigations also indicate that Othon acted in favor of Engevix, another large construction company in Brazil, in bidding processes concerning the engineering contracts of Angra-3 in exchange for illegal payments. The directors of Eletronuclear, José Eduardo Costa Mattos and Luiz Messias, were also indicted for negotiating and/or receiving bribes worth of up to 0.2% of the contracts of Andrade Gutierrez. The former director of Eletronuclear, Luiz Antônio de Amorim Soares, is also said to have received bribes from Engevix. The mechanisms of payment and money laundering were complex and involved, for instance, the operation of offshore companies and the use of fictional contracts with or without intermediate companies, which were in charge of transferring the owed amounts to Eletronuclear officials.

The bidding for contracts on electromechanical assembly took place between 2011 and 2014.

The winners were two consortia, UNA03 (Camargo Correa, UTC, Odebrecht, and Andrade Gutierrez) and Angra 03 (Queiroz Galvão, Technit, and EBE). Investigations of corruption practices involving this set of contracts are still unfolding and no judgment has been made yet. Nevertheless, decisions by TCU identified fraud in the bidding process involving Queiroz Galvão, EBE, Techint, and UTC, while plea bargain agreements signed by the CEOs of some of the companies involved indicated the existence of

[411] J.F.-7, Rio de Janeiro. Sentença D1, Processo No. 0510926-86.2015.4.02.5101, Judge: Marcelo da Costa Bretas, 03.08.2016, p. 24-25.

a cartel that operated fraudulent bidding processes to distribute bribes and illegal payments worth BRL 30 million to public officials, political parties and campaigns, and politicians.

Angra Nuclear Power Station in 2017 (Photo by Divulgação PAC/Agência Brasil)

In March 2019, the Federal Court of Rio de Janeiro[412] ordered the preventive detention of Temer, the former president of Brazil, on corruption charges involving the contracts for the development (not the implementation) of the project on electromechanical assembly of Angra-3. MPF stated that Temer had received illegal payments from the Finnish company AF Consult, which had won the bidding process for that contract. Bribery payments were made through indirect, fictional contracts with AF Consult do Brasil, a joint venture between AF Consult Ltd and Argeplan. The latter belonged to João Batista Lima Filho (Colonel Lima), Temer's friend and broker. Engevix allegedly donated to the upper ranks of the Brazilian Democratic Movement (MDB) in exchange for benefits in these Angra-3 contracts. The investigations indicate that the corruption scheme involving Engevix, AF Consult, and Argeplan in Angra-3 was made possible by the president of Eletronuclear, Othon Pinheiro da Silva, acting under the political influence of Colonel Lima, who represented Temer's interests.

It is worth mentioning how the corruption network extended beyond the Angra-3 project. In one particular case, the payment of the owed amount had to be made through publicity contracts set by a consortium of the airport of Brasilia, in which Engevix was one of the participating firms.

As the scandal broke, it became ever more challenging to finance the Angra-3 project. Eletronuclear now awaits changes to the legislation to allow it to attract foreign direct investment. Since site construction started in 2010, the Angra-3 expected total cost has nearly doubled to BRL 14 billion, and the completion date has been pushed back several times. "The problem," says nuclear physicist Ildo Sauer, "is that lobbyists see the nuclear sector as an opportunity to build expensive megaprojects with little regard for cost." He added, "It's no longer about science or energy. It's about politics and money, and that brings corruption."[413]

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[412] J.F.-7, Rio de Janeiro, Processo No. 0500591-66.2019.4.02.5101 (2019.51.01.500591-0), Judge: Marcelo da Costa Bretas, 18.03.2019.

[413] Jeb Blount, "Brazil Nuclear Leader's Arrest May Stymie its Atomic Ambitions," *Reuters*, July 30, 2015, accessed August 29, 2019, https://www.reuters.com/article/us-brazil-corruption-nuclear/brazil-nuclear-leaders-arrest-may-stymie-its-atomic-ambitions-idUSKCN0Q425O20150730.

PROSUB

Submarine Riachuelo (Photo by José Dias/PR, CC BY-NC-SA 2.0)

In 2014, the Lava Jato investigation uncovered evidence of illicit funds fueling political campaigns via the Prosub contracts[414] signed by the Lula administration, Odebrecht, and France's Naval Group in 2009. Most of the information regarding potential corruption practices in the context of Prosub has been obtained from plea bargain agreements signed by CEOs from the involved companies and political stakeholders in various levels of the Brazilian federal judicial system.[415]

In April 2017, Benedicto Júnior, a high-ranking Odebrecht official testified in court that the company paid a broker EUR 40 million to secure the deal between Odebrecht and the Naval Group (then DCNS). The broker, a well-connected lobbyist, had been previously investigated and is wanted for questioning in Switzerland for money laundering related to his activity as a middleman in a 1990 contract to acquire subway trains for São Paulo from Alstom and Siemens.[416] Othon Pinheiro da Silva, the former president of Eletronuclear and a retired Navy admiral, has allegedly received bribes in the context of Prosub through offshore companies and in cash.[417] Separate investigations by the Military Prosecution Service could not find evidence that active Navy military officials in the Navy Command and in the Prosub had been involved in the corruption practices and decided to close the case in May 2019.[418]

Benedicto Júnior also claimed that a portion of the payments, in the amount of BRL 50 million was earmarked for the Workers Party, Brazil's ruling political party at the time. He suggests the money went to a party official, treasurer João Vaccari,

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414 As explained earlier, Prosub comprises not only the construction of the nuclear-powered submarine but also four conventional submarines.

415 For an overview see STF, Petição 6754, Relator: Min Edson Fachin, 16.03.2017.

416 Fabio Serapião and Beatriz Bulla, "Odebrecht Relata Propina para Projeto de Submarino Nuclear da Marinha," *Estadão*, December 15, 2016, accessed August 29, 2019, https://politica.estadao.com.br/noticias/geral,odebrecht-relata-propina-para-projeto-de-submarino-nuclear-da-marinha,10000094692; Fausto Macedo, "Odebrecht Pagou 40 milhões de Euros por Contratos de Submarinos," *Estadão*, April 14, 2017, accessed August 29, 2019, https://politica.estadao.com.br/blogs/fausto-macedo/odebrecht-pagou-40-milhoes-de-euros-por-contrato-de-submarinos/.

417 *Petição 6683 – Benedicto Junior – Eletronuclear*, G1, Video, 24m25s, April 12, 2017, http://g1.globo.com/politica/operacao-lava-jato/videos/t/todos-os-videos/v/delacoes-da-odebrecht/5797325/; *Petição 6683 – Fabio Gandolfo – Eletronuclear*, G1, Video, 21m42s, April 12, 2017, http://g1.globo.com/politica/operacao-lava-jato/videos/t/delacoes-da-odebrecht/v/peticao-6683-fabio-gandolfo-eletronuclear/5797350/.

418 PGJM, Decisões de 19 de julho de 2019, Procedimento Investigatório Criminal 00.2015.000001, *Diário Oficial da União*, July 23, 2019.

who is currently serving a 24-year prison sentence. According to Benedicto Júnior's testimony,[419] the Workers Party asked the company for 1 percent of the initial submarine contract, or roughly BRL 6.5 million.

According to another high ranking Odebrecht official, Marcos de Queiroz Grillo, who worked in Odebrecht's sector dedicated to the illegal payments, the money for the bribes was secured through diversion of a partial amount of the payments made for the services provided by the Belgian construction company Jan De Nul at the Itaguaí shipyard.[420]

In May 2017, first the Brazilian newspaper *Estadão*[421] and then the French outlet *Le Parisien*[422] reported that French law enforcement officials launched a parallel inquiry into the Naval Group's conduct. According to reports by *Le Parisien* and Reuters,[423] France's *Parquet National Financier*, a prosecutorial office to investigate financial crimes, had been looking into the deal since October 2016 and was focusing on whether any entities under its jurisdiction paid bribes to foreign officials. Following the report in *Le Parisien*, the Naval Group denied any wrongdoing. Both the Brazilian and the French investigations are ongoing and have not resulted in indictments yet. The Naval Group faces charges for the payment of bribes not only in Brazil, but also in India, Malaysia, and Taiwan, and it ranks low in Transparency International's Defence Companies Anti-Corruption Index (2015).[424]

In October 2018, the former Brazilian finance minister and confidante of President Lula, Antonio Palocci, told investigating judges in Brazil that in September of 2009, Lula and French President Nicolas Sarkozy had discussed side payments associated with the submarine contracts. [425]

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[419] *Petição 6683 – Benedicto Junior – Eletronuclear*, G1, Video, 24m25s, April 12, 2017, http://g1.globo.com/politica/operacao-lava-jato/videos/t/todos-os-videos/v/delacoes-da-odebrecht/5797325/.

[420] Plea bargain agreement by Marcos de Queiroz Grillo, Dec 13, 2016, in Minas Gerais. The video of the plea bargain testimonial is available at Fausto Macedo, Ricardo Brandt, and Julia Affonso, "Delator Aponta Origem de R$98 milhões de Propina em Submarino da Odebrecht," Estadão, April 18, 2017, accessed August 29, 2019, https://politica.estadao.com.br/blogs/fausto-macedo/delator-aponta-origem-de-r-98-milhoes-de-propina-em-submarino-da-odebrecht/.

[421] Beatriz Bulla, Fabio Serapião, "Franceses investigam projeto do submarino brasileiro," *Estadão*, May 8, 2017, accessed November 11, 2019, https://politica.estadao.com.br/noticias/geral,franceses-investigam-projeto-de-submarino-brasileiro,70001768464.

[422] Timothée Boutry, Jean-Michel Décugis, Myriam Encaoua, Eric Pelletier, "Vente de sou-marins au Brésil: une enquête por corruption est ouverte,» *Le Parisien*, May 20, 2017, accessed November 4, 2019, http://www.leparisien.fr/faits-divers/vente-de-sous-marins-au-bresil-une-enquete-pour-corruption-est-ouverte-20-05-2017-6967692.php.

[423] "French Prosecutors Investigate DCNS Submarines Sale to Brazil: Source," *Reuters*, May 21, 2017, accessed August 29, 2019, https://www.reuters.com/article/us-france-brazil-submarines-idUSKBN18H0I9.

[424] For India, see, Julio Wiziack, "Investigado, Projeto de Submarino Nuclear Traz Novas Suspeitas," *Folha de São Paulo*, June 13, 2016, accessed August 29, 2019, https://www1.folha.uol.com.br/poder/2016/06/1780963-investigado-projeto-de-submarino-nuclear-traz-novas-suspeitas.shtml#article-aside; For Malaysia and Taiwan, see, "Taiwan's Lafayette Frigate Affair," Compendium of Arms Trade Corruption, accessed August 29, 2019, https://sites.tufts.edu/corruptarmsdeals/taiwan-the-lafayette-affair/. For the index, see, Defence Companies Anti-Corruption Index, (Transparency International, database, accessed August 29, 2019), http://companies.defenceindex.org/.

[425] Fabio Serapião, "Palocci afirma que Lula e Sarkozy acertaram propina em compra de submarinos e helicópteros", *Estadão*, March 18, 2019, accessed November 4, 2019, https://politica.estadao.com.br/blogs/fausto-macedo/palocci-afirma-que-lula-e-sarkozy-acertaram-propina-em-compra-de-submarinos-e-helicopteros/.

CTMSP

In August 2017, the Austrian company Bilfinger signed a leniency agreement with the Office of the Federal Attorney General (AGU) and CGU. The firm confirmed that it had negotiated bribes worth EUR 2 million with a Brazilian official. The agreement analyzed contracts that had been signed with the CTMSP for the supply of materials used in the Navy's nuclear program between 2012 and 2017.[426]

In February 2019, the Federal Police conducted search and seizure actions against a nuclear engineer, Renato Del Pozzo, from CTMSP accused of corruption charges involving Bilfinger. According to MPF in São Paulo, the engineer requested bribes worth BRL 6 million from Bilfinger in contracts with CTMSP for the supply of research materials, goods, technology, and services. Since 2015, the Navy has been acting through CGU to clarify the illegal practices and has initiated an investigation in the Military Prosecution Service.[427]

NUCLEP

Political-party appointments to executive positions in state-owned companies in the nuclear sector are a common practice in Brazil. This is not specific to the nuclear sector but is a common feature across the public sector. In 2017, members of Congress from the Progressive Party, the Republic Party (now the Liberal Party), and the Brazilian Democratic Movement lobbied the executive branch to make appointments to directorships and the presidency at Nuclep, a state company that provides heavy industrial equipment to the nuclear industry.[428] At the time, press reports showed that none of the appointees for directorships fulfilled the minimum requirements established by law. For instance, the appointments violated a prohibition on appointing individuals to such positions if they had worked for political parties or played a role in political campaigns in the previous three years. The appointments were made nonetheless. When the head of CNEN opposed the appointments, he was fired from his job. The Brazilian Academy of Sciences, the Brazilian Society for the Advancement of Science, and the Brazilian Society of Physics issued public letters of protest against the appointments and the firing of the president of CNEN.[429]

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[426] "AGU e CGU Celebram Acordo de Leniência Com Empresa Bilfinger," AGU, accessed August 29, 2019, http://www.agu.gov.br/page/content/detail/id_conteudo/588202; Fábio Fabrini, "Alemã Bilfinger Fecha Liniência por Propina na Marinha," *Estadão*, July 28, 2017, accessed August 29, 2019, https://www.estadao.com.br/noticias/geral,alema-bilfinger-fecha-leniencia-por-propina-na-marinha,70001911715.

[427] Bruno Tavares, "PF Cumpre Mandados em SP para Investigar Suspeita de Cobrança de Propina para Construção de Submarino da Marinha," *G1*, February 7, 2019, accessed August 29, 2019, https://g1.globo.com/sp/sao-paulo/noticia/2019/02/07/pf-cumpre-mandados-em-sp-para-investigar-suspeita-de-cobranca-de-propina-para-construcao-de-submarino-da-marinha.ghtml.

[428] Lucas Vettorazzo, "Por Apoio no Congresso, Temer Quer Lotear Estatal da Área Nuclear," *Folha de São Paulo*, March 16, 2017, accessed August 29, 2019, https://www1.folha.uol.com.br/poder/2017/03/1866913-por-apoio-no-congresso-temer-quer-lotear-estatal-da-area-nuclear.shtml; Letícia Fernandes, "Autor do Voto que Deu Vitória a Temer, Áureo Ganhará Cargo em Empresa Nuclear," *O Globo*, August 10, 2017, https://oglobo.globo.com/brasil/autor-do-voto-que-deu-vitoria-temer-aureo-ganhara-cargo-em-empresa-nuclear-21691323.

[429] Lucas Vettorazzo, "Temer Exonera Servidor Contrário a Indicação que Loteia Órgão Nuclear," *Folha de São Paulo*, March 19, 2017, accessed August 29, 2019, https://www1.folha.uol.com.br/poder/2017/03/1867760-temer-exonera-servidor-contrario-a-indicacao-que-loteia-orgao-nuclear.shtml; João Mello, "ABC e SBPC Criticam Exoneração de Presidente da Comissão de Energia Nuclear," *GGN*, March 28, 2017, https://jornalggn.com.br/crise/abc-e-sbpc-criticam-exoneracao-de-presidente-da-comissao-de-energia-nuclear/; "Sociedade Brasileira de Física se Manifesta

IMPLICATIONS AND NEXT STEPS

Corruption in the nuclear industry is not exclusive to Brazil. In recent years, allegations and confirmed cases of corruption were reported in various countries, including the United States, Canada, Japan, South Korea, Russia, France, and China. Major nuclear-related corruption scandals broke out in Lithuania, Bulgaria, and Pakistan, and allegations were made in Egypt, India, Jordan, Nigeria, Slovakia, South Africa, and Taiwan.

The Brazilian case stands out because the anticorruption investigations have made remarkable progress, and information has reached the public sphere in ways that can inform the public debate and pave the way for stronger anticorruption policies. This gives grounds for hope. Brazil now needs to build upon the progress that it has already made. In particular, managers in the nuclear sector have been particularly keen on engaging with various state control institutions. New bills were introduced in Congress to curb corruption and improve governance in the public sector (for example, the State Companies Act). As ongoing investigations proceed, more information will come to the fore that will, hopefully, help craft effective policies.

Contra Exoneração do Presidente da CNEN," *Jornal da Ciência*, March 24, 2017, http://jcnoticias.jornaldaciencia.org.br/5-sociedade-brasileira-de-fisica-se-manifesta-contra-exoneracao-do-presidente-da-cnen/; Maurício Tuffani, "Pressão Política Deixa Kassab sem Respostas sobre Demissão na CNEN e Corte de Verbas," Direto da Ciência, accessed August 29, 2019, http://www.diretodaciencia.com/2017/03/27/pressao-politica-deixa-kassab-sem-respostas-sobre-demissao-na-cnen-e-corte-de-verbas/.

HUMAN RESOURCES AND EDUCATION

As addressed earlier in this report, in recent years, the naval nuclear program has seen a sustained increase in hiring while civilian nuclear institutions have experienced a steady decrease in employed professionals. This section addresses the governance of human resources and education in the nuclear field. It also discusses how the issues afflicting attraction, retention, and training of the professionals who sustain Brazil's nuclear program – in particular, in CNEN, Eletronuclear, and the radioisotope industry – have implications for the provision of goods, for the security and safety of research reactors and nuclear power plants, and for the future of Brazilian nuclear R&D. The section concludes with an overview of weaknesses stemming from the way Brazil manages human resources in the nuclear field.

EMPLOYMENT

Hiring at state nuclear institutions in Brazil is carried out with the help of state entry exams.[430] In addition, new employees can be employed for state positions through three additional channels: appointments to commissioned positions,[431] temporary contracts in cases of "exceptional public interest,"[432] and indirect hiring via third-party companies when the case can be made that professionals hired that way do not compete with state personnel and do not have jobs directly involved with the entity's main area of competence.[433] Reliance on state exams as the primary vehicle to hire new personnel places a burden on Brazilian nuclear managers as shrinking state budgets have limited the number and scope of new entry exams, leading to losses of personnel.

CNEN is a case in point. The last large-scale admission exam took place in 2010 when the federal government authorized only 180 positions out of 202 requested by CNEN. CNEN's request for an additional entrance exam in 2013 was denied, and in 2014, the federal government approved only 86 out of the 365 positions requested by CNEN, but, in the end, only 78 of these were confirmed.[434] According to its internal

430 Constituição Federal do Brasil (1988), art. 37, it, II; Lei No. 8.112, de 11 de Dezembro de 1990, *Diário Oficial da União*, April 19, 1991.

431 Constituição Federal do Brasil (1988), art. 37, it, II.

432 Lei No. 8.745, de 9 de Dezembro de 1993, *Diário Oficial da União*, December 10, 1993.

433 Decreto No. 9.570, de 20 de Novembro de 2018, *Diário Oficial União*, November 21, 2018.

434 CNEN, *Relatório de Gestão 2017*, 174-75.

estimates, CNEN needs to hire 500 staff for new positions immediately if it is to meet its responsibilities, and it estimates that it has 1,417 vacant posts within its structure that it needs to fill.[435]

Between 2010 and 2019, CNEN (including its research institutes) lost some 20 percent of its staff (See "Human Resources" in "1 - Capabilities and Major Players"), which directly affects its ability to regulate and inspect facilities, and therefore to ensure safety, security, and compliance with nonproliferation. The commission currently oversees 6,070 facilities, 2,992 of which are currently active.[436] The facilities include clinics and hospitals operating radiological equipment and using radiopharmaceuticals. The number of facilities in operation is expected to rise if the government's plans to revive the nuclear program materialize, and as a result, the complexity of procedures undertaken in Brazil increases. Nuclear medicine will likely expand in the next few years. In addition, new actors might enter the field as the production of radioisotopes via cyclotrons expands, or the oil and gas industry draws on radioactive sources to expand its production. Labgene will add another nuclear reactor to the existing number, and the eventual commissioning of the nuclear-powered submarine will expand nuclear-related assets nationwide.[437]

Immediate and substantial changes in training, hiring, and retaining qualified personnel are critical if CNEN is to keep up with the growing demands of an expanding nuclear sector. In one striking example of CNEN's desperate need for more personnel, as of 2019, there were only three individual inspectors in charge of nuclear security/physical protection nationwide.[438] CNEN's 2017 annual report highlights its struggle to regulate and inspect the nuclear sector due to lack of personnel. CNEN warns that, in the near future, it might not be able to meet all needs in areas as sensitive as nuclear safeguards.[439]

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IPEN accounts for a significant portion of the losses in human resources in CNEN described above. The institute used to have nearly 1,800 professionals on its payroll, but it now operates with less than half of that workforce – 673 employees.[440] Figure 10 shows that between 2000 and 2016, there were only two years in which there were more new hires than departures at IPEN.

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[435] Ibid., 175.

[436] CNEN, *Relatório de Gestão 2017*, 53-59.

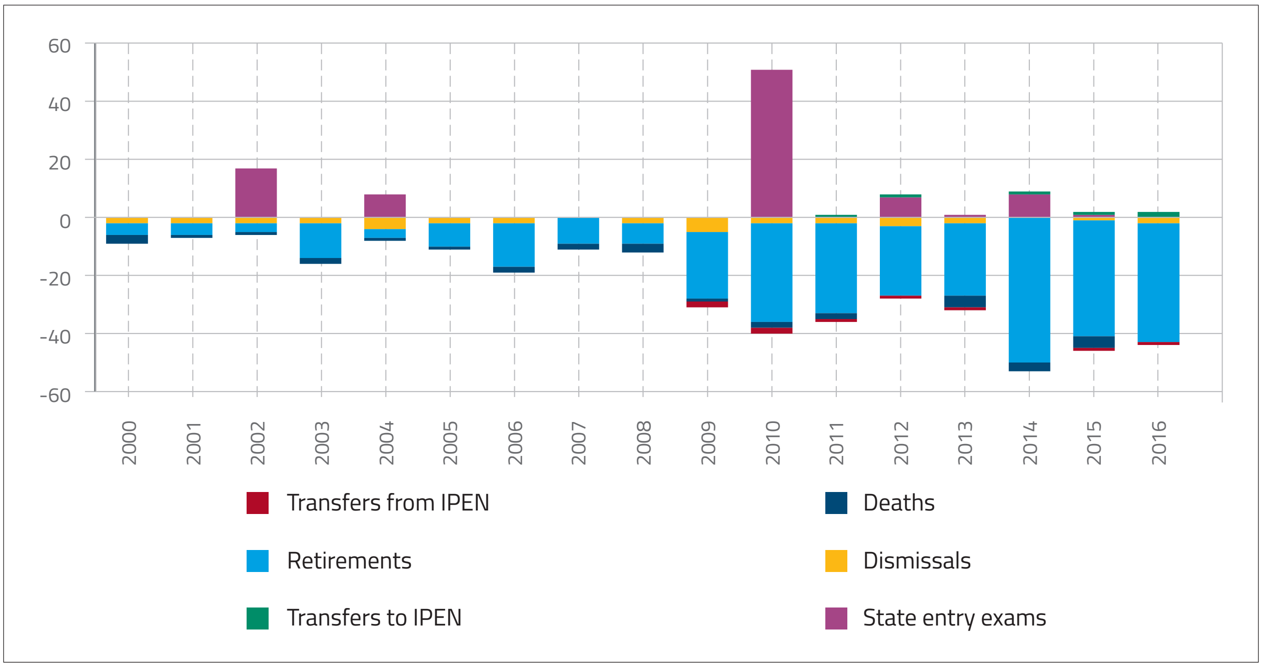
[437] Whereas the Naval Agency for Nuclear Security and Quality will be in charge of the norms, licensing, and inspection of the submarine itself, CNEN will remain responsible for the licensing and inspection of the Labgene.

[438] Tavares, "Physical Protection of Brazilian Nuclear Materials and Facilities."

[439] CNEN, *Relatório de Gestão 2017*, 51-53, 56, 61, 65.

[440] SIAPE CNEN – Quadro de Cargos Efetivos por Carreira e Unidade (accessed February 2019).

Figure 10: Losses and gains of IPEN's human resources (2000-2016)



Source: Adapted from IPEN, *Relatório de Gestão 2016*, 92.

IPEN is now considering shutting down the Laboratory of Radiological Protection and merging other labs. The production of radioisotopes and radiopharmaceuticals may be compromised in the very near future due to shortages of staff. In a search for temporary alternative solutions, research institutes such as IPEN have resorted to research internships, externally funded scholarships, and voluntary work to complement their staff.[441] These employees must be allocated to research and education divisions and cannot work with the provision of services or products, so, in practice, this alternative to human-resource shortages helps to keep only IPEN's research strength but not its production capacity.

Eletronuclear lost 30 percent of its workforce, or 806 employees, in five years.[442] This will likely affect the operation of the two existing reactors and compromise the licensing process for Angra-3. The inability to demonstrate that the company has a sufficient workforce to operate the new unit might make the project ineligible for licensing as it would not fulfill the minimal requirements pertaining to technical and legal capacity. Shrinking personnel numbers will also compromise construction work on Angra-3 once its funding problems are resolved.[443]

The Navy managed to overcome these hurdles by setting up a state-owned company, Amazul, as described earlier in this report. (See "Human Resources and Education" in "1 - Capabilities and Major Players.") A more flexible system for temporary contracts and a simplified hiring process allowed Navy officials to build

[441] IPEN, *Relatório de Gestão 2016*, 93.

[442] Eletronuclear, *Relatório de Gestão 2017*, 73.

[443] Ibid.

up the human resources it needs to develop the submarine project.[444] Due to the program's success, Amazul has increasingly provided personnel to Navy units such as CTMSP and Cogesn. This, however, does not mean that human resources in the naval nuclear sector are entirely immune to the fluctuations in the federal budget. When in 2015 the government reduced payments to Odebrecht, the company at the heart of Navy's construction projects, reportedly fired nearly 1,200 employees.[445]

KNOWLEDGE MANAGEMENT

CNEN and Eletronuclear estimate that the complexity of technical and managerial processes involved in the operation of nuclear and radiological facilities in Brazil requires about five years of knowledge building for newcomers, including periods specifically dedicated to close interaction with and learning from senior officials.[446] As the authors learned during their field trips for this report, the nuclear sector in Brazil largely depends on the oral transmission of knowledge.

This intergenerational exchange has been compromised in Brazil in recent years. As highlighted above, nuclear institutions continue to face difficulties with hiring new permanent staff through the state admission exams. In addition, the sector struggles with high rates of retirement due to staff aging. In late 2017, 780 professionals at CNEN were eligible for retirement, a number that corresponded to 42% of the total staff.[447] The lack of admissions and the departure of senior personnel create a gap in the intellectual capital of the nuclear sector.[448]

At Eletronuclear, under the Program for Voluntary Leave, experienced officials retired, vacating top managerial positions for more junior officials.[449] In an attempt to prevent "brain drain," in 2018, Eletronuclear management blocked access to the Program for Voluntary Leave for highly skilled personnel. Eletronuclear also established a working group for knowledge management tasked with identifying main human-resources-related risks and promoting capacity-building programs for people moving up the ranks.[450]

The Navy is attentive to knowledge management too. It developed policies to retain skilled workers and is rolling out new capacity-building activities for its personnel.[451]

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[444] Lei No. 12.706, de 8 de Agosto de 2012, *Diário Oficial da União*, August 9, 2012; Amazul, Estatuto Social, (São Paulo, April 5, 2019); Amazul, Regimento Interno da Amazul, RCA 034 (October 3, 2018), art. 45.

[445] "PROSUB: Contingenciamento Afeta os Projetos," Tecnodefesa, accessed August 29, 2019, http://tecnodefesa.com.br/prosub-contingenciamento-afeta-os-projetos/; Alana Gandra, " Base de Submarinos da Matinha Reduz Ritmo de Trabalho por Corte de Gastos," *Empresa Brasil de Comunicação*, January 11, 2016, http://agenciabrasil.ebc.com.br/geral/noticia/2016-01/ajustes-reduzem-ritmo-de-trabalho-na-base-de-submarinos-da-marinha-em-itaguai.

[446] Eletronuclear, *Relatório de Gestão 2017*, 73; CNEN, *Relatório de Gestão 2017*, 174.

[447] CNEN, *Relatório de Gestão 2017*, 174.

[448] CNEN, *Relatório de Gestão 2017*, 185.

[449] Eletronuclear, *Relatório de Gestão 2017*, 73.

[450] Ibid.

[451] Cogesn, *Relatório de Gestão do Exercício de 2017* (Rio de Janeiro, 2018), 56.

Amazul has introduced a transfer-of-knowledge program connecting retirees to younger staff.[452]

PUBLIC-SECTOR CAREERS

Incentives for pursuing a career in the Brazilian nuclear sector are mixed. Most employees receive special employment conditions unique to federal public servants. They benefit from privileges in comparison to those in the private sector, including higher salaries and generous retirement rules.[453] The workforce enjoys career and financial incentives to pursue graduate degrees and further develop their skills. Moreover, certain personnel in the nuclear sector receive additional financial benefits to compensate for the risk of working in potentially hazardous conditions. Professionals also receive other bonuses for their work in the production of radioisotopes and radiopharmaceuticals.[454] Military officials working in the nuclear sector are subject to the labor regime of the Armed Forces, which similarly provides a range of benefits that do not normally apply for workers who are not in the state sector.

The labor unions in the nuclear sector complain, however, that working conditions are less attractive than the appearances suggest. The current legislation does not allow the payment of bonuses for overtime work in the production of radiopharmaceuticals.[455] Instead, the government grants special fixed bonuses to all professionals directly involved in this type of activity. The only requirement is to fulfill the 40-hour workweek, no matter the work schedule (regular work hours, shifts or anything else).

This regime of payments and work hours for these professionals is likely to affect the total output of radioisotopes. Given the current rules, most professionals opt to work during regular working hours. This leads to reduced hours of research reactor operation and decreased production of radioisotopes. Complicating matters further, there are ongoing judicial disputes as to whether professionals directly exposed to radioactive sources can be eligible for a reduction in their working hours from 40 to 24 hours per week. This, in turn, could restrict even more the operating time of research reactors. Some public officials won their cases,[456] while the attorney general for the federal government argued that all personnel receiving bonuses for nuclear-related work should comply with a 40-hour requirement.[457] Senior officials in the nuclear R&D

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452 Amazul, *Relatório da Administração 2017* (São Paulo, 2018), 6.

453 Lei No. 8.112, de 11 de Dezembro de 1990, *Diário Oficial da União*, April 19, 1991.

454 IPEN, *Relatório de Gestão 2016*, 63-64.

455 Medida Provisória No. 441, de 29 de Agosto de 2008, *Diário Oficial da União*, September 5, 2008; Lei No. 11.907, de 2 de Fevereiro de 2009, *Diário Oficial da União*, February 4, 2009; Decreto No. 8.421, de 20 de Março de 2015, *Diário Oficial da União*, March 20, 2015, art.3.

456 "TRF2 Determina Redução de Jornada de Servidores da CNEN," TRF2, accessed August 29, 2019, https://www10.trf2.jus.br/portal/trf2-determina-reducao-de-jornada-de-servidor-da-cnen/.

457 Wilson Castro, "Advocacia-Geral Impede Redução Indevida de Jornada de Servidor da CNEN," AGU, accessed August 29, 2019, https://www.agu.gov.br/page/content/detail/id_conteudo/579413.

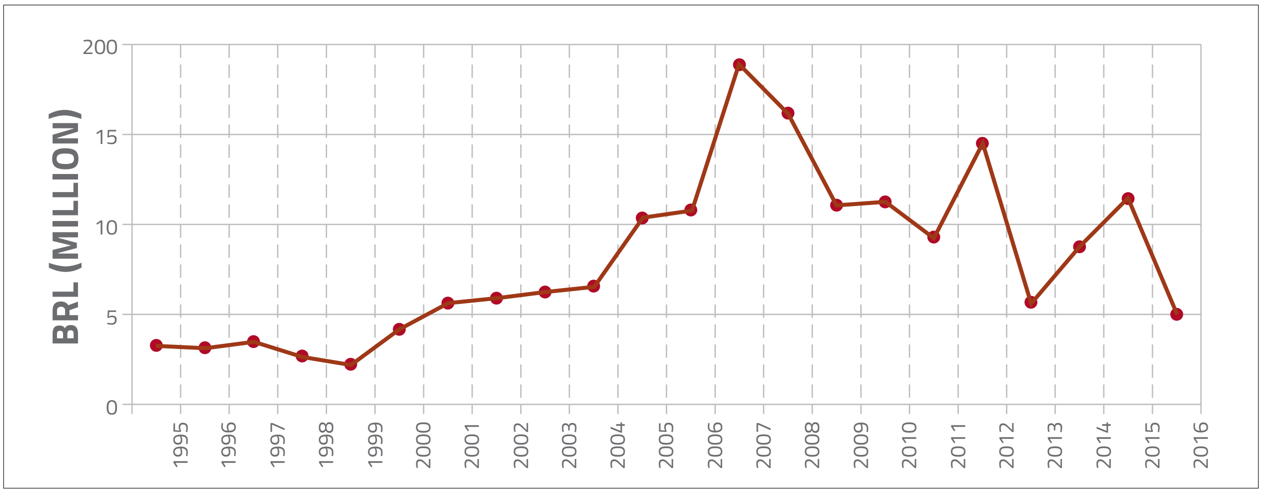
sector told the authors that, as long as this situation remains, the operation of future reactors such as the RMB will face similar hurdles.

Another factor negatively affecting the future of nuclear science as a professional choice is not related to labor regulations. The authors' extensive interviews with the representatives of the nuclear research sector indicated that young Brazilian scientists are reluctant to pursue careers in the nuclear field because nuclear science is more mature and less prone to disruptive innovation than, for example, emerging fields such as artificial intelligence or genome mapping.

EDUCATION

Brazil lacks a unified policy to promote education in the field of nuclear science or nuclear policy. State-owned universities, research institutes, and the Military Institute of Engineering dominate the field. The Navy plays a secondary role in nuclear education at the university level. Graduate nuclear-science programs mostly rely on their own budgets for research; they rely on external funding from governmental foundations for science, technology, and education (research foundations in the state level, the Coordination for the Improvement of Higher Education Personnel from the Ministry of Education, the National Council for Scientific and Technological Development from the Ministry of Science, Technology, Innovations, and Communications, and others), as well as on minor contributions from private companies. As a result, like human resources, nuclear science is highly dependent on federal budgets for the provision of education. Figure 11 illustrates the evolution of the financial support IPEN received from state funding agencies and other specific contracts. (It should be noted that from 2013 onward, scholarships were excluded from these figures.)

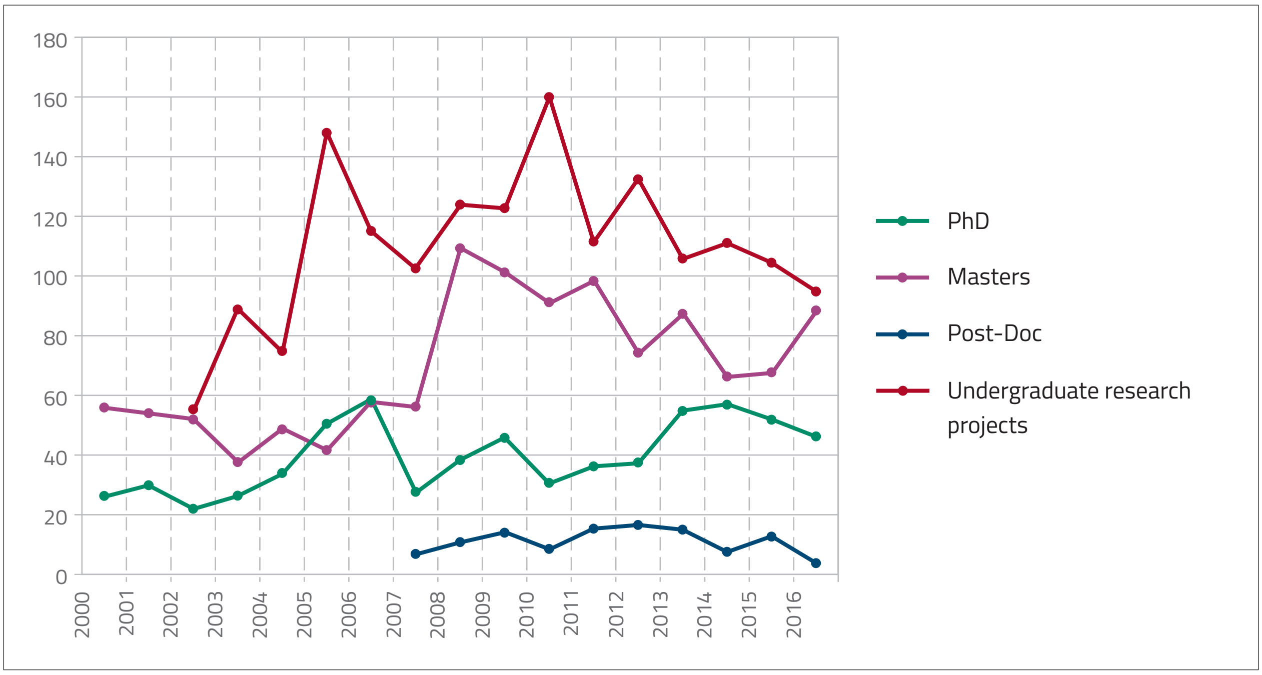
Figure 11: The evolution of IPEN's financial support from state funding agencies and specific contracts (1995-2016)



Source: Adapted from IPEN, *Relatório de Gestão 2016* (São Paulo, 2017), 86.

The lack of human resources in nuclear research institutes is another factor affecting education. According to IPEN's 2017 annual report, the high level of retirement is one of the factors explaining the recent decline in the number of students who graduated from the institution, as illustrated in Figure 12:

Figure 12: Students who graduated from IPEN (2000-2016)



Source: Adapted from IPEN, *Relatório de Gestão 2016*, 88.

Military and civilian stakeholders are trying to find new mechanisms and initiatives to revitalize nuclear education in the country. In this process, the Navy, in its ever-expanding political role in the nuclear field, leads the way, while civilian research institutes follow. Within the framework of the Nuclear Committee at the GSI, the Navy and the Ministry of Education agreed to launch a program for strengthening nuclear education. The Navy Command and the Ministry of Education are expected to issue a special call for applications to allocate BRL 20 million in research scholarships in the field of nuclear science.[458] The Navy also plans to create new graduate programs in nuclear science at CTMSP[459] that it hopes will become the basis for a new center of training and education for nuclear science in the region. The Navy expects that its graduate programs will be closely connected to the RMB project and other research institutes in the nuclear sector, such as IPEN, in the field of research and education.

[458] "MEC destinará R$ 20 milhões a programa de bolsas para pesquisadores em energia nuclear," Ministério da Educação, accessed on February 9, 2020, http://portal.mec.gov.br/component/content/article/12-noticias/acoes-programas-e-projetos-637152388/70971-mec-destinara-r-20-milhoes-a-programa-de-bolsas-para-pesquisadores-em-energia-nuclear?Itemid=164.

[459] "Centro Tecnológico da Marinha Projeta Curso de Pós-Graduação na Área da Tecnologia Nuclear," Brasil-Ministério da Educação, accessed on January 20, 2019, http://portal.mec.gov.br/ultimas-noticias/212-educacao-superior-1690610854/70691-centro-tecnologico-da-marinha-projeta-curso-de-pos-graduacao-na-area-da-tecnologia-nuclear.

RECOMMENDATIONS

CIVIL-MILITARY RELATIONS

- The growing influence of the Brazilian Navy in the nuclear sector – including the nuclear industry – highlights the need for civilian control. As progress unfolds in the country's nuclear program in the coming years, the importance of independent, nonmilitary monitoring mechanisms will only grow. A robust framework for civilian control will help future administrations reassure the Brazilian people that a prominent place for the military in the country's nuclear politics does not mean militarization or the abandonment of the constitutional commitment to a peaceful program. To this end, the Brazilian presidency's Nuclear Committee and working groups would do well to ensure representation of civilian leaders in nuclear-relevant institutions and make an effort to engage with and consult civil society and scholars.
- As the Brazilian market for uranium enrichment expands, it will be useful for nuclear policy to focus as comprehensibly as possible on improving existing levels of trust within the sector, in particular as it pertains to the relationship between the Navy and INB.
- The next few years will see a flurry of activity within Brazil's nuclear sector as officials develop a new framework for safeguarding the fuel for the nuclear-powered submarine and as negotiations on this matter begin with the IAEA and possibly ABACC. The administration will benefit from commissioning a consultative process among government entities coupled with comparative studies that might illuminate the range of options for safeguards arrangements that are available. Furthermore, it would be prudent for the Brazilian government to delineate the division of labor and responsibilities between CNEN and the Naval Agency for Nuclear Safety and Quality. Potential overlap between these two agencies on issues such as safety, security, and safeguards needs to be avoided for the sake of the smooth running of Brazilian program at home and its standing abroad. Maintaining civilian authority over the safeguarding of nuclear fuel for the submarine is particularly relevant as Brazilian capabilities evolve.
- R&D in the nuclear field provides a unique opportunity to increase mutual trust among the major stakeholders in Brazil's nuclear program. For example, cooperation on the RMB can open new space for cooperation between CNEN and military technology organizations such as CTMSP and Amazul. R&D can also play a key role in attracting and retaining a new generation of nuclear scientists and engineers who can secure the program's future. A long-term commitment to investing in technological development and innovation, even in times of fiscal constraints, will contribute to the sustainability and vitality of Brazil's nuclear program.
- In recent years, the Brazilian establishment has been largely successful in communicating the peaceful nature of its nuclear program to audiences abroad. The efforts included engagement with civil society, an outreach program to international nuclear professionals, and an increasingly open attitude toward public debate. This trend is very positive and will become ever more necessary as the nuclear submarine project moves forward.

NUCLEAR REGULATION

- The debate over whether CNEN's functions as a regulator and an implementer of nuclear policy should be separated is well advanced, and there is a near consensus that establishing an independent nuclear regulator would be beneficial for the country. Brazil's eventual establishment of an independent nuclear regulator would help it to solidify its reputation as an advanced nuclear country with appropriate regulatory oversight over its nuclear program.

ENVIRONMENTAL REGULATION

- The relationship between Brazil's nuclear sector and the environmental authorities has at times been fraught with disputes over responsibilities and reach. Although no off-the-shelf model exists that be can easily adapted to the Brazilian context, it may be useful to consider a dedicated and multi-stakeholder effort to disentangle existing regulation. Improvement in the working relationship between the nuclear and environmental authorities is needed as awareness is growing that ameliorating standards for environmental protection will be key for the future and expansion of the nuclear sector, especially if it becomes increasingly integrated with private actors.
- Although Brazil's civil society is very active in the field of environmental protection, it is hardly involved in the debates over nuclear policy. It would be beneficial for the future of Brazil's nuclear program if nongovernmental organizations, scholars, and advocacy organizations actively engage in public discourse. At the end of the day, greater involvement by civil society, including contribution of expertise, will help the Brazilian government and the nuclear sector to develop a robust and sustainable nuclear program.

NUCLEAR SAFETY AND SECURITY

- Brazilian authorities are now updating their nuclear safety and security requirements. The country would benefit greatly from a process for updating the rules, procedures, and governance that is as systematic as possible.
- The region that hosts Brazil's nuclear reactors – Angra dos Reis – is prone to criminality and violence. While there is no immediate threat to the site of the reactors, the vulnerability of surrounding areas and the routes that are normally used for the transportation of nuclear and radioactive materials has proven to be a matter of serious concern. Mitigation of the risks to the Angra site will require coordination and effort from key stakeholders – federal and state authorities, as well as management at Electronuclear.
- Brazil would benefit from developing a single platform to monitor nuclear and

radioactive materials nationwide, with special attention to the deployment, transportation, and disposal of radioactive sealed sources and nuclear fuel. Such a monitoring mechanism could prevent both safety- and security-related incidents.

NUCLEAR CYBERSECURITY

- Brazilian authorities are aware of the need for a culture of cybersecurity in key areas of government policy. The nuclear sector would benefit from dedicated attention, in particular with regard to raising awareness among professionals in the field as to the emerging risks to nuclear safety and security in cyberspace. This need does not involve the development of major surveillance programs or an approach that is militarized. Involving civilian actors will be critical to ensure the development of such a culture that reaches all parts of the nuclear sphere.

RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT

- Independent contractors are best suited to monitor tailings dams at uranium mining facilities in Caldas and Caetité. Drawing on their expertise should become a matter of course as the uranium mining industry expands. Information about the conditions of the tailings systems should be readily available for the public at large.
- The construction of new storage facilities for spent fuel and radioactive waste is a priority if Brazil is to extend the lifetime of reactors in operation, namely the Angra power reactors and IEA-R1 at IPEN.
- CNEN should consider a new round of collection of disused sealed sources nationwide to mitigate the risks associated with inadequate disposal of radioactive sources.
- Brazil would benefit from developing a single national database of radioactive waste that uses unified metrics.
- Constructing a final geological repository for low- and medium-level radioactive waste would alleviate issues of storage capacity onside and at intermediate-storage facilities.
- The Brazilian government would benefit from submitting to Congress a revised and updated set of legal norms on radioactive waste management that eliminates the operational gaps in the system.
- Finding both technical and financial solutions for the final decommissioning of INB facilities at Caldas and São Paulo would reassure the public as Brazil moves ahead with the expansion of its current nuclear-related activities.
- Whether Brazil will one day adopt policies to reprocess spent fuel remains to be seen. Until it does – or if it chooses not to – it will benefit from new legislation on managing high-level radioactive waste (such as spent nuclear fuel), adapting existing storage facilities, and building new ones.

NUCLEAR SAFEGUARDS

- Brazilian authorities have begun discussions over the application of "special procedures" for nuclear material used in naval propulsion. The coming years will see negotiations within Brazil unfold, as the Navy sets the enrichment level for naval nuclear fuel and specifies the stage of the nuclear fuel cycle at which these procedures will apply. Discussions will also take place with Argentina, ABACC, and the IAEA. These negotiations will benefit from inputs of independent experts holding a range of views on the subject.
- The regional nuclear order in South America will benefit if ABACC manages to update and modernize its mandate in the face of the changes in the nuclear programs of both Argentina and Brazil. Avoiding the duplication of procedures that are already conducted by the IAEA and playing a greater role in raising regional awareness and fostering education on nuclear nonproliferation would be an obvious way forward.
- Recent times have seen a new, positive attitude on the part of both Argentina and Brazil with regard to a potential additional protocol to be jointly negotiated between the two countries, ABACC, and the IAEA. No longer a taboo, this issue should be seen by all parties as a unique opportunity to cement the bilateral relationship and the continuing commitment of Argentina and Brazil to nonproliferation.

PRIVATE INVESTMENT

- If the Angra-3 reactor is to be completed, Brazil will require significant support from foreign investors. As debates evolve on how best to do that, the Brazilian authorities would benefit from putting in place legal frameworks and procedures to prevent interest groups from capturing this particular area of policy.
- As Brazil prepares to increasingly bring in the private sector into its nuclear program, authorities should ensure the regulatory framework is duly updated to prevent the rent-seeking behavior that recent waves of corruption scandals in the country unveiled.
- The RMB will require a business model that includes a decision on how best to allocate the profits that are expected to be obtained.
- Opening the radiopharmaceuticals market to private actors should be balanced with meeting social needs, a debate that Brazil needs to have.

CORRUPTION

- Brazil has made major strides of late in curbing the recurrence of corruption in relations between business and government, including in the nuclear sector. The costs of corruption are now clear for all to see. The process of opening up the nuclear sector to external control institutions that demand ever-growing levels of transparency ought to be both celebrated and encouraged.

- Brazil can and should aspire to become a model for anticorruption practice in the nuclear field. This would involve leading the global public conversation on how best to address corruption in this particular industry and engaging a wide range of international stakeholders in identifying and promoting best practices.

HUMAN RESOURCES AND EDUCATION

- The future of Brazil's nuclear program depends to a large extent on retaining and attracting new talent. Capacity building and education in the field are critical at this stage. Nuclear science and training in global nuclear politics ought to be encouraged across the board. Partnerships between the government and the private sector will be essential in making this happen, particularly as Brazil's fiscal situation is likely to remain fragile for years to come.