

Conexão
Nuclear

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Brazil's Nuclear Ecosystem

Studies from FGV and Sebrae reveal socioeconomic impacts.

U.S. and Canada Missions

Discussion of advances and partnerships in nuclear technology.

Poland's Nuclear Program

Transition from coal-fired power plants.

Interview with Rafael Grossi

Director-General of the IAEA

In a relevant discussion, Nuclear Connection explores various topics, such as Brazil's current progress in the nuclear sector and the role of renewable energies.

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WHAT IS MISSING FOR NUCLEAR TO BE INCLUDED IN OUR LEGISLATION?



IT IS URGENT THAT BRAZIL TAKES A PROACTIVE AND INCLUSIVE STANCE.

ergy source, and are significantly incorporating it into their energy matrices. COP30, an event that will mark the next year, reaffirms this trend and places us before an imperative challenge: to keep up with this global movement.

However, it is concerning to note that, after Germany, Brazil is among the few countries that have not yet included nuclear energy as an essential part of their energy transition. This gap represents both a missed opportunity and a risk to our future energy and environmental security. It is urgent that Brazil adopts a proactive and inclusive stance, ensuring that nuclear energy is a key component in our path towards a sustainable future.

Our magazine, committed to informing and reflecting on the most relevant topics of our time, features articles and interviews addressing this issue and others that are also necessary. Highlighted, we have an exclusive interview with Rafael Grossi, President of the IAEA, where we discuss the challenges and opportunities of nuclear energy in Brazil and the world.

Additionally, we explore the inspiring example of the Polish Nuclear Program, which is transitioning from coal-fired power plants to cleaner and safer sources. We also analyze the financing of nuclear projects and the nuclear ecosystem in Brazil, through studies conducted by Sebrae and FGV, among other relevant topics in our sector.

The time has come to act with determination and a long-term vision. Nuclear energy is not just a viable option, but an urgent necessity to ensure a prosperous and sustainable future for future generations.

Enjoy your reading! ■

Dear Readers,

It is with great enthusiasm that we bring to the forefront a crucial topic for the sustainable development of our country: the presence of the nuclear industry in the energy transition legislation and the hydrogen plan. We are at a decisive moment in our history, where nuclear energy emerges as a fundamental pillar to ensure energy security and reduce greenhouse gas emissions.

The recent global trend towards nuclear energy cannot be ignored. Countries around the world have recognized the benefits of this clean and reliable en-

ABDAN'S MISSIONS IN THE UNITED STATES AND CANADA EXPLORE THE NUCLEAR FUTURE

THE INITIATIVE CONTRIBUTES TO THE SAFE, EFFICIENT, AND SUSTAINABLE DEVELOPMENT OF NUCLEAR ENERGY IN BRAZIL

In April and May, Brazil embarked on an international mission to discuss advancements and partnerships in nuclear technology. Organized by the Brazilian Association for the Development of Nuclear Activities (ABDAN), the trip included technical visits and strategic meetings in the nuclear industries of the United States and Canada.

"Brazil, a major power in the nuclear segment, seeks to enhance its technical capacity and expand its global partnerships. In this context, each mission represented a unique opportunity to strengthen relations with nuclear powers and foster collaborations that can boost the scientific and technological development of the country," explains ABDAN President Celso Cunha.

MISSION IN THE UNITED STATES

The United States emerges as a crucial epicenter in the development of advanced SMRs, offering a diverse range of technologies, resources, and deployment scenarios. In collaboration with the Department of Energy (DOE) and the Energy Policy Enterprise (EPE), ABDAN conducted a preliminary assessment of SMR prospects in Brazil. The project also included a partnership with Idaho National Laboratory, reinforcing international ties in the nuclear field.

The mission included a series of technical visits and participation in prominent global nuclear events, such as the one held at the new Westinghouse design and manufacturing unit focused on accelerating the commercialization of the eVinci microreactor.

A strategic meeting was held with representatives of the American industry, aiming to continue bilateral relations and joint exploration of the nuclear market between Brazil and the United States. The event culminated in a networking dinner with key sector stakeholders.

BRAZILIAN DELEGATION STRENGTHENED TIES AND OPENED DOORS FOR FUTURE PARTNERSHIPS WITH BOTH COUNTRIES IN THE NUCLEAR SEGMENT.





SMR & ADVANCED REACTOR 2024

This prominent event brought together market leaders and change agents in the nuclear sector to discuss the future of nuclear energy. Over two intense days, the latest technological, regulatory, and investment innovations related to SMRs and advanced reactors were shared.

The Brazilian delegation had the opportunity to explore the facilities of the Krishna P. Singh Technology Campus of Holtec in New Jersey, which includes factories, engineering centers, and system testing facilities. The visit provided an in-depth view of the company's technological capabilities in the nuclear field.

The SMR & Advanced Reactor 2024 attracted more than 600 companies and nuclear industry leaders, representing a wide range of interests from utilities to technology developers. With 68% of participants being industry leaders, the event offered strategic and tactical insights to overcome the challenges faced by the supply chain, financing, and regulation.

Additionally, the event featured 45 booths, providing updates on the most promising technologies in the SMR field, while more than 60 prominent speakers shared valuable insights on the progress achieved and future opportunities in the sector.

ABDAN's mission in the United States represented a significant milestone in the pursuit of international partnerships and the leveraging of the latest innovations in the field of SMRs. By bringing together key players in the nuclear sector, the event consolidated a joint commitment to driving the future of nuclear energy safely, efficiently, and sustainably.

MISSION IN CANADA

Since 2017, Canada has been leading the development of an SMR roadmap, involving a wide range of stakeholders, including the federal government, provinces, electric power companies, suppliers, and Indigenous communities. The challenges and applications for the use of SMRs are shared between Brazil and Canada, making the collaboration between the two countries highly promising. In addition, Canada hosts projects and suppliers of SMRs that can significantly contribute to ongoing studies in Brazil.

The mission to Canada was carefully organized by the local government, offering the Brazilian delegation the opportunity to interact with renowned research centers, regulators, and suppliers of nuclear technologies. Among the activities developed, we highlight:

- **Presentation of the Canadian action plan for SMRs:** The Brazilian delegation participated in a meeting where Canada's strategies and projects related to SMRs were presented. Authorities from Natural Resources Canada (NRCAN), the Organization of Canadian Nuclear Industries (OCNI), the Canadian Nuclear Association, and the government of Ontario shared valuable insights.
- **Meeting with Canadian manufacturers:** Brazilian representatives met with Canadian manufacturers of SMR technologies, including companies such as ARC, Terrestrial Energy, Westinghouse, Global First Power, and CANDU MONARK, promoting an exchange of knowledge and experiences.
- **Meeting with engineering companies:** Brazilian representatives met with Canadian engineering companies, such as Hatch, Kinectrics, Promatom Nuclear, and SNC Lavalin Nuclear (now AtkinsRéalis), strengthening ties and exploring possible future collaborations.
- **Networking with the Canadian industry:** The Brazilian delegation had the opportunity to participate in a fair with Canadian nuclear sector equipment and component manufacturers, promoting contacts and partnerships.
- **Meeting and technical visit at Ontario Power Generation:** The meeting with Ontario Power Generation, operator of the Darlington New Nuclear project, offered valuable insights into technological advancements in the field of SMRs and MMRs.

ABDAN's mission to Canada represented a significant step in the search for international collaborations and advancements in the nuclear field. By exploring Canadian strategies and technologies related to SMRs, the Brazilian delegation strengthened ties and opened doors for future partnerships, aiming for the safe, efficient, and sustainable development of nuclear energy in Brazil. ■

POLAND PROGRESSES IN DECARBONIZATION WITH NUCLEAR ENERGY

THE END OF THE COAL ERA HAS A SET DATE

Poland, traditionally dependent on coal for electricity generation, stands at an energy crossroads. With 17 operational nuclear reactors and ambitious plans to expand its nuclear capacity, the country is poised for a significant shift in its energy matrix, aligning with the global trend of replacing coal-fired power plants with Small Modular Reactors (SMR) and other forms of clean energy. This shift is crucial not only for reducing carbon emissions but also for ensuring the country's energy security by reducing dependence on imported energy.

Last month, the European country announced through its State Secretary for Climate, Urszula Zielinska, plans to set a date to end the use of coal-derived energy, the fossil fuel that contributes the most to CO₂ emissions. This decision marks a significant change from the previous government's stance on the climate crisis.

HISTORICAL CONTEXT AND CURRENT CHALLENGES

As highlighted by Leonam Guimarães, Technical Director of ABDAN, Poland has a long history of coal dependency, which currently accounts for approximately 70% of the country's electricity generation. "This dependency creates significant challenges, especially in the face of increasing environmental pressures and climate regulations," he considers. To address these challenges, Poland is adopting a multifaceted approach that includes expanding nuclear energy, developing renewable sources, and improving energy efficiency.

NUCLEAR ENERGY AS A PILLAR OF ENERGY TRANSITION

Nuclear energy plays a central role in Poland's decarbonization plan. The country plans to build its first nuclear power plants, including three initial units from Westinghouse, under agreements signed with the United States. Marcelo Gomes, Head of the Department of Development of New Enterprises at Eletronuclear, notes that these plans are part of a robust government program with strong popular support — about 70% of the population supports nu-

clear energy. "Poland has quite concrete and ambitious plans," comments Gomes. "They are initiating projects on new sites that previously had nothing, demonstrating a firm commitment to diversifying and cleaning their energy matrix."

GLOBAL TRENDS AND LOCAL INITIATIVES

Poland is not alone in this effort. Globally, there are 102 SMR projects under development, with China and Russia already operating some of these reactors. The trend to replace coal-fired power plants with SMRs responds to the need for cleaner and safer energy sources that can provide a stable base for the electrical grid. Leonam Guimarães points out that the expansion of nuclear energy in Poland complements renewable sources, such as solar and wind, which are intermittent by nature. "By providing a firm base for energy generation, nuclear allows for a more resilient system and less dependent on fossil fuels," he explains.

GOVERNMENTAL AND POPULAR SUPPORT

Poland is witnessing significant popular support and strong government commitment to the energy transition. "The country is an example to be watched, with great support from the population and government efforts," states Marcelo Gomes. This combination of popular and governmental support is vital for the success of decarbonization plans.

POLAND ANNOUNCED PLANS TO SET A DATE TO END THE USE OF COAL-DERIVED ENERGY, THE FOSSIL FUEL THAT CONTRIBUTES MOST TO CO₂ EMISSIONS.

According to sources consulted by the magazine Nuclear Connection, the path to a cleaner and more sustainable energy matrix in Poland is well delineated and, by reducing dependence on coal, the country will not only meet its climate targets but also ensure greater energy security.

COAL REPLACEMENT STRATEGIES

The replacement of coal-fired power plants in Poland can occur through several interconnected strategies:

1. Expansion of nuclear energy: In addition to the Westinghouse reactors, there are other private initiatives involving the construction of large nuclear power plants and SMRs. These projects aim to replace a significant portion of the coal generation capacity.
2. Development of renewables: Continuous investments in renewable energies, such as solar and wind, are crucial. Integrating energy storage technologies and smart grid solutions will help ensure a stable energy supply.
3. Improvement of energy efficiency: Increasing energy efficiency in the industrial, residential, and commercial sectors can reduce the total demand for energy, decreasing the need for coal-based generation.
4. Energy system integration: Strengthening interconnection with neighboring countries will allow Poland to import energy from cleaner sources, further reducing the dependence on local coal.
5. Just transition: Transition policies should consider the socioeconomic impact on regions dependent on coal mining, including plans for professional retraining and alternative economic development.

SCENARIO BRAZIL

Currently, there are 13 coal-fired thermal plants operating in Brazil: Figueira, Jorge Lacerda I and II, Jorge Lacerda III, Jorge Lacerda IV, Metal Nóbrega Siderurgia Eireli, Concórdia, Alunorte, Alumar, Porto do Itaqui (formerly Termomaranhão), Porto do Pecém I (formerly MPX), Candiota III, Porto do Pecém II, and Pampa Sul.

In January 2022, Law 14.299 was published, creating a policy to support the coal sector in Santa Catarina. The law also establishes the Policy of Just Transition (PTJ) for clean energy incentives in the state. Created from Bill PL 712/2019, approved on De-

cember 16 in the Senate, the law mandates that the Union extend the authorization for the Jorge Lacerda Thermoelectric Complex (CTJL) for 15 years from 2025. During the extension, the Ministry of Mines and Energy (MME) must sign a contract for reserve energy purchase from the plant in an amount sufficient to consume the volume of fuel acquisition stipulated.

The contract must contain a fixed revenue covering the costs associated with coal-based energy generation. At least 80% of the mineral purchase will be concentrated in Santa Catarina. The law provides for the creation of an energy transition program (TEJ), aligning carbon emission neutrality goals with socioeconomic impacts and the valorization of mineral and energy resources. The program aims to prepare Santa Catarina for the likely closure, by 2040, of coal-based thermal power generation activities. A council composed of government representatives, workers, and companies will define the Just Transition Plan (PTJ).

The group will seek resources for the development of activities that compensate for the closure of coal mines and the repositioning of economic activities. It may also consider technological development aimed at using the region's coal for other purposes or continuing coal-based thermal power generation, but with zero carbon emissions from 2050. The concessionaires for power generation and companies authorized for independent electricity production in Santa Catarina using coal must apply the mandatory percentage determined by law for research and development in projects associated with TEJ.

The law also provides for an economic subsidy from the Energy Development Account (CDE) to subsidize electricity rates for consumers from distributors with their own annual market under 350 gigawatt-hours (GWh). The subsidy ensures affordability in tariffs for small distributors so that prices are not higher than the rates of adjacent area concessionaires with their own annual market over 700 GWh, when located in the same state. The law also stipulates that a distributor that acquires another concessionaire with its own market under 700 GWh/year to which it supplies energy will have the right for ten years to 25% of the proposed subsidy. This is already the case with the existing subsidy for rural electrification cooperatives. ■

*Source: Senate Agency

GREATER NATIONAL PARTICIPATION IN THE NUCLEAR SECTOR

DEMAND AIMS TO STRENGTHEN THE NATIONAL INDUSTRY

In recent years, the Brazilian nuclear sector has witnessed a growing demand for greater participation of national companies in development projects. This movement reflects the desire to strengthen the national industry and ensure Brazil's technological autonomy in a sector vital for the country's sovereignty and sustainable development. The goal is to encourage partnerships between national companies and traditional foreign firms active in the sector, as revealed by sources interviewed by the magazine Nuclear Connection.

TRAINING AND STRATEGIC PARTNERSHIPS

Giacomo Staniscia, Business Director at Atech, a national company of the Embraer group, highlights the company's trajectory in the nuclear area. "Our entry into the nuclear field occurred about twelve years ago. We operate in a specialized segment of nuclear plant control and protection systems, based on Instrumentation & Control (I&C) solutions," says Staniscia. He underlines the importance of national training that Atech has promoted over the years, with a team of about fifty engineers and specialized professionals.

Staniscia emphasizes that Atech has a solid and strategic partnership with the Brazilian Navy, and seeks to participate in other nuclear sector projects, such as the modernization of the Angra 1 and 2 plants, the implementation of the new Angra 3 plant, and future Small Modular Reactors (SMR) projects. "The experience with the Navy's Nuclear Program allows us to apply our national capabilities to several of these projects, over short, medium, and long-term horizons," observes Staniscia, highlighting the relevance of such enterprises for the country.

He also mentions Atech's work in partnerships with international companies to provide solutions requiring nuclear qualification, highlighting global cooperation experience in the LABGENE project, a laboratory that will test the prototype on land of the reactor to be used in Brazil's first Conventionally Armed Nuclear Propulsion Submarine (SNCA). For Staniscia, it is crucial that Brazil strengthens national training in the nuclear area, in or-

der to promote greater autonomy and leadership in future sector projects.

The need for specific legislation that regulates the participation of local companies in nuclear projects is another issue raised by Staniscia. He compares the situation with the compensation or offset processes in the Defense area, which require contributions from foreign suppliers to promote national training, or even the eventual requirement of a minimum percentage of local content in nuclear sector projects. "Legislation that brings this regulation issue to the nuclear sector would be very welcome," says Staniscia.

STRENGTHENING THE NATIONAL INDUSTRY

Carlos Alberto Matias, Technical Director at AMAZUL, sees the participation of Brazilian private companies as fundamental to strengthening the national industry and ensuring the country's technological autonomy. Matias points out that collaboration between national and foreign companies can result in a transfer of knowledge and technology that empowers Brazilian companies and enhances their global competitiveness.

"This approach not only drives local development but also contributes to the safety and technical excellence of the Brazilian nuclear sector," says Matias. He advocates for the creation of public policies that encourage this collaboration, such as tax incentives and specific financing lines for technological innovation projects in the nuclear sector.

AMAZUL, according to Matias, plans to integrate national partners in its future projects, recognizing the importance of involving Brazilian companies from the early stages of projects. "This includes both the development of new nuclear technologies and the maintenance and improvement of existing infrastructures," explains Matias. He highlights that the main benefits of contracting Brazilian companies include stimulating the national economy, creating qualified jobs, increasing energy security, reducing external technological dependence, and developing a solid and competitive industrial base.



THE ROLE OF THE NAVY AND THE IMPORTANCE OF LEGISLATION

Marcos Cesar, Business Developer at Atech, emphasizes the company's strong connection with the Brazilian Nuclear Program and the Brazilian Navy's Nuclear Program. "Atech has been a major partner of the Navy in its nuclear program for over twelve years," states Cesar. He highlights that this partnership has been fundamental for learning and investing in training professionals to work in the sector.

Cesar suggests that the experience gained with the Navy can be extended to other segments of the nuclear sector, such as energy generation and health applications. He believes that the participation of public and private Brazilian companies in nuclear projects, including in partnership with foreign companies, could result in significant evolution for the sector.

FUTURE PERSPECTIVES

Brazil has the potential to become an exporter of knowledge and nuclear technology. The partnership with countries that are structuring in the area of small modular reactors (SMR) is seen as a promising opportunity. National training and strategic partnerships can position Brazil as a global leader in the nuclear sector, offering advanced solutions to other countries.

IT IS CRUCIAL THAT BRAZIL STRENGTHENS NATIONAL TRAINING TO ENSURE SOVEREIGNTY IN THE NUCLEAR AREA.

To achieve these goals, according to the sector, it is essential that the Brazilian government creates incentive policies and supports the participation of national public and private companies in nuclear projects. This includes implementing training programs, tax incentives, and facilitating international partnerships.

Strengthening the Brazilian nuclear industry, with greater participation of national companies, will not only contribute to the country's energy security and sovereignty but also boost the national economy and the creation of qualified jobs, as believed by the interviewed companies. Technological training and innovation are key to a sustainable and prosperous future in the nuclear sector. ■

RAFAEL GROSSI OF THE INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

Rafael Grossi is the Director-General of the International Atomic Energy Agency (IAEA), a prominent figure in the global nuclear energy scene. In this edition, we delve into crucial issues shaping the energy future of Brazil and Latin America, from the perspective of one of the most respected leaders in the field of nuclear energy.

1 – What is your assessment of Brazil's current progress in the nuclear sector, and what challenges do you identify for its sustainable expansion in the future?

Overall, Brazil has shown significant progress in the nuclear sector, reflected in the stable operation of its nuclear plants and advanced nuclear technology research. The country has a robust nuclear program, including nuclear fuel production and reactor research advancements. However, sustainable expansion faces challenges such as the need to develop additional infrastructure, secure long-term financing, maintain nuclear safety, and achieve public acceptance.

A solid and sustainable nuclear program needs to be consolidated. Specifically, this program should support the resumption of Angra 3 construction, expand the activities of Indústrias Nucleares do Brasil (INB) to all aspects of the nuclear fuel cycle, complete the Brazilian Multipurpose Reactor (RMB), and increase the use of nuclear techniques and radioisotopes in areas such as health, business, and agriculture. Nuclear energy should be appropriately included in the Brazilian energy matrix due to its advantages as a baseload generator, considering the increasing contribution of wind and solar energy.

Despite the completion of the Angra 3 nuclear plant, it could also contemplate the possibility/suitability of developing small modular reactors (SMR) for cogeneration of electricity. The benefits of expanding generation from nuclear sources for the electric system lead to greater reliability and security in the electricity supply. The construction of the Brazilian Multipurpose Reactor (RMB) has strategic relevance for the autonomous production of radiopharmaceuticals, essential to meet the demand for nuclear medicine.

With this framework, the future of the electric sector demands a balance (mix) between distant, seasonal, and intermittent sources with constant generation sources near



consumer centers, thus ensuring system security. It is in this context that the reintegration of nuclear plants into the country's energy planning becomes timely. The IAEA is committed to supporting Brazil in overcoming these challenges through technical cooperation and sharing best practices.

2 – What impact will the Summer Institute have on the nuclear sector?

The World Nuclear University's Summer Institute represents an excellent opportunity to strengthen human and institutional capacity in the Brazilian and global nuclear sector. By bringing together professionals from various parts of the world, the event facilitates the exchange of knowledge and the formation of collaboration networks, essential for innovation and ongoing progress. Participants are expected to acquire advanced skills and global perspectives that can be applied to improve the operation and safety of nuclear facilities in their countries, as well as to foster the development of new nuclear technologies.

3 – Considering the global commitment to reducing carbon emissions, how do you see the role of renewable energies, in complement to nuclear energy in the Brazilian energy mix? What are the benefits and challenges of this diversification?

Given the National Energy Plan 2050 (PNE 2050), Brazil will need to nearly double its installed capacity to meet demand growth by then. Hydropower will continue to predominate, but in the coming decades, it is expected to reach its potential limit. In this context, renewable energies will play a significant and irreversible role in this expansion. However, integrating renewable energies requires another source capable of providing operational flexibility, or “dispatchability.”

Combining nuclear and renewable energy in the Brazilian energy mix is a promising strategy to reduce carbon emissions. Nuclear energy, along with hydropower, provides a reliable and baseload source of electricity, while the “new” renewable energies, such as solar and wind, offer complementary and sustainable resources. The IAEA supports the adoption of a holistic and coordinated approach to maximize the benefits of these energy sources.

4 – Brazil has ambitious plans for the construction of new nuclear power plants. How does the IAEA view this potential?

Plans developed in the past within the governmental framework recognized the importance of continuing nuclear energy in the composition of the Brazilian Electric Energy Matrix. Several scenarios were outlined, each associated with the pace of development of the Brazilian economy, thus pointing to different numbers of reactors to be developed. Since then, events of utmost importance for the country’s energy sector have occurred, requiring the revision of previously made long-term analyses and projections.

It is important to note that the IAEA is ready to support any plans Brazil has for the construction of new nuclear power plants, recognizing the country’s potential to become a regional leader in nuclear energy.

5 – Recently, Brazil and Argentina signed an agreement to jointly build a new nuclear power plant. How do you view this regional collaboration in nuclear development, and what is the potential for similar partnerships in Latin America?

The example of cooperation between Brazil and Argentina is an important milestone due to the creation of the Brazil-Argentina Agency for Accounting and Control of Nuclear Materials (ABACC). Its creation involved generating trust and developing a strategic alliance between the two countries in the nuclear sector. The importance of the political

process that led to the creation of an international entity for nuclear materials control in the context of relations between Brazil and Argentina, which in this specific case, became an admired example in various countries around the world, is undeniable.

The collaboration between Brazil and Argentina in building research reactors, which could even be extended to the construction of SMRs (Small Modular Reactors), is another notable example of regional cooperation that can bring significant benefits to both countries. This partnership promotes the exchange of technical knowledge, optimizes resources, and strengthens nuclear security in the region. Moreover, it serves as a model for other Latin American nations, encouraging the formation of strategic alliances that can accelerate sustainable nuclear development. It is believed to be a good time for Latin American countries to unite to consolidate nuclear technology. The IAEA supports these collaborative initiatives, offering technical support and facilitating the sharing of experiences among the countries in the region.

6 – Looking to the future, how do you envision Brazil’s role in the international nuclear and renewable energy scene in the coming decades? What are the opportunities and challenges the country will face, and how can the IAEA support these efforts?

Brazil achieved 93.1% of electricity generation from renewable sources in 2023. Hydropower, photovoltaic, and wind energy contributed to the country’s electric matrix continuing to stand out as one of the cleanest in the world. The total generation was 70,206 average megawatts (MWm). Hydropower remains the main source of energy, with 58% of the installed capacity of the National Interconnected System (SIN). The hydroelectric modality provided 50,000 MWm, an increase of 1.2% compared to 2022. The year 2023 marked significant growth in wind and solar sources, which added 13,000 MWm to national production, representing an increase of 23.8% compared to last year. The power of these sources totaled 42,600 MWm. Biomass reached 3,218 MW, an increase of 9.6%. Thus, in the coming decades, Brazil has the potential to play a leadership role in the international nuclear and renewable energy scene. The country can become an example of efficient integration of different clean energy sources, significantly contributing to mitigating climate change. Opportunities include exporting nuclear technology, leading in energy innovation, and developing a robust green economy. However, Brazil will face challenges such as the need for large investments, in infrastructure development, and maintaining nuclear safety. The IAEA is committed to supporting Brazil through technical cooperation programs, training, regulatory advice, and sharing of best international practices. ■

UNRAVELING THE FINANCIAL CHALLENGES BEHIND NUCLEAR ENERGY PROJECTS

SUCCESSFUL FINANCING REQUIRES COMPREHENSIVE COLLABORATION BETWEEN GOVERNMENTS, FINANCIAL INSTITUTIONS, AND PROJECT DEVELOPERS

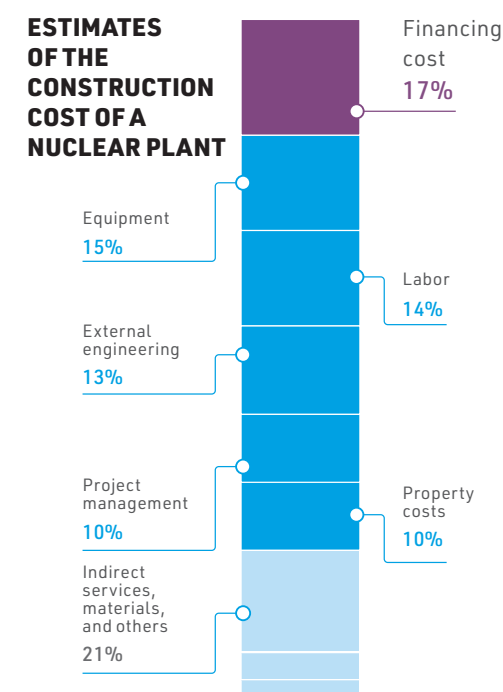
Nuclear energy, while recognized for its potential as a clean and reliable energy source, faces a series of financial challenges that have hindered its expansion. The complexity and magnitude of nuclear projects, coupled with various economic and regulatory factors, have made financing a daunting task. However, given the growing importance of nuclear energy in transitioning to a sustainable energy matrix and in reducing carbon emissions, it is essential to address these challenges and diversify the available financing options.

WHY ARE NUCLEAR PROJECTS DIFFICULT TO FINANCE?

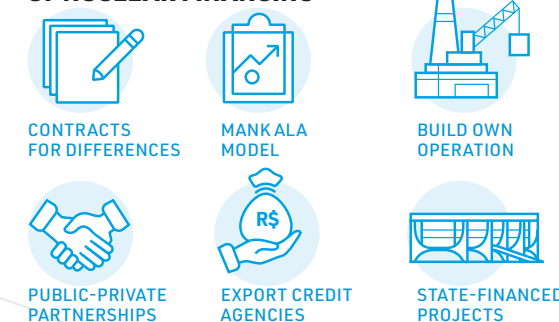
Financing nuclear energy projects encounters several significant obstacles. One of the main challenges lies in the high initial investment required for the construction of these plants. Complex engineering, stringent safety standards, and regulatory demands substantially increase initial costs. Additionally, the lengthy construction period, which can extend for years or even decades, exacerbates financial risks and uncertainties, making it difficult for investors to estimate returns on their investments within a reasonable timeframe.

The rigidity of regulations and changes in political dynamics also contribute to the financial challenges of nuclear projects, increasing costs and delays. Given these complexities, successful financing of nuclear energy projects requires comprehensive collaboration among governments, financial institutions, and project developers, as well as a structured financing model that combines public and private investments.

The prolonged construction period increases financial risks and uncertainties, making it difficult for investors to predict returns on their investments within a reasonable timeframe. *Figure 1* shows that the financing cost in a typical nuclear project can be almost one-fifth of the total project costs.



TYPICAL MODELS OF NUCLEAR FINANCING



Source: ABDAN



INNOVATIONS IN NUCLEAR PROJECT FINANCING

Various financing models have been explored in the nuclear energy sector to overcome these challenges. Multilateral financial institutions play a crucial role in this process, although historically they have not supported nuclear projects. However, recent efforts, such as the declaration signed by over 30 countries at the International Atomic Energy Agency's (IAEA) Nuclear Energy Summit in March 2024, seek to influence these institutions to be more receptive to nuclear projects. Additionally, the creation of the International Bank for Nuclear Infrastructure (IBNI) aims to fill the gap in nuclear financing and accelerate the development of advanced nuclear technologies.

Several financing models have been employed in the global nuclear energy sector. In the following table, we share some summaries.

Advancements in Advanced Reactors: Financial Advantages of SMRs and Other Advanced Reactors

The development and deployment of advanced reactors, including Small Modular Reactors (SMRs), offer significant financing advantages compared to larger nuclear plant projects. These innovative reactor technologies provide improved safety features, scalability, and cost efficiency, making them more attractive to investors and financial institutions.

ANGRA 3: AN IMMINENT FINANCIAL CHALLENGE

With 65% of the construction completed, the Angra 3 nuclear plant already stands as a significant milestone in Brazil's

energy landscape. However, the financial challenge for its completion is imminent. With investments of BRL 7.8 billion and an additional need for BRL 20 billion, as stated by Eletronuclear, the project faces a crucial dilemma regarding its financing. Once operational, Angra 3 is expected to meet the energy needs of 4.5 million people and contribute to 3% of Brazil's total energy consumption, bringing significant benefits.

Given these figures, the persistent question is: how to adequately finance this vital enterprise for the country? While the Federal Audit Court (TCU) estimates a substantial loss of BRL 13.6 billion if the project is abandoned, the search for robust and sustainable financial solutions becomes even more urgent. In this context, exploring different financing strategies for nuclear projects emerges as an urgent need to ensure the success of large-scale endeavors like Angra 3.

TOWARDS A SUSTAINABLE NUCLEAR FUTURE

Although nuclear energy projects face significant financial challenges, innovations in financing and the development of advanced nuclear technologies offer promising prospects for the sector. It is essential that governments, financial institutions, and energy sector companies work together to overcome these obstacles and ensure a sustainable, low-carbon energy future. ■

*Collaboration by Carlos Leipner.

INNOVATION AND THE NUCLEAR ECOSYSTEM: BRIDGING ACADEMIA AND MARKET

NUCLEAR CONNECTION SPOKE WITH DANIEL LEIPNITZ, AN ENTREPRENEUR, AND PAULA LIMA, DIRECTOR OF CIETEC, ABOUT THE THEME AND THE NEED FOR AWARENESS EFFORTS.

Nuclear energy is an area that has long faced challenges in public perception and understanding. Often associated with images of atomic bombs and nuclear disasters, it is frequently viewed with distrust and apprehension. However, experts like Daniel Leipnitz and Paula Lima are each trying in their own way to change this perception by emphasizing the need to create an innovation ecosystem in the nuclear area that aims to connect academia with the market and companies.

Daniel Leipnitz, an entrepreneur and expert in innovation ecosystems, highlights the importance of communication when addressing issues related to nuclear energy. In his words: "Today, unfortunately, there is a narrative that distorts the reality about nuclear energy. It is part of our everyday life, and the narrative needs to reflect that." Daniel emphasizes the need for a new approach in communication that highlights the benefits and safety of nuclear en-

ergy compared to other energy sources.

In turn, Paula Lima, President Director of the Center for Innovation, Entrepreneurship, and Technology (CIETEC), stresses the importance of greater integration between academic institutions and companies in the nuclear sector. According to her, "There are many research and development initiatives in universities and research centers, but there is a lack of more effective connection with companies." Paula highlights the need to create an environment conducive to innovation and entrepreneurship in the nuclear area, encouraging technology transfer and the development of startups and innovative companies.

"When you start to put more people thinking, more new people, more people with desire and different visions, more ideas start to appear. There are more ideas of ideas, there are more solutions, and the solutions will grow in terms of products. The issue of improvements that will result in economic benefits, which will result in better productivity," reflects Leipnitz.

"WE HAVE NO CHOICE, BRAZIL DEPENDS ON WHAT IT IMPORTS IN TERMS OF ELECTRICITY, AND GENERATION CURRENTLY DEPENDS HEAVILY ON THE BURNING OF FOSSIL FUELS. THE NUCLEAR SECTOR NEEDS TO GROW, WITH THE OUTLOOK OF THIS NEW GENERATION, FACING CURRENT PROBLEMS AND PREPARING SOLUTIONS FOR THE FUTURE."

HACKAPOWER: THE NUCLEAR HACKATHON

Paula Lima emphasized the relevance of initiatives such as the Hackathon, promoted by ABDAN, to boost innovation in the nuclear sector. She noted that this type of event provides a unique opportunity to bring together students, researchers, and entrepreneurs to work on creative and disruptive solutions to the challenges faced by the sector. "The Hackathon encourages collaboration and teamwork, urging participants to share ideas and knowledge in a dynamic and collaborative environment. This experience not only promotes technological innovation but also contributes to the development of skills such as critical thinking, problem-solving, and communication. These are essential for professionals wishing to enter the nuclear sector and for those looking to venture into the field of clean and sustainable energy," considers Lima.

The director of CIETEC emphasized that the Hackathon

is just the first step in the process of innovation and entrepreneurship in the nuclear sector. “It is essential that the projects and ideas developed during the event receive ongoing support to be transformed into real products and services that can generate a positive impact on the nuclear industry and society as a whole.”

TRAINING AND DEVELOPMENT OF NEW PROFESSIONALS

To fill this environment conducive to innovation and entrepreneurship, it is also essential, in their view, “to promote incubation programs, financing, and strategic partnerships that encourage the creation and growth of startups and companies in the nuclear sector. It is crucial to promote a culture of innovation and collaboration, where ideas can be shared and developed collaboratively,” states Leipnitz.

To achieve this goal, according to the experts, it is essential that academic institutions, companies in the nuclear sector, and the government work together to create policies and programs that encourage research, development, and implementation of innovative nuclear technologies. This may include tax incentives, subsidies for research and development, and public-private partnerships to accelerate the adoption of innovative solutions.

“Furthermore, it is vital to invest in the training and development of qualified professionals to work in the nuclear sector. This involves not just developing specialized courses and training programs, but also promoting a culture of continuous learning and knowledge exchange among different actors in the nuclear ecosystem,” explains the director of CIETEC.

“I am increasingly aware of this need. I see the opportunity for us to collaborate as an institution at CIETEC. An example is the work we are doing with IPEN. There was only the Material Development Center (CDPM) in charge of Granoiter, but now we have the National Challenge for New Materials and Strategic Minerals, a program of MCTI. It involves financing and a challenge for new research and new people. We need to create a mix of participants. And it is important to publicize this because we are in the University City, with engineers from USP and IPT next door. We need to reach the right audience. We can't leave anyone out. We must advertise to everyone. Because it is the support we want to provide,” suggests Paula.

ENERGY TRANSITION

“We have no choice, Brazil depends on what it imports in terms of electricity, and the generation currently relies heavily on burning fossil fuels. The nuclear sector needs to grow, with the outlook of this new generation, facing current problems and preparing solutions for the future. It is a strategic sector and will become increasingly important. There is no turning back,” recognizes Daniel.

“If we look at Brazil in 10 years, we will see how time passes quickly. We are in a new context, where the country wants and needs sources like nuclear energy to grow and expand. With this youth, innovations, and partnerships, we are building a Brazil with cleaner energy and a stronger industry. We are taking our place in the world. This is fundamental. What we are doing today will result in a promising future for the nuclear sector in Brazil,” believes the entrepreneur.

Another important aspect is public awareness about the benefits and risks associated with nuclear energy. “A coordinated effort is necessary to demystify misconceptions and highlight technological advances and the rigorous safety standards that make nuclear energy a viable and safe option for the country's energy future,” ponders Daniel.

FUTURE

Looking to the future, Daniel Leipnitz and Paula Lima envision a stronger and more dynamic nuclear sector in Brazil. Daniel comments: “The nuclear sector has to grow, and it has to grow with the outlook of this new generation, with solutions for current and future problems.” Paula adds: “We are planting seeds now to reap the fruits in the future, with a Brazil with cleaner energy and a stronger industry.”

Therefore, for them, building an innovation ecosystem in the nuclear area requires the joint effort of all involved. “Only through collaboration and continuous investment will it be possible to harness the full potential of nuclear energy for the benefit of society and the environment. With a positive narrative and an innovative approach, Brazil can become a leader in the production of clean and safe energy, contributing to the economic and sustainable development of the country,” concludes Daniel. ■

“WITH THIS YOUTH, INNOVATIONS, AND PARTNERSHIPS, WE ARE BUILDING A BRAZIL WITH CLEANER ENERGY AND A STRONGER INDUSTRY. WE ARE TAKING OUR PLACE IN THE WORLD. THIS IS FUNDAMENTAL. WHAT WE ARE DOING TODAY WILL RESULT IN A PROMISING FUTURE FOR THE NUCLEAR SECTOR IN BRAZIL.”

RIO DE JANEIRO: STAGE FOR THE WORLD NUCLEAR UNIVERSITY SUMMER INSTITUTE

EVENT WILL GATHER NUCLEAR SECTOR PROFESSIONALS FROM AROUND THE WORLD

Rio de Janeiro will host a prominent event in the international nuclear sector scene from June 2 to July 6: the World Nuclear University (WNU) Summer Institute, a five-week professional development program that will feature the presence of Rafael Grossi, the Director-General of the International Atomic Energy Agency. The event will gather nuclear sector professionals from around the world and will be an opportunity to explore the latest advances in the nuclear industry, promoting an exchange of knowledge and ideas among participants. Through a combination of lectures, supervised group work, industry-focused projects, and technical site visits, participants of the Summer Institute will enhance their leadership skills and team effectiveness.

“The Summer Institute represents a unique opportunity for the exchange of knowledge and experiences among future leaders of the nuclear sector. The fact that it is taking place in Rio de Janeiro only reinforces the city's position as a center of excellence in this crucial field for the future of energy,” says Celso Cunha, president of the Brazilian Association for the Development of Nuclear Activities (ABDAN), which was the host institution in Rio de Janeiro.

Nuclear Connection magazine spoke with Sama Bilbao, president of WNU. Read the full interview below.

1 – What is the significance of this edition of the World Nuclear University Summer Institute being held in Rio de Janeiro?

It is an immersive five-week nuclear leadership and professional development program for future leaders of the nuclear sector. The program offers participants a holistic view of the sector, develops their leadership abilities, enhances their communication

skills, and empowers them to become advocates for innovation. This is the first time the Summer Institute is held in South America. We had planned to come to Brazil in 2021, but unfortunately, COVID interfered. It just wasn't possible to achieve the goals of the Summer Institute other than with a fully immersive on-site program. We are excited to finally be in Rio this summer! It was definitely time to bring the program to South America, engage more actively with nuclear sector professionals in this part of the world, and most importantly, showcase the many success stories of the nuclear sector in Brazil.

2 – How does choosing Rio de Janeiro as the venue reflect the city's status as a center of excellence in the nuclear sector?

Rio de Janeiro is home to the Almirante Álvaro Alberto Nuclear Center (CNAEA), where Angra 1 and 2 operate. Additionally, there are ongoing plans to complete the Angra 3 unit and potentially even build a fourth unit on site, which would further enhance the city's importance as a center of excellence in the nuclear sector. Certainly, this was a significant factor in choosing Rio as the host city for the Summer Institute 2024, as one of the main components of the program is visits to nuclear facilities and exchange with local nuclear experts.

3 – How do you expect this edition of the event to contribute to the professional development of the participants?

The potential of each of the fellows has already been recognized by their originating organizations: that's why they are here. Now, it is up to them to develop that potential into a unique leadership style that will drive change in their organizations and in the sector at large. The WNU Summer Institute provides

FIVE-WEEK IMMERSIVE AND COMPREHENSIVE PROGRAM, DESIGNED TO NURTURE THE FUTURE LEADERS OF THE NUCLEAR INDUSTRY.

access to unique resources, such as a network of experienced peers, high-level leaders, experts, highly skilled mentors, and cutting-edge knowledge. Every detail of this program, from our stunning location in Rio to the carefully selected content and activities, has been designed to provide a transformative experience. But transformation requires effort. It requires an open mind, a willingness to challenge oneself, and a commitment to growth. The fellows will make the most of this opportunity if they are ready to absorb, engage, and work hard.

4 – How does the World Nuclear University Summer Institute promote collaboration and knowledge exchange among participants?

The World Nuclear University (WNU) Summer Institute promotes collaboration and knowledge exchange among participants through a comprehensive program that combines nuclear experience, leadership development, and cultural immersion. Among all aspects of the carefully selected curriculum, I would highlight Group Work and Mentoring as some of the main facilitators of this collaboration. Throughout the program, fellows work in small groups on real-life scenarios related to critical issues faced by the nuclear sector. These groups are intentionally diverse, including participants from different technical backgrounds, genders, and nationalities. Each group is facilitated by a mentor, a very senior leader, who provides guidance and personal coaching, enhancing leadership skills and organizational flexibility. This collaborative approach encourages knowledge sharing and teamwork.

5 – What are the main highlights or innovations of this edition of the event?

We introduced a unique leadership model that affects all our activities and aims to develop strate-

gic awareness and intelligence at individual, collective, and systemic levels. Meeting the sector's needs in terms of effective leadership at a global level, we transformed the program curriculums. For this, we developed a unique program model that uses a systemic approach with four interconnected pillars: industry knowledge and needs, communications (interpersonal and intrapersonal), innovation, and leadership development. All four pillars are addressed through a combination of activities, seminars, and interactions carefully planned to ensure that fellows have the opportunity to apply their learning in sector-relevant scenarios and learn from others, sharing knowledge with their peers, industry experts and leaders, and their mentors.

6 – How does the World Nuclear University plan to involve the local community of Rio de Janeiro in this event?

We have been working closely with ABDAN to ensure that the Brazilian nuclear sector is adequately portrayed and represented, and we have over 10 speakers from the Brazilian nuclear sector contributing to various parts of the Summer Institute program, including one of the mentors. WNU's goal is to create a strong bond between the fellows and the local community, showcasing the culture, food, personality, and unique traditions of Rio de Janeiro and Brazil. We have planned visits to culturally relevant sites, cultural events, and collaborative projects that benefit both the fellows and the residents of Rio de Janeiro, such as the activities we will conduct at the Botanical Garden, which will help the fellows experience the value of community engagement.

7 – What impact do you expect the Summer Institute 2024 to have on the global nuclear sector after its realization in Rio de Janeiro?

The World Nuclear University Summer Institute is a beacon of inspiration, empowerment, and connection. Our goal is to cultivate generations of nuclear leaders who are not only subject matter experts in their specific areas but are also visionary, compassionate, and adaptable agents of change. Bold and effective global leadership is essential for us to achieve our clean energy goals, sustainability, and an equitable future for all. The nuclear sector is at a critical point, where our contributions to mitigating climate change and ensuring energy security are more important than ever. ■

OVERVIEW OF THE NUCLEAR ECOSYSTEM IN BRAZIL

STUDIES BY FGV AND SEBRAE REVEAL SOCIOECONOMIC IMPACTS OF NUCLEAR ACTIVITIES IN THE COUNTRY

A recent study published by FGV Energia in February 2024 presented an in-depth analysis of the socioeconomic impacts of nuclear activities in Brazil. Focusing mainly on energy generation, the study revealed that Brazil, along with other leading countries, is at the center of a growing global industry, accounting for 14% of the world's electrical energy.

Nuclear technology has been highlighted as one of the most efficient forms of energy generation, with low greenhouse gas emissions, positioning it as a key player in the global energy transition. Additionally, its impact on national and regional economies is significant, especially in Rio de Janeiro, where nuclear activity plays a crucial role.

With significant growth potential, Brazil is directing its efforts towards the development of the Brazilian Multipurpose Reactor (RMB). This project will not only strengthen national infrastructure but also open doors for significant advancements in health and scientific research.

However, the need for crucial supplies, such as technetium-99, underscores the importance of continuous investment and autonomy in the production of nuclear materials. In this context, Brazil has been working to expand its uranium enrichment and conversion capacity, reducing its dependency on external sources.

The economic opportunities presented by the nuclear industry are generating debates in Congress about the possibility of exporting enriched uranium. Despite only 30% of its territory being surveyed, Brazil holds a significant portion of the world's uranium reserves, placing it in a strategic position in the global market.

Regarding direct economic benefits, nuclear power generation contributes to the Brazilian GDP, creating jobs and adding value to the economy. Projects such as Small Modular Nuclear Reactors (SMRs)

BRAZIL IS WELL POSITIONED TO EXPAND ITS PRESENCE IN THE GLOBAL NUCLEAR INDUSTRY, INCREASING ITS INVESTMENTS IN PRODUCTION AND EXPORT

promise to further boost these figures, opening new investment and growth opportunities.

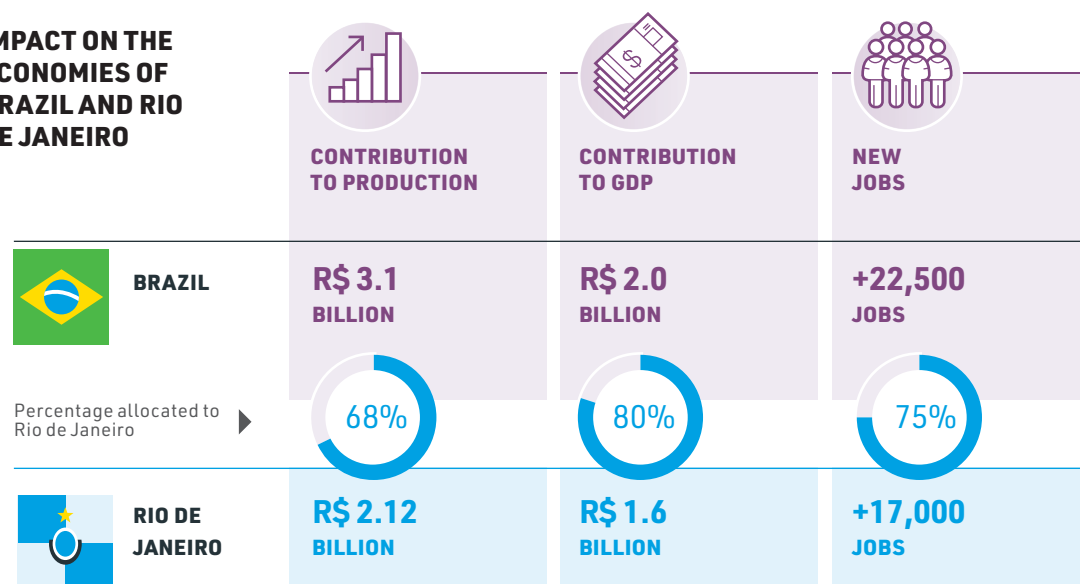
Furthermore, the applications of nuclear technology in health and other economic areas offer significant potential for the country, both in terms of social impact and value generation. Given the geopolitical challenges and the ongoing energy transition, Brazil is well positioned to expand its presence in the global nuclear industry, increasing its investments in the production and export of refined raw materials.

In summary, the study highlights not only the current benefits but also the vast potential that nuclear activities offer Brazil, consolidating it as an important and strategic player in an evolving sector. This positioning is corroborated by Sebrae Rio, as detailed below.

SEBRAE: OPPORTUNITIES FOR MICRO AND SMALL BUSINESSES IN THE BRAZILIAN NUCLEAR INDUSTRY

The Rio Business Opportunities Program, an initiative led by Sebrae Rio, launched a study in 2022 pointing to vast opportunities for Brazilian micro

IMPACT ON THE ECONOMIES OF BRAZIL AND RIO DE JANEIRO



Source: FGV

and small businesses in the nuclear sector's value chain. Although complex, the sector presents fertile ground for economic growth and technological innovation, provided the identified challenges are overcome.

The study highlights that many parts and components currently imported could be produced locally, generating millions in economic turnover, increasing job creation, and fostering technological development and national workforce. However, to realize this potential, joint actions are necessary, both from entrepreneurs and anchor institutions in the sector.

One of the main challenges faced by the entire production chain is the lack of stability in a long-term program, essential for stimulating growth and scaling projects. Moreover, optimizing regulatory demands and developing business models for nuclear projects are crucial to advance the sector, strengthening collaboration between the public and private sectors.

Another significant issue is the dependency on foreign suppliers in various segments of the production chain, which creates cost instability and risks related to logistics and supply. To overcome these obstacles, it is crucial to strengthen the local supplier network and certify the national industry to supply inputs, products, and services to the nuclear sector.

Human resource training is also a critical point.

The lack of investment in training specialized professionals in the nuclear field over the past decades has left significant gaps. Investing in the training and development of professionals is essential to drive the sustainable growth of the sector.

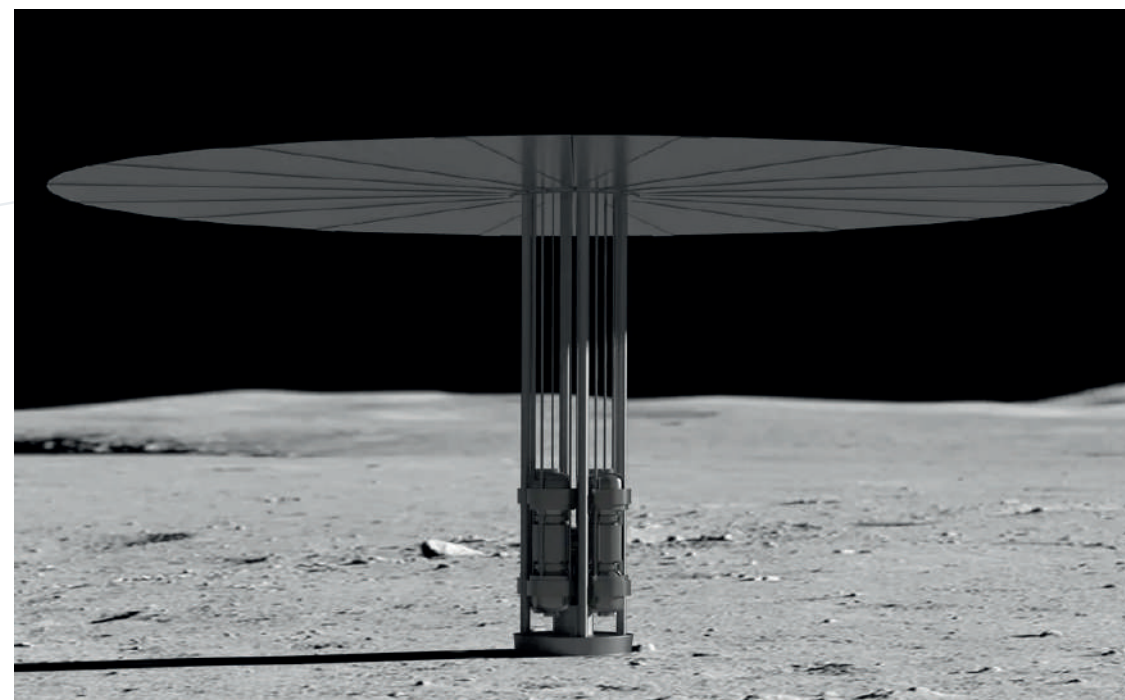
Given these challenges, the Brazilian Association for the Development of Nuclear Activities (ABDAN) suggests a series of strategic initiatives. This includes developing specific financing lines for the sector, promoting trade fairs and business rounds, creating training programs, and valuing existing knowledge transfer.

Additionally, ABDAN emphasizes the importance of partnerships between industry, educational and research institutions, and development bodies to strengthen the infrastructure of the Brazilian nuclear production chain. Implementing initiatives like a program similar to the Nuclear Procurement Issues Corporation (NUPIC), as well as studying tax incentives and financing mechanisms, are essential to boost the sector.

In an international context where the demand for clean energies is rising and the discussion on nuclear technology is being revived, it is crucial that Brazil reaffirm its commitment to nuclear development. With adequate investments and a well-crafted strategy, the country can not only overcome existing challenges but also become a global leader in the nuclear industry, generating significant economic and social benefits for the country. ■

ADVANCEMENTS IN THE GLOBAL NUCLEAR INDUSTRY: POTENTIALS UNVEILED ACROSS VARIOUS SECTORS

LEARN HOW NUCLEAR IS PLAYING A VITAL ROLE IN BUILDING A MORE SUSTAINABLE AND TECHNOLOGICALLY ADVANCED FUTURE



For decades, nuclear energy has been a driving force in the search for technological advances and innovation across multiple fields. A recent study conducted by the Nuclear Energy Institute (NEI), based in Washington, D.C., revealed how this form of energy is shaping the future not only of electricity but also in sectors as diverse as aerospace, agriculture, information technology, medicine, and transportation.

NEI, a leading policy organization in the sector of nuclear technologies, was founded in 1994

through the merger of several sector entities, whose roots date back to 1953. With hundreds of members, the institute plays a crucial role in developing policies that shape legislative and regulatory issues impacting the global nuclear sector.

EXPLORING NEW FRONTIERS IN SPACE WITH NUCLEAR

Energy In the aerospace sector, nuclear energy is driving innovations that will shape the future of space exploration. Now, the industry is developing

new nuclear energy technologies to power the next phase of space travel: initial unmanned missions, terrestrial satellites, permanent lunar bases, and missions to Mars. Companies like Zeno Power, X-energy, and Ultra Safe Nuclear Corporation are creating state-of-the-art radioisotope power systems to send spacecraft and probes even further into space.

NASA is exploring nuclear thermal propulsion to reduce flight time, enabling human missions to Mars and beyond. As part of the historic Artemis space program, NASA also awarded contracts for a small nuclear power system that could operate a permanent surface power base on the Moon for over 10 years.

REVOLUTIONIZING AGRICULTURE WITH NUCLEAR TECHNOLOGY

In the field of agriculture, nuclear technologies can reduce the carbon footprint of this energy-intensive sector's processes. Nuclear energy is capable of producing hydrogen for carbon-free ammonia production and can directly provide the process heat needed to produce synthetic fertilizers. Nuclear technology can be used to improve crop yields and develop plant varieties that require less water and are more resilient to the impacts of climate change.

Nuclear-powered desalination resources enable irrigation in arid regions, as well as minimizing disputes over water between agricultural, commercial, and residential interests. Nuclear energy is also poised to help combat pests, eliminating the need for harmful pesticides. Food irradiation kills *E. coli*, *listeria*, and *salmonella*, so that fresh foods last longer.

DATA CENTERS AND INFORMATION TECHNOLOGY: HEADING TOWARDS ENERGY SUSTAINABILITY

Major technology companies, such as Google and Microsoft, are increasingly turning to nuclear energy to ensure a reliable, carbon-free power source for their data centers. The vision of a future where data centers are powered by small modular reactors (SMRs) or independent microreactors is becoming a reality, promising unprecedented energy efficiencies.

CRUCIAL CONTRIBUTIONS TO HUMAN HEALTH

Furthermore, the nuclear industry plays a key role in the health sector, providing essential radioiso-

NUCLEAR ENERGY IS PLAYING A VITAL ROLE IN BUILDING A MORE SUSTAINABLE AND TECHNOLOGICALLY ADVANCED FUTURE.

topes for diagnosing and treating diseases, such as cancer. Companies like Bruce Power and Ontario Power Generation are at the forefront of producing and distributing these vital radioisotopes, which play a crucial role in public health worldwide. And, as previously mentioned, nuclear radiation is also used to treat food, killing bacteria and eradicating insects and parasites that cause diseases.

Finally, microreactors offer the potential to provide clean energy to hospitals 24/7, 365 days a year, independently or as part of a system, without relying on a larger electrical grid. These compact reactors can be transported by land, air, or sea to remote areas, enabling hospitals in communities with inadequate medical access or those affected by disasters to be powered by reliable energy.

TRANSFORMING TRANSPORTATION WITH CLEAN ENERGY

Finally, nuclear energy is demonstrating its potential to revolutionize transportation, producing large amounts of carbon-free hydrogen to power various modes of transport and providing stable, reliable electricity for electric vehicle charging stations. Yes, nuclear energy is also a highly viable option for providing stable, reliable, carbon-free electricity for electric vehicle charging stations 24/7, 365 days a year.

As these innovations continue to develop, it is clear that nuclear energy is playing a vital role in building a more sustainable and technologically advanced future across a wide range of sectors. With support from the NEI and other industry leaders, these advancements promise to continue shaping the world we live in. ■

MBIR: AN EXPERIMENTAL BASE FOR THE DEVELOPMENT OF FUTURE NUCLEAR ENERGY TECHNOLOGIES

To launch fourth-generation industrial reactors, close the nuclear fuel cycle, and make nuclear energy renewable, it is necessary to introduce many new technologies that need to be tested. Throughout the history of nuclear energy use, research reactors have been used to conduct the most important experimental studies because they are the only possibility to reproduce as accurately as possible the complex effects of detrimental factors, such as neutron flux, temperature, and coolant corrosives.

To address these challenges, within a comprehensive program for the development of nuclear science, engineering, and technology, the State Atomic Energy Corporation Rosatom is constructing a 4th generation fast neutron multifunctional research reactor, MBIR.

PROJECT ADVANCEMENTS

The implementation of the MBIR project began in 2015 at the facilities of the State Scientific Center "Research Institute of Nuclear Reactors," part of Rosatom's scientific division and the largest research institute in Russia, with six nuclear research reactors. It is the largest complex in Europe for post-reactor research of nuclear reactor core elements, a complex of facilities for R&D in the nuclear fuel cycle, a radiochemical complex, and a complex for radioactive waste management.

Thanks to the technologies used and cooperation between scientists and builders, the MBIR project is ahead of schedule, which is extremely important in the context of reducing the global fleet of research reactors. In 2022, manufacturing and testing were completed, and the reactor vessel was delivered to the MBIR construction site. In January 2023, the reactor vessel was installed in its designated position. One of the main events of 2023 was the

construction of the reactor room dome. More than 1,000 people participated in implementing this task. The commissioning of MBIR is scheduled for 2027.

UNIQUE FEATURES

MBIR will replace the BOR-60 fast experimental reactor, a 60 MW multifunctional research reactor launched over half a century ago and widely sought after today. The projected power of MBIR is 150 MW – this is a very high number for research reactors, 2.5 times more than the BOR-60.

Once operational, MBIR will be the world's most powerful research reactor and will provide the nuclear industry with technologically advanced research infrastructure for the next 50 years.

MBIR includes a reactor with two sodium cooling circuits and a third steam-water circuit, a steam turbine, transport and technology systems, circuit facilities, vertical and horizontal experimental channels, a set of research protection chambers, a laboratory complex, and an automated process control system.

The sodium coolant and high power of MBIR will provide the highest neutron flux density for research reactors - $5.3 \cdot 10^{15}$ n/cm²s. This will allow achieving an integral radiation effect on the materials under study of up to 40 displacements per atom (dpa) per year. Therefore, radiation exposure in material samples of future fast reactors of 120÷200 dpa can be achieved in MBIR in 3÷5 years, and not in 10 years, as would be the case with BOR-60.

The wall thickness of the MBIR reactor vessel is only 25–50 mm, which is 6–12 times thinner than that of the VVER. The reactor length is 12 m, the maximum diameter is 4 m, and the weight is over 83 tonnes. To meet all parameters with greater precision, specialists from the company Atomash, part

of Rosatom's mechanical engineering division where the reactor vessel was manufactured, used specially designed devices.

MBIR will be able to study any type of fuel (uranium, plutonium, thorium), any shell material.

MULTIFUNCTIONALITY

Any research reactors perform three tasks: irradiation of materials and assemblies for post-reactor research, study of the behavior of materials and assemblies directly in the reactor (instrumented assemblies), and emission of neutron/neutrinoradiation to laboratory facilities located around the reactor.

MBIR was designed as a multifunctional reactor and is capable of solving these three problems simultaneously. For this, special channels are installed in the reactor core, and autonomous circuits with their own thermomechanical equipment and various types of coolant are connected to these channels. In such channels, experimental fuel assemblies can be installed, whose irradiation is carried out at temperatures and chemical effects of the coolant different from the standard fuel assemblies of the MBIR reactor core. Thanks to this, MBIR will allow testing not only technologies for future sodium reactors but also technologies for lead, liquid salt, gas, and other types of reactors. In the MBIR circuit facilities, it is even possible to simulate accidents without compromising the operation of the reactor as a whole. From design and operational viewpoints, this is a very challenging task: normally, the architecture of the reactor core is closely related to the type of its coolant, and there is no "gap" there.

A PERFECT RESEARCH SITE

The main objective of MBIR is to conduct mass tests on innovative materials and models of core elements for fourth-generation nuclear energy systems.

"The MBIR reactor is being created to comprehensively solve the problems of accelerated development of equipment, technology, and scientific research in the field of nuclear energy use. MBIR is indispensable, being a key element and, in some aspects, even unique, of Rosatom's research infrastructure to ensure the development and verification of 'new nuclear energy' and 'low-carbon development' technologies," commented Yuri Olenin, Deputy Director General for Science and Strategy of the State Atomic Energy Corporation Rosatom.

The unique experimental and technological capabilities of the new research reactor will significantly expand the areas of study to justify solutions for two-component nuclear energy and the closure of the fuel cycle, and will also help accelerate the creation of safe fourth-generation reactors, including fast neutron reactors with a closed fuel cycle, as well as low and medium power thermal reactors.

MBIR is also suitable for a wide range of work in the

area of non-energy applications: medical research in the field of fundamental and applied physics, improvement of technology for isotope and modified material production. Additionally, the reactor will generate electricity and heat.

PERSONNEL TRAINING AND SCIENTIFIC COLLABORATION

The strategic priority of the project is the implementation of a training and personnel development program to work on fast reactors, including multilateral experiments. This program will be elaborated from the interaction of hundreds of scientists and experts from different countries and will allow defining global trends and accelerating the development of fast nuclear energy.

Based on MBIR, an international research center is being created that will establish the foundation for promoting fast neutron reactor technologies in the global market, creating broad international scientific collaboration.

"The creation of the most powerful and technologically advanced research reactor will be an incentive for scientific advances and an important element of our country's technological leadership. As part of the Center, a scientific cooperation platform in forming an 'international neutron landscape,' we offer the world opportunities for the development of national programs in the field of future nuclear energy," said Vasily Konstantinov, Director of International Scientific and Technical Projects at Rosatom and General Director of the company "Leader of the Consortium" IRC MBIR.

Additionally, the project is gaining new partners: in 2023, MBIR, along with "megascience" projects, officially became one of the members of the international research facility network BRICS-GRAIN (Global Research Advanced Infrastructure Network).

MBIR was conceived not just as a research reactor, but as a true magnet for experts from around the world and a platform for global scientific collaboration. Within the framework of the MBIR IRC Advisory Board, representatives of the leading organizations of the global nuclear industry are drafting an international program of advanced experimental research that will begin in the next decade. Interaction is also developing on platforms under the auspices of the International Atomic Energy Agency.

Key to a Carbon-Free Future The ambitious MBIR project is a catalyst for a breakthrough in nuclear energy. Thanks to its unique features, this reactor will accelerate the creation of safe and efficient fourth-generation nuclear power plants, close the nuclear fuel cycle, and make significant discoveries in medicine, material science, and other areas. The commissioning of MBIR will open a new era in the history of nuclear energy, based on innovation, safety, and sustainable development. ■

IS NUCLEAR ENERGY RENEWABLE?

ONE OF THE ADVANTAGES OF NUCLEAR ENERGY IS ITS INDEPENDENCE FROM CLIMATIC CONDITIONS.

Renewable energies are so called because they are naturally and continuously replenished under normal conditions. However, the renewability of these sources can be impacted by climate change. In this article, we will discuss how each of the main renewable energy sources behaves in this scenario.

HYDROPOWER

Hydropower depends on water cycles, which are directly influenced by climate. Changes in precipitation, prolonged droughts, and glacier melt can affect water availability for power generation. In regions

where climate change results in less predictable precipitation patterns, the reliability of hydroelectric plants can be compromised.

WIND ENERGY

Wind energy depends on wind patterns, also influenced by climatic conditions. Changes in wind regimes, whether in terms of speed, direction, or consistency, can affect the efficiency of wind turbines. Some areas may experience stronger winds, while others may see a reduction, impacting energy production.



SOLAR ENERGY

Solar energy depends on the amount of solar radiation reaching the Earth. Climate change can alter patterns of sunlight, with regions experiencing more clouds or variations in sunlight intensity. However, solar energy tends to be less sensitive to climate changes compared to hydro-power and wind, though there are still potential impacts.

IMPACT OF CLIMATE CHANGE ON RENEWABLE ENERGIES

Renewable energies are theoretically inexhaustible because they derive from continually replenished natural sources. However, in practice, their renewability can be influenced by climatic variables. In a scenario of climate change, the reliability and availability of these energy sources cannot be guaranteed indefinitely in all regions, compromising their effective sustainability.

For a sustainable energy transition, it is crucial to develop resilient and diversified infrastructure capable of adapting to climate changes and ensuring a continuous and stable energy supply. In this context, the role of nuclear energy deserves attention.

NUCLEAR ENERGY: SUSTAINABILITY AND LONGEVITY

Nuclear energy is often debated in terms of sustainability and longevity, especially when compared to renewable energy sources. Although nuclear fuels, such as uranium and thorium, are not renewable in the strict sense, there are arguments for considering them a virtually inexhaustible energy source in the long term.

NUCLEAR FUEL RECYCLING

Known uranium reserves are significant, and advances in technology could increase the amount of available uranium. Recycling used nuclear fuel, known as reprocessing, allows the recovery of uranium and plutonium, which can be reused to generate more energy. Countries like France, Russia, and Japan already utilize reprocessing to reduce nuclear waste and increase fuel efficiency.

Economic Viability of Recycling Currently, recycling nuclear fuel is not economically viable in all contexts. Reprocessing costs range from \$1,000 to \$2,000 per kilogram of fuel, which can result in negative net values. However, with increased

UNLIKE RENEWABLE ENERGIES THAT CAN BE INFLUENCED BY CLIMATE CHANGES, NUCLEAR ENERGY PROVIDES A CONSTANT SOURCE OF ELECTRICITY.

scale and advances in research and development, costs can be reduced, enhancing the value of used fuel.

THORIUM POTENTIAL

Thorium, more abundant than uranium, can be converted into uranium-233, a fissile material usable in nuclear reactors. Although still in development, thorium reactor technology is progressing, with countries like India and China leading the research.

NUCLEAR ENERGY AND CLIMATIC CONDITIONS

One of the advantages of nuclear energy is its independence from climatic conditions. Unlike renewable energies that can be influenced by climate changes, nuclear energy provides a constant source of electricity. The concentrated nature of nuclear fuel allows small quantities to generate large amounts of energy, facilitating transport and storage.

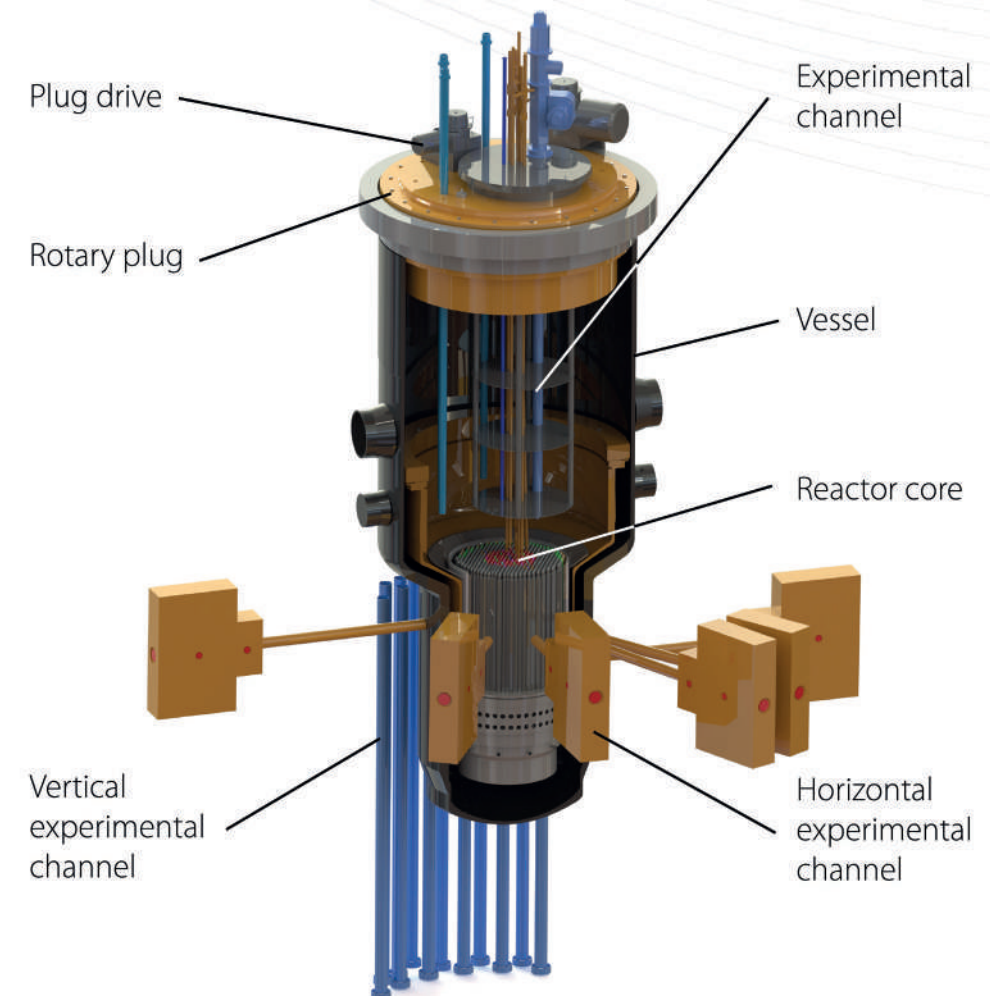
Although uranium and thorium are not renewable in the classical sense, the vast availability of these materials and the possibility of recycling indicate that they can provide a stable and long-lasting energy source. With proper management and technological advances, nuclear energy can meet energy needs for significantly long periods, making it a viable solution for the energy transition in a climate-changing world.

The adoption of emerging technologies, such as thorium reactors and advancements in nuclear fuel reprocessing, can further strengthen this argument, positioning nuclear energy as a key component in the mosaic of sustainable energy sources for the future. ■



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