



Conexão  
Nuclear

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## SMRs on the Rise

Countries discuss the crucial role of this technology in the energy transition

## Sustainability

With the G20 and COP30, nuclear energy stands out in the sustainable energy transition

## Goodbye Old Year, Hello New Year

A look back at 2024 and what to expect in 2025

# Interview with Silas Rondeau

A conversation with the President of ENBPar  
on nuclear challenges and priorities

**ABDAN**

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# 2024: A YEAR OF UNCERTAINTIES FOR THE NUCLEAR SECTOR



What a turbulent year, dear readers! In 2024, we experienced a true roller coaster of emotions in the nuclear sector. The government, as a whole, failed to establish a clear position on our role in Brazil's energy matrix. While some sectors show support for nuclear energy, others seem to completely disregard its importance.

This lack of definition is reflected in various government plans. The Climate Plan, for example, demonstrates a clear aversion to nuclear energy,

while the PDE 2024, released for public consultation, signals the removal of the fourth plant from the planning. And the worst part: the previous plan, which should have been updated over two years ago, remains unpublished, transforming what should be a state plan into a mere government plan. The removal of the fourth plant, my friends, is a very bad sign for the sector.

We did have some positive moments, such as participation in the G20, where Brazil, under international pressure, recognized the importance of nuclear energy. But immediately after came the green taxonomy, which excluded uranium and nuclear energy.

The Congress has not been much help either. Around 70 bills on renewable energy are under discussion there, and none of them mention nuclear energy. However, we achieved a few victories, such as the approval of the hydrogen project, which, albeit timidly, opens up space for nuclear. The energy transition bill, reported by Senator Laércio, also includes nuclear, but it still needs to be voted on.

In the end, 2024 was a year of a divided government, resembling a major fan rivalry, with each side defending its interests without reaching a consensus. This instability, of course, impacts our association, which lost two major companies. EDF Nuclear, for instance, decided to leave Brazil, citing the country's lack of definition regarding the future of nuclear energy.

Amid so many uncertainties, we need to unite and seek allies to strengthen the sector. And to stay informed about all these challenges and the outlook for the future, I invite you to enjoy this edition of *Conexão Nuclear*, the last one of 2024. It features important articles on the future of Angra 3, an exclusive interview with Silas Rondeau, President of ENBPar, a report on the feasibility of producing radioisotopes at Angra 2 and 3, and an analysis of the use of nuclear energy to power data centers, among other relevant topics.

Happy reading! ■



# INNOVATION IN RADIOLOGICAL EMERGENCY TRAINING WITH ARTIFICIAL INTELLIGENCE

**THE RADIOLOGICAL SECTOR INCLUDES HOSPITALS, INDUSTRIES,  
AND RESEARCH INSTITUTES, REPRESENTING A HIGH DEMAND**

A doctoral thesis developed at COPPE-UFRJ is revolutionizing how professionals handle radiological emergencies. Under the guidance of Dr. Davi Ferreira de Oliveira and Dr. Francisco Cesar Augusto da Silva from IRD/CNEN, the research by Camila Araújo, ambassador of the World Institute for Nuclear Security (WINS), integrates artificial intelligence (AI) to create virtual training aimed at optimizing the continuous learning of specialists, including first responders, radiation protection supervisors, and postgraduate students.

The primary focus of the project is to train these professionals to address various scenarios involving accidents with radioactive sources, encompassing medical, industrial, research, and transportation environments. The training is designed to enhance decision-making skills and reinforce essential technical concepts while standardizing the curriculum by including complex and rare cases. This approach ensures participants are well-prepared for both real and hypothetical situations.

Due to its innovative methodology, the National Institute of Industrial Property (INPI) awarded the SisRad EmergencyTrainer a Computer Program Registration Certificate, and the patent was filed through INOVA at UFRJ. This move underscores the originality and exclusivity of the research. Camila Araújo celebrated a significant milestone in her academic and professional career.

Recently, part of the project was presented at the IRPA16 and Health Physics Society international conference held in July 2024 in Orlando, USA. The presentation received recognition during the “MA-3 Session 2 Education and Training” session, highlighting the relevance and potential impact of the initiative in the field of radiological protection.

By combining advanced technology with a practical

training approach, COPPE-UFRJ’s project stands out not only for its innovation but also for its promise to transform the training of professionals operating in critical situations, contributing to safety in radiological emergency scenarios.

## **BRAZILIAN INNOVATION IN THE RADIOLOGICAL FIELD**

The SisRad EmergencyTrainer was designed to enhance training for radiological emergency response. Camila explains that while training for the nuclear sector already exists and is well-developed, the radiological field is groundbreaking globally, as no online training is currently available.

The radiological sector includes hospitals, industries, and research institutes, representing significant demand. Camila developed a methodology that standardizes the level of knowledge, enabling participants to take tests. This training is structured in scenarios resembling video games, where participants progress through various stages with difficulty levels adjusted to their individual knowledge.

Regarding access to the tool, UFRJ requires the preparation of an article to defend her thesis, as the patent alone is not sufficient, being a normative requirement. Once the article is published, Camila intends to make the platform available to society. She also hopes to count on the support of sector organizations to provide free access, on the condition that users are professionals in the radiological field, students, or first responders.

## **WHAT IS CONSIDERED A RADIOLOGICAL EMERGENCY?**

A radiological emergency refers to an incident involving exposure to ionizing radiation that could pose a risk to human health and the environment. Specific situations that



Photo: Dean Calma / IAEA

**TRAINING FOR THE NUCLEAR SECTOR IS ALREADY AVAILABLE. HOWEVER, THE RADIOLOGICAL FIELD IS A GLOBAL FIRST, AS NO ONLINE TRAINING IS CURRENTLY AVAILABLE.**

can be considered radiological emergencies include:

**Accidents at radiological facilities:** Incidents at hospitals, laboratories, or nuclear plants that result in accidental radiation release or exposure to individuals.

**Occupational exposure:** Situations where workers in radiation-related fields (e.g., radiologists or technicians) are exposed to levels exceeding established limits.

**Natural disasters:** Events like earthquakes or floods damaging nuclear facilities, leading to radioactive material leaks.

**Transportation of radioactive materials:** Accidents during the transport of radioactive materials that may result in contamination or exposure.

**Misuse of radioactive sources:** Cases where radioactive sources are used improperly or deliberately, such as in acts of terrorism.

Radiological emergencies require a rapid and coordinated response, including assessing radiation levels, implementing protective measures for exposed individuals, and containing any environmental contamination. Specialized teams, such as Radiological Emergency Services, are critical to safety and effectively addressing these situations.

## DEVELOPMENT OF EFFECTIVE VIRTUAL TRAINING

Collaboration between the Faculdade de Casa Branca (FACAB) and the MAXIM Group led to the creation of a postgraduate in-person course on “Radiological Protection in Medical, Industrial, and

Nuclear Applications.” A tabletop exercise from this course, focusing on “Preparation and Response to a Radiological Emergency,” is being adapted for virtual platforms, emphasizing practical knowledge application. With the use of artificial intelligence (AI) tools, a new method of virtual training is proposed to enhance preparation and response effectiveness for radiological emergencies, providing a dynamic and engaging learning experience.

The target audience includes first responders, radiation protection supervisors, professionals, and students facing radiological emergencies. The interactive and animated content was created using the Genially platform, incorporating Google Maps and YouTube resources for practical simulations. D-ID was used for an instructional “deepfake” guide, offering an engaging educational experience, along with the “Learning Landscape” tool for personalized learning environments.

The narrative outlines the potential of an imminent radiological emergency, highlighting challenges such as the loss of five pieces of equipment with radioactive sources from a vehicle. The exercise comprises 24 scenarios distributed on a strategic map of a specific city in Brazil.

Integrating artificial intelligence (AI) into radiological emergency response training is innovative and ensures professional development. This project underscores the importance of realistic training methods, with AI emerging as a revolutionary solution, exemplified through a practical scenario of road transport of radioactive sources. ■

# ABDAN: A YEAR OF ADVANCEMENTS AND PARTNERSHIPS FOR THE FUTURE OF NUCLEAR ENERGY IN BRAZIL

## A RETROSPECTIVE OF 2024 AND WHAT TO EXPECT IN 2025

The year 2024 was particularly significant for the Brazilian Association for the Development of Nuclear Activities (ABDAN), which solidified its role as a catalyst for innovation, international cooperation, and sustainable development in the nuclear sector. Under the leadership of President Celso Cunha, ABDAN maintained a robust agenda with high-level events, strategic partnerships, and participation in global conferences, reaffirming Brazil's commitment to energy transition and sustainability.

### SOCIOECONOMIC STUDY OF THE NUCLEAR SECTOR

In February, the Getúlio Vargas Foundation (FGV), in partnership with Eletronuclear, presented a study on the socioeconomic impacts of nuclear activities in Brazil, highlighting the strategic role of nuclear energy in job creation and economic growth. According to Cunha, "The results of this study confirm that the nuclear sector is one of the largest generators of economic value for the country, directly impacting job creation and national GDP."

### INTERNATIONALIZATION OF THE SECTOR: STRATEGIC PARTNERSHIPS AND THE CONFERENCE IN BELGIUM

In March, ABDAN represented Brazil at the Nuclear Energy Summit in Brussels, where world leaders discussed expanding the use of nuclear energy as part of decarbonization commitments. The initiative, aimed at tripling global nuclear energy use by 2050, included the presence of Rafael Mariano Grossi, Director-General of the International Atomic Energy Agency (IAEA), and Alexander De Croo, the

Belgian Prime Minister. Cunha emphasized Brazil's key role in this global agenda: "Brazil's participation in these discussions is an essential step toward strengthening the nuclear sector and meeting carbon reduction targets."

### NUCLEAR SUMMIT IN RIO DE JANEIRO: AN INNOVATIVE VISION FOR THE SECTOR

Among the most significant milestones of the year, the Nuclear Summit stood out. Held on April 8–9 in Rio de Janeiro, the event featured renowned figures such as Rafael Grossi (IAEA). In his keynote address, Grossi discussed global trends in the nuclear sector and highlighted Brazil's potential to become a world leader in clean and safe energy production.

Celso Cunha celebrated the event's innovation and the impact of its diverse programming. "The presence of global leaders and experts reinforces the relevance of the nuclear sector in the energy transition. With panels covering topics from sustainability to innovation in nuclear medicine, the Summit marked an essential moment for the sector's future in Brazil," he said.

### STRENGTHENING THE NATIONAL SECTOR: TECHNICAL MISSION TO THE USA AND CANADA

In April, ABDAN organized a strategic mission to the United States and Canada to expand technological exchanges and partnerships in the sector. This visit included meetings with leading companies such as Westinghouse and Holtec and participation in a global event on Small Modular Reactors (SMRs). The mission



was a milestone in seeking partnerships to boost technical capacity and develop new technologies in Brazil.

### **FOCUS ON NUCLEAR MEDICINE: SEMINAR IN PARTNERSHIP WITH FIESP AND ROSATOM**

Also in April, ABDAN, in collaboration with FIESP and the Russian company Rosatom, held a seminar on Brazil's nuclear medicine market. The event brought discussions on sector expansion and investment potential. "Our goal is to expand access to medical treatments that use nuclear technology, positively impacting the lives of thousands of Brazilians," said Celso Cunha, reaffirming ABDAN's commitment to nuclear medicine.

### **INNOVATION AND ENTREPRENEURSHIP: PARTNERSHIPS WITH CIETEC AND ITAIPU PARQUETEC**

To foster innovation in the sector, ABDAN partnered with the Center for Innovation, Entrepreneurship, and Technology (CIETEC), creating an environment conducive to the growth of startups focused on nuclear technology. In a complementary move, the association also teamed up with Itaipu Parquetec to focus on renewable energy and new technologies, promoting the development of joint innovations.

"We want Brazil to be a hub for nuclear innovation, enabling startups to transform their ideas into concrete market solutions," Cunha declared.

### **PARTICIPATION IN THE G20 AND HIGH- LEVEL CONFERENCES**

Another significant milestone was ABDAN's participation in the G20 Energy Transitions Working Group in Foz do Iguaçu, where global leaders discussed solutions for the energy transition. Celso Cunha emphasized Brazil's role in presenting viable and sustainable proposals. Additionally, the association attended the International Energy Agency (IEA) High-Level Conference in Paris, where Cunha represented Brazil's nuclear sector in debates on financing and expanding nuclear energy as a solution for global energy security.

### **CAPACITY BUILDING AND EXPANSION: IAEA CONFERENCE AND SUMMER INSTITUTE IN RIO**

ABDAN's presence at the 68th General Conference of the International Atomic Energy Agency (IAEA) in Vienna represented an important step in expanding SMR use in Brazil. Cunha took the opportunity to emphasize the need for professional training in the sector. Additionally, the association hosted the World Nuclear University Summer Institute in Rio





de Janeiro, bringing together future global nuclear leaders for an intensive development program.

### MIXED PARLIAMENTARY FRONT

The Mixed Parliamentary Front for Technology and Nuclear Activities - FPN, in 2024, advocated for policies favoring the expansion of nuclear energy in Brazil, seeking to ensure energy security and diversify the country's energy sources. Key efforts in 2024 included energy sovereignty and the completion of the Angra 3 nuclear plant.

"The FPN believes Brazil should expand its nuclear energy capacity to ensure greater energy sovereignty, reduce dependence on external energy sources, and achieve self-sufficiency. Regarding Angra 3, the Front has been pressing for the project's completion without further delays, as the plant is considered crucial for strengthening Brazil's energy matrix. For 2025, we will remain committed to promoting safe and sustainable nuclear energy, paving the way for a cleaner and more independent Brazil," said Deputy Julio Lopes, President of the Parliamentary Front for Technology and Nuclear Activities.

### CLOSING THE YEAR WITH THE NUCLEAR LEGACY EVENT

The Nuclear Legacy event, held on November 5–6,

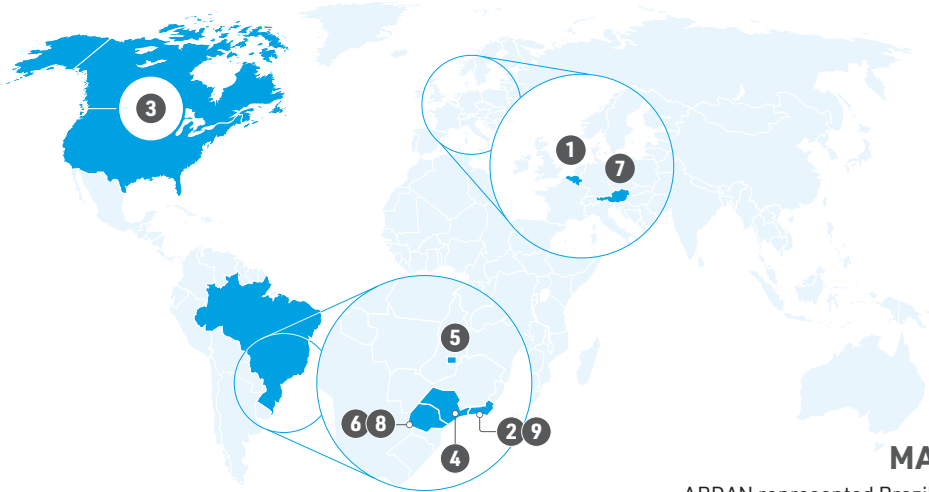
celebrated achievements and formalized new partnerships. With the presence of authorities and tributes to industry figures, the event highlighted the nuclear sector's role in the energy transition. Strategic agreements were signed with Rosatom, Framatome, and Tractebel Engie to strengthen Brazil's nuclear value chain. In his speech, Cunha emphasized the importance of strengthening the nuclear sector in an energy transition scenario: "It is essential for the nuclear sector to be included in energy transition policies to ensure a more secure and sustainable energy matrix."

### OUTLOOK FOR 2025: NT2E AND SECTOR STRENGTHENING

For 2025, ABDAN is already planning the NT2E, Brazil's largest nuclear business and technology event, scheduled for May 20–22, 2025, in Rio de Janeiro. The upcoming edition has been expanded to include innovation, technology, and sustainability, reinforcing its role as a meeting point for key players in the sector.

"We hope NT2E will be a turning point for Brazil's nuclear sector, promoting the strengthening of the production chain and attracting essential investments for developing new technologies," Cunha commented. ■

# ABDAN THROUGHOUT BRAZIL AND THE WORLD



**MAR**

ABDAN represented Brazil at the *Nuclear Energy Summit* in Brussels, reinforcing the country's role in global decarbonization.

**1**

**APR**

The *Nuclear Summit* event brought together internationally renowned leaders, highlighting Brazil as a reference in clean and safe energy.

**2**

**APR**

Mission to the USA and Canada expanded partnerships in technology and explored advancements such as Small Modular Reactors (SMRs).

**3**

**MAY**

Seminar with FIESP and the Russian company Rosatom discussed the sector's growth and emphasized investments in medical treatments.

**4**

**9**

**NOV**

The *Nuclear Legacy* event in Rio celebrated partnerships and the consolidation of the nuclear sector as essential in the energy transition.



**8**

**OUC**

Participation in the G20 Energy Transitions Working Group in Foz do Iguaçu.



**7**

**SEP**

At the 68th General Conference of the IAEA in Vienna, ABDAN advocated for the use of nuclear technologies in Brazil.



**6**

**JUL**

Entrepreneurship: partnerships with CIETEC and Itaipu Parquetec aim for solutions in nuclear technology and renewable energy.

The Mixed Parliamentary Front of Technology and Nuclear Activities has been advocating for policies favorable to the expansion of nuclear energy in Brazil.

**5**

# SILAS RONDEAU, PRESIDENT OF ENBPAR

*In this edition, Conexão Nuclear presents a special interview with Silas Rondeau, president of ENBPar, the Brazilian Company for Nuclear Energy and Bimational Holdings. ENBPar oversees three companies: Itaipu, Eletronuclear, and INB. Read the highlights below!*

**1 – You are taking over ENBPar’s presidency during a significant debate about expanding nuclear energy in Brazil. What is your vision for the role of nuclear energy in Brazil’s energy matrix, and how does ENBPar plan to contribute to the development of this energy source?**

This debate is part of a broader discussion about growing energy demand, energy transition, and low-carbon energy sources. Last year, 22 of the world’s most influential countries announced their intention to triple their nuclear energy generation capacity by 2030 to meet the demand for decarbonization. Global energy demand is predominantly met by fossil fuels (80%), with only 20% coming from other sources, of which 16% are renewable. This illustrates the enormous challenge the world faces in achieving energy transition. In this context, Brazil has a privileged energy matrix, with 40% of its energy demand met by renewable sources and only 2% by nuclear energy. This positioning allows us to make significant progress, such as resuming construction on Angra 3. Aware of the risks and the necessity of continuously improving safety standards, Brazil can and should invest in increasing its nuclear energy supply. Clean, safe, and predictable, without the intermittence of other sources, nuclear energy is the least CO<sub>2</sub>-emitting option across the entire production chain. Since the first of Brazil’s two nuclear plants began operations in 1985, we have generated nuclear energy safely. After 50 years of research and investment, Brazil is one of the few countries to master all stages of the nuclear fuel cycle. Moreover, we have one of the largest uranium reserves in the world. It is crucial to demonstrate to society the constant and beneficial coexistence with nuclear technology in areas like security, food preservation, cultural heritage con-



servation, and health. The progress in cancer diagnosis and treatment achieved in recent years with radiopharmaceuticals is undeniable.

**2 – Considering the challenges of financing and environmental licensing, how do you intend to facilitate the resumption of Angra 3 construction and the potential development of new nuclear plants in Brazil?**

Demystifying nuclear technology is an important step in addressing environmental requirements. Statistics show the viability of a sector that generates about USD 250 billion annually worldwide and attracts both domestic and international funding. There is a global demand for energy, and resources are available to support the nuclear fuel cycle. At COP 29, recently concluded in Azerbaijan, 31 countries—nine more than in 2023—reaffirmed their decision to expand global nuclear energy supply. They also called on banks and international development agencies to include nuclear energy in their financing policies.

**3 – ENBPar controls INB, a strategic company in the nuclear fuel cycle. What are your priorities for INB's management, and how do you plan to ensure fuel supply for Brazil's nuclear plants?**

We face the challenge of completing the mapping of Brazilian territory to fully understand our uranium reserves. With only one-third of the territory surveyed, Brazil already ranks among the top ten countries with the largest reserves. Minister Alexandre da Silveira (Mines and Energy) is an enthusiast, recognizing enormous potential in this area. In partnership with private stakeholders, we are working to make the Santa Quitéria deposit in Ceará viable, which could bring significant advancements to the sector.

**4 – How do you evaluate ENBPar's performance in 2023, with a primary surplus of R\$ 3.1 billion? Does this result create room for greater investments in the nuclear sector?**

ENBPar invests continuously and consistently in the nuclear sector. In 2024, R\$ 60 million has already been invested in INB, with the possibility of this amount nearly doubling to R\$ 111 million. Eletro-nuclear has already received R\$ 1.7 billion in investments to extend the operational life of Angra 1. Additionally, ENBPar allocates resources to pri-

**“  
ABDAN'S ROLE  
IS CRUCIAL  
IN ENSURING  
THAT NUCLEAR  
TECHNOLOGY  
IS SEEN BY  
SOCIETY AS A  
SOLUTION TO THE  
GLOBAL ENERGY  
CHALLENGE.  
”**

ority government programs, such as Luz para Todos and Procel, ensuring a fair and inclusive energy transition.

**5 – You have extensive experience in the electricity sector. What are the key lessons from your tenure at Eletrobras and the Ministry of Mines and Energy that you plan to apply at ENBPar, particularly in the nuclear area?**

Throughout my professional life, I have learned the importance of planning and attention to detail in execution. These lessons are applicable to every area of public service.

**6 – Considering ABDAN's role in advocating for nuclear knowledge, how does ENBPar plan to engage with the association and civil society to promote the debate about the future of nuclear energy in Brazil?**

ABDAN is a crucial actor in the nuclear sector, tasked with uniting public and private stakeholders, both domestic and international. It promotes ongoing dialogue with academia and representatives from various nuclear energy applications. The association's role is fundamental in ensuring that nuclear technology is viewed by society as a solution to the global energy challenge, free from prejudice against the sector. ENBPar stands ready to support this mission. ■



# SMRS IN FOCUS: 90 COUNTRIES DEBATE SMALL MODULAR REACTORS AT THE IAEA INTERNATIONAL CONFERENCE IN VIENNA

**EVENT DISCUSSES THE CRUCIAL ROLE OF TECHNOLOGY IN PURSUING A CLEANER, MORE RELIABLE ENERGY MIX DURING THE ENERGY TRANSITION**

In October this year, Vienna, Austria, hosted an intense debate about the future of nuclear energy during the International Conference on Small Modular Reactors and Their Applications. Organized by the International Atomic Energy Agency (IAEA) from October 21–25, 2024, the event brought together experts, industry leaders, and government representatives from over 90 countries to discuss the critical role of SMRs in achieving a cleaner and more reliable energy mix.

This conference, the IAEA's first dedicated exclusively to SMRs, highlighted the growing importance of this technology on the global stage. "The conference was significant as it was the Agency's first on SMRs, bringing together over 90 countries, including Brazil, demonstrating the topic's relevance to the international community," said Bento Albuquerque, former Minister of Mines and Energy of Brazil, who attended the event.

## SMRS: A PROMISING SOLUTION TO FUTURE ENERGY CHALLENGES

With rising energy demand and the urgent need to reduce carbon emissions, SMRs emerge as a promising alternative to drive the energy transition. The IAEA projects a significant increase in electricity consumption by 2050, while fossil fuels, currently responsible for over 60% of global electricity generation, remain the primary contributors to climate change.

In this context, nuclear energy stands out as a low-carbon, reliable energy source capable of driving sustainable socio-economic development. "Nuclear energy will play a significant role in energy security, and these small reactors will also have a crucial role in a continental country like Brazil, providing energy to remote and isolated areas," Albuquerque emphasized.

SMRs, with their modularity, flexibility, and enhanced safety features, offer significant advantages over conventional nuclear reactors, particularly for developing countries and applications in remote areas or regions with limited infrastructure.

### MAIN CHARACTERISTICS

- Smaller power generation capacity (up to 300 MWe), while conventional plants produce at least 700 MWe.

### APPLICATIONS

- Rural areas with limited electrical infrastructure.
- Backup power in emergencies.
- Replacement for diesel generators in communities and businesses.
- Areas affected by natural disasters.

### ADVANTAGES

- Shorter manufacturing time.
- Modular design.
- Adaptable to various situations.

## BRAZIL PLAYS AN ACTIVE ROLE IN GLOBAL SMR DISCUSSIONS

Brazil, one of the pioneering countries in nuclear technology development, played an active role at the conference, with a representative delegation comprising industry, academia, research centers, and regulatory bodies. "Brazil was among the top 10 largest delegations, highlighting the country's interest across all segments," Albuquerque noted.

Brazil’s extensive experience in the nuclear sector, including the operation of nuclear plants in Angra dos Reis and mastery of uranium enrichment technology, positions the country to contribute significantly to the development and deployment of SMRs. “Brazil is one of the founding members of the Agency and has been conducting nuclear research for 70 years... SMRs are a potential application of this development,” Albuquerque added.

CHALLENGES AND OPPORTUNITIES FOR SMR ADOPTION IN BRAZIL

Despite the great potential of SMRs, their implementation in Brazil faces challenges such as the need for a more agile regulatory environment and the establishment of a robust supply chain. “It would be extremely important for Brazil to activate the National Nuclear Safety Authority (ANSN) to enable the necessary legislative and regulatory adaptations to make nuclear and environmental licensing for these new models more efficient,” argued Vice-Admiral Carlos Alberto Matias, Technical Director of AMAZUL, in an interview with Conexão Nuclear magazine.

AMAZUL, a strategic company for nuclear technology development in Brazil, has actively participated in all phases of the Permanent SMR Forum, led by ABDAN and EPE, to foster discussions on using small modular reactors in the country.

Matias also emphasized the importance of international cooperation to accelerate SMR adoption: “International cooperation is crucial for the successful development and adoption of SMRs, and the IAEA has been proactive with various initiatives to achieve this goal.”

CONFERENCE BOOSTS DISCUSSIONS AND INTERNATIONAL COOPERATION

The International Conference on Small Modular Reactors and Their Applications provided a valuable platform for exchanging knowledge, experiences, and perspectives

“IT WOULD BE EXTREMELY IMPORTANT FOR BRAZIL TO ACTIVATE THE NATIONAL NUCLEAR SAFETY AUTHORITY (ANSN) TO ENABLE THE NECESSARY LEGISLATIVE AND REGULATORY ADAPTATIONS TO MAKE NUCLEAR AND ENVIRONMENTAL LICENSING FOR THESE NEW MODELS MORE EFFICIENT.”

on the future of nuclear energy. The event covered topics such as technological innovations, safety, best practices for deployment, and the socio-economic benefits of SMRs.

“There is hope that the conference will become an annual event, with more seminars and international and national events to discuss sector challenges,” Albuquerque stated, reinforcing the importance of continuous dialogue among countries to drive the safe and efficient development and adoption of SMRs.

ABDAN, in partnership with the IAEA, played a fundamental role in coordinating the conference’s activities, contributing to advancing discussions on SMRs and solidifying nuclear energy as an essential component of the transition to a cleaner and more sustainable energy mix. ■

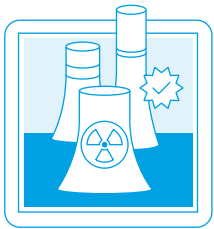
VANTAGENS E SIMPLIFICAÇÕES DOS SMRS

COSTS	FINANCIAL	CHALLENGES	OPPORTUNITIES
Simplified design	Faster returns	Easier logistics	Decarbonization
Standardization	Scalability	Regulatory simplifications	Accessibility
Modular construction	Lower CAPEX	Public opinion improvement	Complement to intermittent renewables

# ANGRA 3: DECISION ON CONSTRUCTION DELAYED BY THE NATIONAL ENERGY POLICY COUNCIL

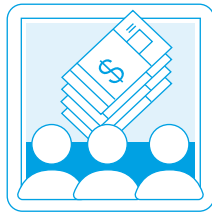
**FRUSTRATED EXPECTATIONS AND AN UNCERTAIN FUTURE FOR THE PROJECT**

## WHAT IS ENERGY TRANSITION?



### Energy Security

Reliable energy supply, preventing blackouts



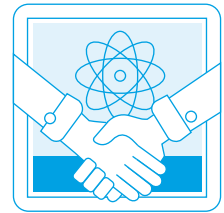
### Economy

Job creation, boosting the local economy and the nuclear production chain



### Environment

Reduction of millions of tons of CO2 emissions per year



### Technology

Development of the Brazilian Nuclear Sector and Mastery of Cutting-Edge Technology



WHEN COMPLETED, THE ANGRA 3 POWER PLANT WILL BE CAPABLE OF GENERATING:

**1,405**

MEGAWATTS OF ENERGY

sufficient to supply



**4.5**

MILLION HOUSEHOLDS

Source: ABDAN

In an unexpected turn of events, the National Energy Policy Council (CNPE) has postponed its decision on whether to proceed with the construction of the Angra 3 nuclear power plant. The meeting, highly anticipated by the market, concluded without a resolution on the project's future, creating uncertainty in Brazil's energy sector.

The completion of Angra 3 was on the CNPE's agenda, where it was expected to decide on the authorization to build the plant and set the price of its energy. Despite expectations of approval, a collective request for further review delayed the decision until the first extraordinary meeting of 2025, scheduled for late January.

uled for late January.

The postponement has frustrated market expectations and cast doubt on the continuity of a project deemed critical to Brazil's energy security and sustainability. Once completed, Angra 3 will have the capacity to generate 1,405 megawatts of energy, enough to supply 4.5 million households, helping to prevent blackouts and ensure the stability of Brazil's electrical system.

## REACTIONS AND NEXT STEPS

The news of the postponement was met with surprise by the Brazilian Association for the Development of Nucle-



ar Activities (ABDAN). Celso Cunha, ABDAN's president, expressed disappointment and concern over the government's indecision. "We understood that this issue would be resolved today, and unfortunately, it was not. For the market, this indecision was bad news," Cunha stated.

The CNPE has requested studies on improving Eletronuclear's governance and identifying new funding sources to complete the construction. The expectation is that, with these studies completed, the Council will make a final decision on Angra 3's future during its January 2025 meeting.

## IMPACTS AND UNCERTAINTIES

The postponement of the decision on Angra 3 creates uncertainty about the future of Brazil's electricity matrix. In addition to ensuring energy security, the plant would bring significant economic benefits, such as job creation and contributions to Brazil's climate goals.

The CNPE's indecision risks undermining these benefits and could negatively impact the develop-

ment of Brazil's nuclear sector. All eyes are now on the January 2025 meeting, when the Council is expected to finally decide the fate of Angra 3.

## 2025: A YEAR OF UNCERTAINTY FOR BRAZIL'S NUCLEAR SECTOR

With the postponement of the Angra 3 decision, 2025 begins with uncertainties for Brazil's nuclear sector. The realization of strategic projects and the strengthening of the nuclear industry are jeopardized by the lack of clarity regarding the plant.

Other critical issues for the sector in 2025, such as advancements in uranium mining and nuclear fuel production, may also be affected by the absence of a clear decision on Angra 3.

The outlook for 2025, once promising, now appears uncertain, with potential delays and difficulties in developing Brazil's nuclear sector. The final decision on Angra 3, anticipated at the CNPE's January meeting, will be crucial in shaping the direction of the national energy matrix and the future of Brazil's nuclear industry. ■



# SMALL MODULAR REACTORS: A NEW HOPE FOR DATA CENTERS

## DEMAND WILL INCREASE DUE TO THE EXPONENTIAL USE OF ARTIFICIAL INTELLIGENCE

In the information age, data centers are essential for the operations of companies, governments, and cloud service providers. These facilities, which operate 24/7, are the backbone of digital connectivity, ensuring the continuity of online services. However, one critical factor is vital to keeping everything running smoothly: a reliable energy supply.

### THE ENERGY CHALLENGE OF DATA CENTERS

Data centers consume significant amounts of electricity. Servers, cooling systems, and other equipment operate continuously, and any interruption in the power supply can lead to financial losses, data loss, and reputational damage to companies. Currently, most data centers rely on electrical grids and diesel generators as their energy sources. However, these solutions face challenges such as grid interruptions and high operating and maintenance costs. Additionally, increasing environmental concerns have pressured companies and institutions to seek more sustainable alternatives to meet their energy demands.

In this context, Small Modular Reactors (SMRs) emerge as a promising solution. Unlike traditional nuclear power plants, these reactors are smaller, more flexible, and designed to operate safely and efficiently in various applications, including electricity generation. Using SMRs to power data centers offers significant advantages, such as high availability and reliability.

By installing SMRs in clusters with redundancy and dual feeds, the need for diesel generators can be minimized, and reliance on batteries reduced. The goal is to ensure energy availability exceeding 99.99%.

However, implementing SMRs comes with challenges. Water usage for cooling is a concern, requir-

ing proximity to large water bodies or closed cooling systems. Additionally, environmental licenses and legal approvals make the installation process complex and time-consuming, with an estimated timeframe of 3 to 5 years for implementation.

Major technology companies are beginning to explore SMRs in response to the growing need for clean and reliable energy. Among them, Microsoft and Google are leading these initiatives.

### MICROSOFT

In 2023, Microsoft partnered with Helion Energy, a company focused on nuclear fusion, to develop reactors capable of providing electricity to its data centers. Additionally, the company is evaluating the feasibility of SMRs to ensure a safer and more independent energy supply.

### GOOGLE

Google has also shown interest in new forms of clean energy generation. In 2021, company executives discussed the possibility of adopting modular nuclear reactors as part of their carbon neutrality strategy.

### THE FUTURE OF DATA CENTERS AND SUSTAINABLE ENERGY

The application of SMRs to data centers represents a promising alternative to meet the growing demand for reliable and sustainable energy. Although significant challenges remain, the benefits in terms of reliability and emission reductions make this technology an attractive option for companies seeking to ensure continuous operations in an increasingly digital world. Addressing these challenges responsibly and rigorously is essential to maximize this innovation and build a more sustainable future.

## INTERVIEW WITH MARCO LAURIA

### The era of ai and the energy challenge

In an exclusive interview with our magazine, Marco Lauria, an AI specialist and member of the Digital Brazil Movement's board, discusses the challenges of increasing energy demand in the AI era.

Lauria, who has led AI projects at IBM and has extensive experience in big data, highlights the explosion of generative AI, driven by models such as ChatGPT, Claude, Gemini, and Mistral. Once limited to enterprise use, AI's popularity has expanded to everyday users, elevating energy demand to unprecedented levels.

Training these models relies on GPUs, initially used for gaming but now essential for AI. This demand has heated the market, with NVIDIA, a sector leader, surpassing Apple's market valuation. The GPU shortage has even created a black market, underscoring the race for this technology.

Data centers, housing thousands of GPUs, consume enormous amounts of energy. The new Colossus data center from Meta in Memphis, expected to house 100,000 GPUs, illustrates this reality. The Colossus's energy consumption is estimated to be three times that of a conventional data center. Giants like Meta, Google, Amazon,

and Microsoft compete for these GPUs, with Microsoft emerging as the largest buyer.

Lauria emphasizes the need for continuous energy sources with a smaller carbon footprint to meet this rising demand. While Brazil's energy matrix is relatively clean, relying on hydropower, wind, and solar energy, these sources are intermittent. The high cost of battery storage, like those used in electric cars, remains a barrier.

In this context, nuclear energy emerges as an alternative, offering continuous production and a smaller environmental impact per area compared to solar and wind energy. New modular reactor (SMR) technologies provide increased safety and efficiency. However, nuclear energy faces challenges such as high initial costs, operational risks, and radioactive waste storage. Nuclear fusion, still under development, is seen as a promise for the future.

Lauria concludes by emphasizing the importance of discussing the energy impact of data centers and seeking sustainable solutions to meet the growing demand in the AI era. Combining different sources, such as nuclear, offshore wind, tidal, and geothermal energy, may be the path to ensuring the future energy needs of data centers.

## INTERVIEW WITH JAN CARLOS SENZ

### Data centers may use nuclear reactors as an energy source

In an exclusive interview with Conexão Nuclear, Jan Carlos Senz, director of LZA Engenharia and a leading data center designer in Brazil and Latin America, highlights Small Modular Reactors (SMRs) as a promising solution to the growing energy demands of the sector.

According to him, the energy density of data centers has increased exponentially with AI, consuming the equivalent energy of an entire city. "A data center today can consume between 600 and 900 megawatts because it operates continuously, 24 hours a day, 365 days a year, or 8,760 hours annually. And the consumption is constant, unlike, for example, an office, which has peak consumption during working hours but decreases at night," he explains.

Senz highlights the stability and reliability of nuclear energy, which, unlike renewable sources like solar and wind, operates continuously regardless of climatic conditions. "SMRs, with their redundancy, increase availability to over 99.99%, making them an ideal solution for data centers," he says.

Senz also suggests importing pre-approved SMRs to expedite regulation in Brazil while developing domestic technology. "We cannot wait for a reactor to be built from scratch in Brazil as a short-term solution," he argues. SMRs would eliminate the need for diesel generators, reducing costs and environmental impacts.

Senz concludes, "Data centers typically do not rely on the grid as a reliable energy source. They install generators equal to their grid capacity as a backup, which requires diesel storage and infrastructure. With SMRs and redundant reactors, availability exceeds 99.99%, making diesel generators unnecessary."

# RADIOISOTOPE PRODUCTION IN ANGRA 2 AND 3: A PROMISING OPPORTUNITY

**CURRENTLY, THE UNITED STATES IS THE LEADING PRODUCER OF RADIOISOTOPES, ESPECIALLY FOR MEDICAL AND INDUSTRIAL APPLICATIONS**

Brazil's nuclear power plants, Angra 2 and the future Angra 3, present a significant opportunity for producing radioisotopes, which are essential in various medical and industrial applications. The Aeroball system, used in Siemens/KWU-designed Pressurized Water Reactors (PWR), offers an innovative method that can be adapted for this purpose.

## WHAT IS THE AEROBALL SYSTEM?

The Aeroball system consists of small spheres, known as balotes, which are moved by compressed air through tubes located along the reactor core. Originally designed to monitor neutron flow and reactor power, this system shows promise for irradiating targets to generate radioisotopes. The system is named "Aeroball" because the balotes are transported by compressed air through tubes in and out of the reactor.

## HOW DOES RADIOISOTOPE PRODUCTION WORK?

By replacing the balotes with targets containing specific materials, reactors can irradiate these targets during normal operation. Exposure to the intense neutron flux enables the production of various radioisotopes, such as molybdenum-99, cobalt-60, and lutetium-177. Strategically positioning the tubes ensures effective irradiation, maximizing production without compromising reactor safety.

After irradiation, the targets can be quickly retrieved using the same pneumatic system, avoiding the need to interrupt reactor operation. These targets are then taken to processing facilities, where the radioisotopes are extracted and prepared for use.

## BENEFITS AND CHALLENGES

This approach allows continuous production of radioisotopes without the need for dedicated cycles, maintaining

operational efficiency. However, the Aeroball system's tube space limits the number of targets that can be irradiated simultaneously. Additionally, the subsequent processing of radioisotopes requires local economic development and strengthens the production chain, demanding additional infrastructure.

## THE ROLE OF THE NUCLIDE ACTIVATION SYSTEM (NAS)

In addition to the Aeroball, the Nuclide Activation System (NAS) from Framatome offers an advanced commercial solution that can also be integrated into PWRs. The NAS does not replace the Brazilian Multipurpose Reactor (RMB) but complements its functions. While the NAS focuses on isotope production in power reactors, the RMB is dedicated to research and large-scale production.

The RMB, designed for producing larger volumes of essential radioisotopes, also facilitates advanced research activities such as material testing and the development of new nuclear technologies. Meanwhile, the NAS could meet urgent demands or diversify production in a shorter timeframe.

Integrating the Aeroball system in Angra 2 and 3 rep-

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**"THIS APPROACH ENABLES CONTINUOUS PRODUCTION OF RADIOISOTOPES WITHOUT THE NEED FOR DEDICATED CYCLES, INCREASING OPERATIONAL EFFICIENCY."**

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## CHALLENGES IN RADIOISOTOPE PRODUCTION IN BRAZIL

1. **Limited Infrastructure:** A lack of adequate facilities and cutting-edge technology hinders the country's ability to meet demand.
2. **Dedicated Reactors:** Efficient production of many radioisotopes requires specialized research reactors, such as the Brazilian Multipurpose Reactor (RMB), which is still under construction. Without an optimized reactor, production is restricted.
3. **Regulation and Safety:** Strict safety and environmental regulations can delay projects and increase costs.
4. **Funding and Investment:** Inconsistent investment in research and development in the nuclear sector impacts modernization efforts for facilities and technologies.
5. **Dependency on Imports:** Brazil still relies on imports to meet demand for certain radioisotopes, posing challenges during global shortages.

resents a valuable strategy to enhance Brazil's radioisotope production capacity. Although the NAS offers an intriguing alternative, combining the Aeroball system with the RMB can ensure robust and efficient supply, meeting the growing needs of the healthcare and nuclear research sectors. This synergy is vital for Brazil's development and autonomy in radioisotope production, securing a promising future for nuclear energy in the country.

Currently, the United States is the leading producer of radioisotopes, particularly for medical and industrial applications. The country has numerous facilities and nuclear reactors dedicated to radioisotope production, such as molybdenum-99, widely used in imaging exams. Other countries, like Russia and Canada, also have significant production capacities, but the U.S. stands out as the global leader in this sector. ■

## MAIN APPLICATIONS OF RADIOISOTOPES

### MEDICINE:

- **Diagnosis:** Used in imaging exams, such as positron emission tomography (PET) and scintigraphy, to detect diseases like cancer and heart conditions.
- **Therapy:** Treats diseases, including hyperthyroidism and certain cancers, with iodine-131.

### INDUSTRY:

- **Measurement and Control:** Used in density and thickness gauges and to monitor material quality.
- **Industrial Radiography:** Inspects welds and structures to detect faults and ensure equipment integrity.

### RESEARCH:

- Used in scientific studies to trace chemical reactions, biological processes, and in the development of new medicines and technologies.

### AGRICULTURE:

- Used in tracing techniques to monitor plant growth and the behavior of pesticides and fertilizers.

### DATING:

- Techniques like carbon-14 dating determine the age of archaeological and geological materials.



# NUCLEAR: A KEY PLAYER IN THE SUSTAINABLE ENERGY TRANSITION TOWARD COP30 AND BEYOND

**THE G20 IN RIO AND COP29 HIGHLIGHTED THE IMPORTANCE OF NUCLEAR ENERGY IN GLOBAL DECARBONIZATION, PAVING THE WAY FOR BRAZIL TO LEAD THE AGENDA AT COP30 IN BELÉM.**

The growing global demand for energy and the urgency to combat climate change call for effective and sustainable solutions. For these and other reasons, experts consider nuclear energy a clean, reliable source capable of driving the global energy transition. The G20, recently held in Rio de Janeiro, and COP29 in Baku, Azerbaijan, reinforced this perception, paving the way for Brazil to assume a leadership role at COP30, to be held in 2025 in Belém do Pará.

## ENERGY TRANSITION: URGENCY AND STRATEGY

According to the International Energy Agency (IEA), global demand for electricity is expected to grow by more than 50% by 2050, while carbon emissions must fall drastically to curb climate change. To achieve these goals, the energy transition requires a combination of renewable sources and other low-carbon solutions, such as nuclear.

Nuclear energy, responsible for approximately 25% of the world's low-carbon electricity, is seen as an essential technology to ensure energy security, grid stability, and a steady supply of clean energy.

Moreover, Brazil's mastery of the complete nuclear fuel cycle positions it as a strategic player on the global energy stage. This expertise not only strengthens national energy security but also integrates Brazil into a promising international market, especially as the demand for uranium grows, driven by the expansion of nuclear energy as a low-carbon source.

With the advancement of projects like Santa Quitéria and the potential for international part-

nerships under an innovative regulatory model, Brazil has the opportunity to transform its uranium reserves into a competitive advantage, ensuring a leading role in the global energy transition and contributing to decarbonizing the world's energy matrix.

## GLOBAL AGENDAS

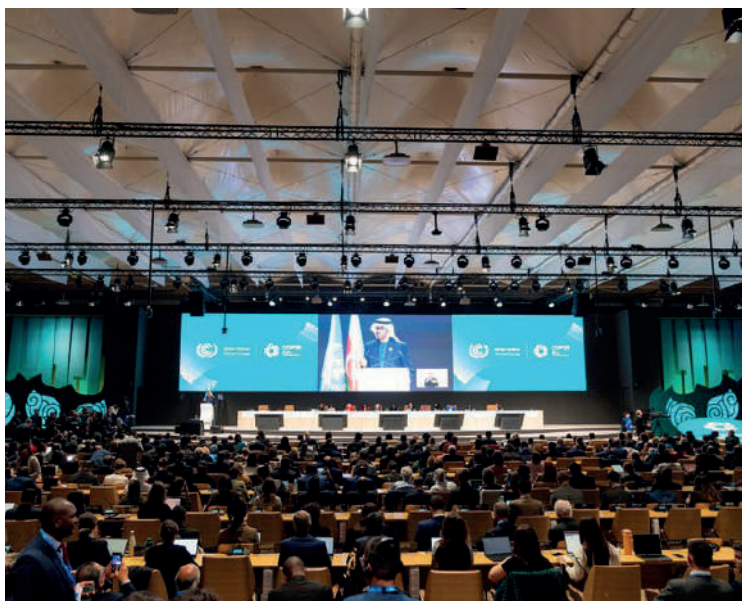
At the G20, member countries made significant commitments to the global energy transition, including a goal to triple installed renewable energy capacity by 2030. However, the group failed to set clear limits on fossil fuel use, highlighting the complexity of aligning the interests of different nations in pursuit of sustainable solutions.

In this context, nuclear energy emerges as a strategic ally, particularly for Brazil, which already has a predominantly renewable energy matrix. Nuclear energy's ability to provide a stable, reliable base, complementing renewable sources like solar and wind, underscores its relevance in discussions on the energy transition and climate policies debated at the G20.

COP29 solidified nuclear energy as a "rising star" in climate and energy transition discussions. A growing number of countries recognize nuclear energy's importance in achieving decarbonization and energy security goals.

At COP28 in the United Arab Emirates, 22 countries committed to tripling global nuclear energy use by mid-century. This year, at COP29 in Baku, Azerbaijan, six more countries joined the commitment, including nations without current nuclear capacity, such as Kenya, Mongolia, and Nigeria. This expanding coalition reflects the acknowledgment of nuclear

## COP29 SOLIDIFIED NUCLEAR ENERGY AS A 'RISING STAR' IN CLIMATE AND ENERGY TRANSITION DISCUSSIONS.



energy's critical role in the global energy transition.

With COP30 taking place in Brazil, the country has the opportunity to lead the nuclear energy agenda and strengthen its position as a key player in the global energy transition. Brazil's expertise in the nuclear sector, with operational plants like Angra 1 and Angra 2 and the development of advanced technologies like SMRs, places the nation in a privileged position to contribute to global decarbonization.

### IN ADDITION TO ITS EFFICIENCY IN CLEAN ENERGY GENERATION, NUCLEAR ENERGY ALSO HAS DIRECT APPLICATIONS IN COMBATING CLIMATE CHANGE AND PROMOTING SUSTAINABLE DEVELOPMENT.

- **Low Carbon:** Nuclear energy is a clean energy source that emits no greenhouse gases during operation, significantly contributing to reducing carbon emissions and combating climate change.
- **Reliability:** Nuclear plants operate continuously, providing stable and reliable energy regardless of climatic factors like sun, wind, or rain.
- **High Energy Density:** Nuclear energy requires a relatively small area to generate large amounts of energy, minimizing environmental impact compared to other energy sources.
- **Safety:** Nuclear plants are designed with stringent safety standards to ensure the protection of populations and the environment.

### NUCLEAR TECHNOLOGY CAN ALSO BE USED IN AREAS SUCH AS:

- **Sustainable Agriculture:** Monitoring soil and efficient water use.
- **Health and Food:** Food irradiation and medical diagnostics.
- **Industry:** Reducing emissions in industrial processes and producing green hydrogen.

With initiatives like the Brazilian Multipurpose Reactor (RMB) project, which will expand the country's research and innovation capacity, Brazil is well-positioned to demonstrate how nuclear energy can be integrated into sustainable development strategies.

### ABDAN'S ROLE IN THE GLOBAL DEBATE

The Brazilian Association for the Development of Nuclear Activities (ABDAN) has positioned itself as a facilitator of dialogue between governments, the private sector, and international organizations. Active participation in global events reinforces the association's mission to promote Brazil's nuclear sector as a global reference in sustainability and innovation.

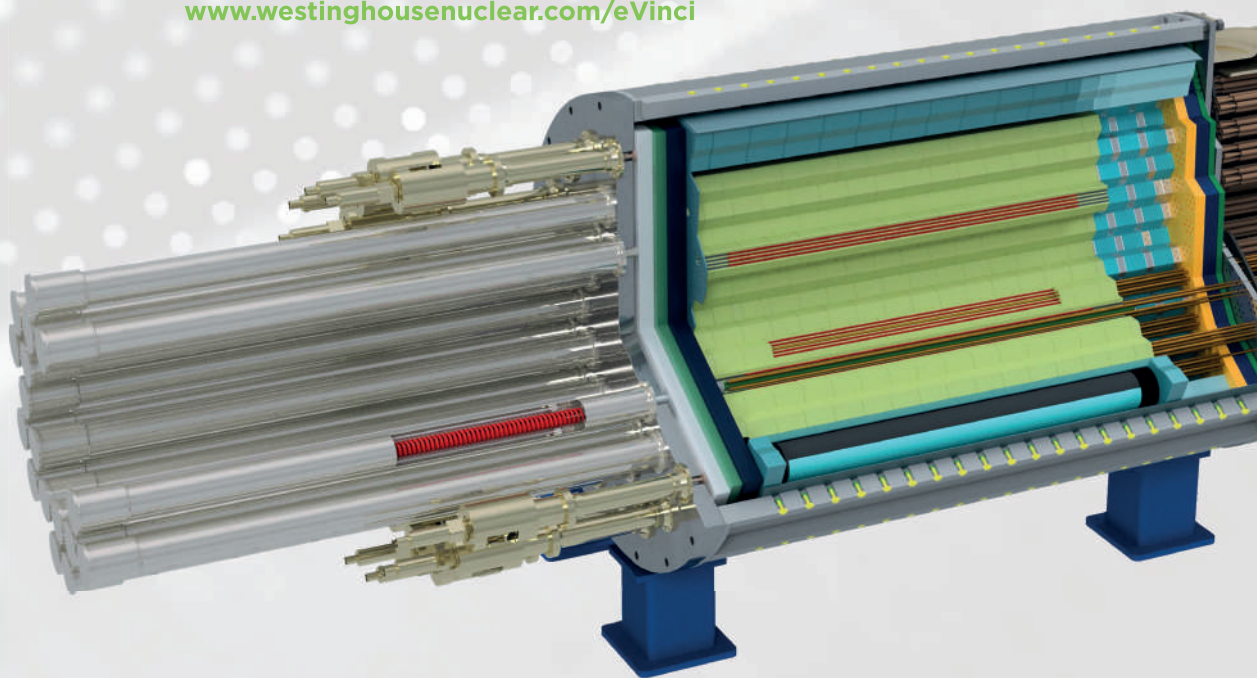
According to Celso Cunha, president of ABDAN, nuclear energy must be seen as one of the pillars of the energy transition: "Brazil has a strategic role in this debate. We have expertise, resources, and an energy matrix that can serve as a model. COP30 will be a historic opportunity for the country to reaffirm its commitment to the planet's future, using nuclear energy as an indispensable ally." ■

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# RUSLAN YUNUSOV: HOW RUSSIA BECAME A LEADER IN QUANTUM COMPUTING

Russia has recently achieved an impressive milestone in quantum technology by launching a 50-qubit computer in 2024—a machine capable of processing information on an exponential scale, leveraging the principles of quantum mechanics to solve complex problems beyond the reach of traditional computers in a reasonable timeframe.

The country is also preparing to unveil two additional models based on different platforms. According to Ruslan Yunusov, advisor to the general directorate of Rosatom and co-founder of the Russian Quantum Center, three competitive advantages were key to this achievement: the strong Soviet-era quantum physics foundation, young specialists trained at top universities, and significant government investment in scientific infrastructure.

“When we started the quantum computing roadmap in 2020, we identified several platforms available globally for building quantum computers: superconductors, atoms, ions, and photons,” Yunusov explains. “We still don’t know which will be the best. That’s why we developed multiple platforms simultaneously. The first computer to exceed the 50-qubit mark was based on ions, but over the years, we’ve been working not only on this technology but on several directions simultaneously.”

This new computer, with an ion-based processor and a processing capacity of 50 qubits, was developed under the organizational management of Rosatom, which, in partnership with the Russian government, has been funding the quantum computing sector with an approximate budget of 24 billion rubles (R\$ 1.45 trillion) from 2020 to 2024.

## WHAT ARE QUBITS?

Qubits (short for quantum bits) are the basic units of information in quantum computing. They function similarly to bits in classical computers but possess much more advanced capabilities based on the principles of quantum mechanics.

## PIONEERING ACHIEVEMENTS

The newly launched equipment is accessible via a cloud platform, enabling the execution of basic quantum algo-

rithms. Russian qudit technology is among the pioneers, alongside developments in Austria and the United States.

Reaching the 50-qubit milestone in just four years—compared to the global average of 15 years—demonstrates the speed of Russia’s advancements.

The Russian Quantum Center’s next steps include achieving 50 qubits on an atomic platform and possibly developing another ion-based computer with the same capacity. Comparisons between platforms reveal varying levels of precision, making each advantageous for specific tasks. This justifies the investment and the priority placed on continuously improving platform quality.

Yunusov believes reaching 50 qubits was a significant psychological milestone that placed Russia among the countries successfully developing quantum computing. “A world-class scientific school, high-caliber graduates, and the created infrastructure allowed us to make rapid progress,” he says.

While universal quantum computers are designed to execute any type of quantum algorithm, their efficiency and effectiveness in solving specific problems depend on two key factors: high precision and a large number of qubits.

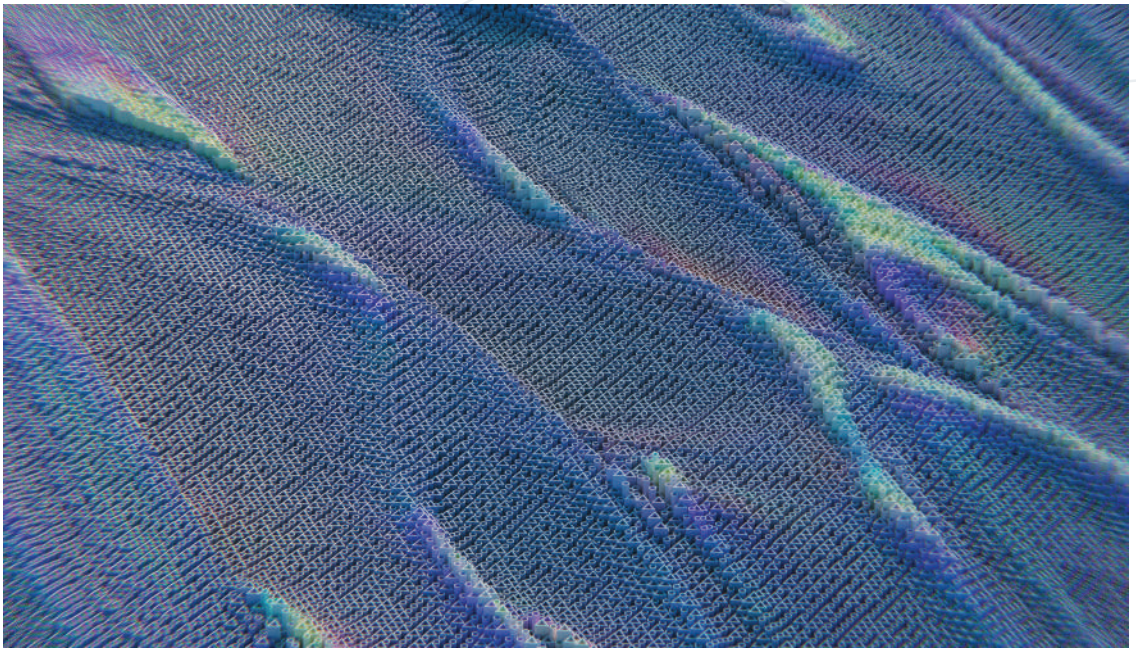
## THE FUTURE

Looking ahead, Yunusov mentions a new development roadmap set to be completed by 2030, which includes increasing qubit capacity and radically improving quality. The center’s goal for 2025 is to reach 75 qubits.

To develop increasingly powerful quantum computers—eventually reaching thousands of qubits—a clustering approach will be necessary. This involves connecting multiple smaller qubit groups (clusters) via quantum interconnections, creating an integrated system that functions as a single machine.

“Solving real industrial problems requires more than just increasing qubit numbers or improving their quality—it’s crucial to optimize algorithms for maximum efficiency,” Yunusov notes. “If even one quantum computer can perform a task better than a supercomputer, that would





already be an extraordinary achievement.” However, he acknowledges the challenges ahead.

“To tackle such problems, it will be necessary to have 300 to 1,000 qubits, depending on the task’s specificity. Additionally, error rates must be below 1%, and operation precision must reach 99.7% to 99.9%. Only with these indicators will significant results be possible.”

## CHALLENGES

Among the challenges, Yunusov highlights the need for research into new materials. “Today, we are said to live in an informational age, but from a materials perspective, it’s known as the silicon age. However, silicon’s possibilities are nearly exhausted, while computational needs continue to grow, and our capacity to meet them is limited,” he explains.

Another bottleneck is energy efficiency. Supercomputers consume tens of megawatts of power, and the increasing demand for computational capacity requires radically new solutions and replacing silicon with alternative materials.

“About 1% of the world’s energy is used for calculations,” Yunusov says. “Even if we used all the energy available today, computational power would increase only 100-fold, but we need much more. There’s an urgent demand for which we currently have no answer.”

He continues, “We can design a perfect quantum chip, but we risk being unable to produce it due to material limitations,” citing biomedicine as an example. “Elon Musk’s Neuralink faces a similar problem. No materials exist that can be implanted in the human body without causing in-

flammation or rejection. That’s why future technologies depend on developing new raw materials.”

This quest has united specialists from various fields in multidisciplinary research. “Quantum calculations, advanced mathematics, traditional chemistry, and biology will all be needed because finding compatible materials is essentially a biological task.”

## CULTIVATED MATERIALS

Yunusov also finds the concept of “cultivating” materials promising. “One solution could involve creating microorganisms capable of producing the necessary material. These organisms would be encoded for this purpose, and the rest would occur naturally. Of course, this is a simplification, but there are no inherent limitations to this idea.”

He uses trees as an example, highlighting their complex structure with specialized regions. “If we added the ability to absorb metals and use them in their structure, we could create something entirely new. In the future, instead of building houses, we might grow them,” he envisions.

Yunusov also emphasizes the importance of regeneration and self-healing—qualities inherent in biological materials. “Everyone would love smartphone screens that heal from scratches. Today, significant efforts are directed at eliminating microcracks, but nature is far ahead in this area.”

“The 19th and 20th centuries were marked by humanity’s attempts to dominate nature, but this perspective proved flawed. It’s now essential to evolve alongside nature, creating in harmony with it,” he concludes. ■





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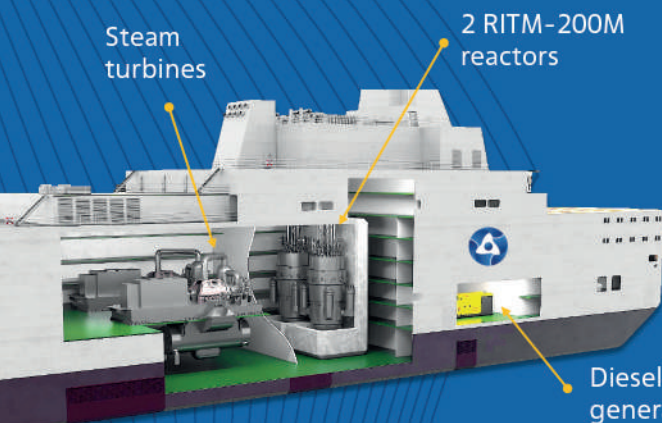


**110 MW**  
total electrical capacity

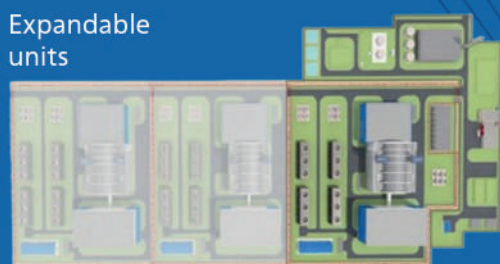
2 reactors of  
**55MWe**  
each

Fuel cycle  
of up to  
**6 years**

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