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New impulse for the BMR

Reactor project receives new funding to produce radioisotopes for industry and for medical use

Summary

Cover: Brazilian Multipurpose reactor - BMR Project Coordination (CNEN)

Publisher
Vera Dantas

Contributor
Bernardo Barata

Artwork
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Rua Candelária, 65 • 14º andar • Centro Rio de Janeiro • RJ • CEP: 20091-906
Tel: (55 21) 2266 0480 • 2588 7000 • Ramal 4721
aben@aben.org.br • www.aben.org.br

Challenges and opportunities

In December 2022, ABEN elected a new board, with a two-year mandate. The board faces a period of both challenges and opportunities.

The opportunities are related to a new era that is emerging, in which nuclear energy and its applications are undergoing a renaissance, with the world now recognising its important role in offering the planet a promising and safe future. Electricity generated from nuclear power is clean and provides a guaranteed source of energy for electricity grids. Alternative energies are experiencing extraordinary development, however, due to their intermittency in generating electricity, they require a guaranteed and permanent baseload to compensate and this can be provided by small nuclear reactors.

New generations of reactors are being developed, seeking not just an optimised form of operation, such as through scale, but which enable them to be built entirely within industrial plants, with direct and quick installation, at the selected sites, leading to lower costs. These are the SMR reactors, with capacities of up to 300 MW.

This new generation of reactors require new types of fuel with higher enrichment levels, such as HALEU.

Equally promising is the fact that Brazil is one of only three countries in the world, along with China and Russia, that has, at the same time, uranium reserves, produces the concentrate, masters the conversion technology producing UF6, as well as isotopic enrichment, manufactures the fuel and builds and operates nuclear power stations. It also manufactures all the heavy equipment used within power stations.

It is an exceptional position to be in and this must be recognised, supported and promoted by society and the authorities, who need to have a much greater level of awareness about it.

The challenges begin, first of all, with ensuring that the construction of Angra 3 continues uninterrupted, thus enabling it to enter operation four decades after construction work began.

As for the new reactors, we are already developing the prototype of an SMR, which is the reactor for the Brazilian Navy's submarine. It is a technology that falls under what the IAEA refers to as PWR+, as it is a technology that is already available, while others are expected to become available within 5, 10, 15 years or more. Russia already uses this type of reactor to generate energy in Siberia and for use on ships and vessels.

HALEU-type fuel is already produced in Brazil, through a partnership between IPEN and the Navy, for research reactors. However, it is critically important that the nuclear fuel cycle be completed on an industrial scale, with the construction of a conversion plant and the acceleration of centrifuge production for the isotope enrichment cascades.

This is an opportunity for Brazil to become not only a country capable of using nuclear energy, but also a major exporter of products and services related to it.

Completing the BMR is another goal that must not be forgotten, given its importance for the production of radiopharmaceuticals and for carrying out research and testing of materials.

Promoting the use of food irradiation and agricultural produce should increase the competitiveness of Brazil's agricultural industry.

For all of this, there is a demand for fully qualified professionals who are currently in short supply due to the ageing of those generations of professionals who were trained in the 1970s and 1980s.

These are challenges that must be faced and can be overcome with determination and persistence.

ABEN, an association that has been in existence for four decades, must work intensively to educate society and the authorities about the advantages of the various uses of nuclear energy. To do this, we must increase our membership, in terms of both individual and corporate members, as our colleagues have grown old and many have left.

We are already seeing the results of the work that has been done, such as the mobilisation of the Joint Parliamentary Front for Nuclear Activities which is providing information and clarifications to society and the authorities. The proposed agreement with France to develop a SMR, the discussions regarding a national SMR, the completion of the nuclear fuel cycle are all proposals that have arisen from this.

With the support of all our members, we can do much more. We're counting on everyone!

John M. Albuquerque Forman
President of ABEN

The Safety Authority must not **be subordinated to the MME**

Photos: Douglas Troufa/Cnen

The appointment of the engineer Francisco Rondinelli to the presidency of the National Nuclear Energy Commission (CNEN, acronym in Portuguese) was very well received by the nuclear sector. Rondinelli's professional career has been marked by his work at CNEN, which he joined in 1984, after having completed a master's degree in Production Engineering, with a focus on nuclear energy, at the Pontifical Catholic University of Rio de Janeiro (PUC-Rio). His multidisciplinary profile is the result of his participation in projects that applied nuclear technology in diverse areas such as energy, the environment and agriculture, among others, as well as in management and strategic planning. He has also taken part in projects with the International Atomic Energy Agency (IAEA). In his interview with Vera Dantas, from Brasil Nuclear, Rondinelli stated that the bill that created the National Nuclear Safety Authority was returned by the Senate and needs to be revised in order to implement structural and budgetary adjustments and also to correct a "conceptual error", which linked it to the Ministry of Mines and Energy (MME). According to him, the Convention on Nuclear Safety establishes that a nuclear regulatory authority cannot be linked to the same government body as nuclear power stations. "The Authority can be subordinate to any ministry, other than the MME," he affirmed.

In your professional career at CNEN, what was the most significant project you took part in?

The project to develop the technology for the nuclear fuel cycle. The project was already underway when I joined CNEN and was carried out in partnership with the Brazilian Navy. I also took part, from the very beginning, in IPEN's production of radiopharmaceuticals.

In your opinion, what are CNEN's main historical milestones?

I find it difficult to name just one milestone, but I would highlight the participation in the development of nuclear fuel technology and the project to implement cyclotrons for the production of radiopharmaceuticals with a short half-life.

With the break-up of CNEN, licensing and inspection activities will be transferred to the National Nuclear Safety Authority (ANSN, acronym in Portuguese), and it is proposed that it be linked to the Ministry of Mines and Energy (MME). The Agency was created at the end of 2021, but it is still not functioning. What is the current situation?

The need to separate the functions of promotion and inspection is a long-standing discussion within the nuclear sector globally. The Convention on Nuclear Safety states that these two activities must be 'functionally independent', but does not say 'institutionally independent'. Brazil met this requirement when it restructured CNEN, creating the Research and Development and Radioprotection and Nuclear Safety directorates, with separate functions. However, I would like to point out one very important detail: the creation of a nuclear regulatory authority is a sovereign act by a country. That's why, in international forums, when asked if we were going to create a separate regulatory authority, we would show that we had a very distinct institutional separation, which does not compromise any of the safety aspects. The discussion stopped there. Recently, this discussion has gained new momentum. In Brazil, there was also some internal debate, which led the government to create a nuclear authority, even though it had no obligation to do so. I see this as a very positive decision. I consider it appropriate, as it can improve the governance of the process and provide society with greater transparency and peace of mind given that the two functions are effectively independent.

However, I do see a problem with the way this process was carried out. Following a determination of the Finance Ministry, the creation of the new regulatory body was to be done at zero cost, which I consider to be an impossible task. In reality, what happened was that CNEN was divided in two with the area responsible for inspection becoming the Authority. This weakened both institutions as their functioning was compromised.

But has this division already occurred in practice?

Fortunately, not yet. At the end of 2022, during the work that was undertaken by the Transition Group of the current government, the need to review the measure was identified, and the bill that established it was returned by the Senate. Therefore, the Authority has been established by law, but has not yet initiated its activities as structural and budgetary adjustments are needed so that the two institutions are strengthened.

In addition, a "conceptual error" committed during the process needs to be corrected, this was the linking of the Regulatory Authority to the MME. The Convention on Safety clearly establishes that a nuclear regulatory authority cannot be linked to the same government body as the nuclear power stations. Therefore, the Authority can be subordinated to any ministry, other than the MME.

The main reason for this decision is that, in the model adopted by Brazil, regulatory agencies are linked to the ministries of their activities and, therefore, a nuclear regulatory agency should be allocated to the ministry that manages nuclear generators. However, there is a big difference between a regulatory agency and a nuclear regulatory authority. Regulatory agencies are tasked with regulating and managing their respective markets, deriving their revenue from them. A nuclear regulatory authority, on the other hand, has no market to regulate and must earn its own income from taxes or public funds. According to the Convention on Nuclear Safety, the regulatory authority cannot get involved with the market under any circumstances. This was the error, which is now being corrected with the re-evaluation that is being carried out.

Is there a trend towards changing the responsibilities and subordination of companies and activities within the nuclear sector in Brazil?

Not as far as I know. A step was taken previously in structuring the nuclear sector, with the transfer of the INB and Nuclep, companies from the Ministry of Science, Technology and Innovation (MCTI, acronym in Portuguese) to the MME. Eletronuclear, on the other hand, was moved from the structure within Eletrobras, which was privatised, and is now under the control of Empresa Brasileira de Participações em Energia Nuclear e Binacional S.A. (ENBPar), along with Itaipu. Perhaps this model will be revised, since these two energy companies operate in quite different areas. I think these issues should be discussed, but I don't see any action in this direction.

What are the main challenges facing CNEN?

In general, science and technology institutions within the public sector have lost a lot of their capacity to act due to staff who have left or retired, and who have not been replaced. These former members of staff need to be replaced. There is also a need to restore budgets to cater for the increase in activities within the country's nuclear sector.

But the biggest challenge for the nuclear sector today is to demonstrate, to society, its importance and its contribution to the development of society and to ensuring a secure energy matrix. When I talk about energy security, I mean guaranteed supply. Another problem to be tackled is the low motivation for professionals to enter the sector. We need to offer young professionals, who are graduating, the opportunity to engage in a sector that provides important results for society.

What are the main projects currently being carried out by CNEN and its technical-scientific centres?

Currently, we have two major projects which have been very rewarding to take part in: the Brazilian Multipurpose Reactor (BMR, acronym in Portuguese) and the Nuclear and Environmental Technology Centre (CENTENA, acronym in Portuguese). The latter aims not only to store low- and medium-level radioactive waste, but also to develop techniques for the storage, treatment and management of waste in general. Another important project is a mobile unit to demonstrate the application of irradiation for treating effluents, which is currently being finalised at IPEN. As well as visiting industrial plants to demonstrate the efficiency of the process, the unit will be able to provide effluent treatment services locally.

Another application, that I consider important, will play a role in mitigating a serious environmental problem, which is the pollution caused in the oceans by microplastics. Our research institutions are developing analysis techniques to identify not only the presence of microplastics, but also their composition and origin. There is an international project, led by the IAEA, to build a network to monitor the presence of microplastics in South America and the Caribbean.

The BMR's timetable has constantly been delayed due to a lack of resources. Is there any prospect of this changing?

The change has already taken place. At the end of last year, with the changes at the MCTI, R$ 172 million were released from the National Fund for Scientific and Technological Development (FNDCT, acronym in Portuguese). We plan to use these funds over the next two years, when all the engineering projects will be completed and we can start the construction phase.

Experts within the sector believe that a project the size of the BMR should have an organisational structure to coordinate and carry out the various planned actions. What do think of this proposal?

I agree that we need to establish an organisational structure dedicated to project management and this will be the embryo of a new CNEN research centre. It is also important, a little further down the line, to recruit and train the technical staff who will work on the project. We have already sought government support for a selection and recruitment process to contract these human resources.

Like the BMR project until just recently, the project for the final waste repository, CENTENA, has made little progress. The lack of resources compromises the project timetable, which is due to start operating in 2029. Does this pose a risk of paralysis for nuclear facilities that generate low- and medium-level radioactive waste?

Over the last two years, the necessary steps have been taken to apply the repository site selection standard, which is very complex. It was a fairly extensive piece of work.

At what stage is the process?

The country's regions that are within reach of the nuclear power stations and CNEN's intermediate storage facilities have already been mapped. Six sites have been identified in São Paulo, Rio and Minas that meet the specifications. This study has been finalised and submitted to the MCTI, and once approved, the next step is to visit the selected sites to confirm, on site, the cartographic data and the data collected from databases. We have complied with the standard and presented it to CNEN to begin the licensing process, but now we need to choose the site.

What is the cost of the project?

It is estimated at R$130 million. So parallel to our work, is the process to secure the resources to make it happen. Construction is scheduled to take four years, which, in a way, is in line with the completion date for Angra 3. The idea is for the project to be completed at the same time as the new power station enters operations in 2029.

The lack of a strategic plan for developing the technology is regarded as one of the weaknesses of the nuclear area. How do you see the prospect of creating projects such as the development of a small reactor (SMR) or new technologies such as the manufacture of fuel rods?

Firstly, it is necessary to carry out nationally a diagnosis of the sector to identify where its capacities and deficiencies lie, in the light of the global context. The internalisation of new technologies must be done through a Brazilian nuclear programme aimed at implementing the strategic projects, which are: Angra 3 and as many more plants as are necessary, CENTENA, the BMR, and the expansion of the centrifuge production plant and the enrichment plant. In terms of technological development, we need to keep up with the state of the art in SMR reactors, new materials, new concepts for fuel elements.

Are SMR reactors already close to becoming a reality?

Around 80 SMR reactor projects are being developed around the world, but today there is still no facility ready to supply energy. One of the most advanced projects is Argentina's Carem1, which is already at its first experimental prototype stage. We are in a privileged position because Argentina is our partner in the BMR.

Is there already movement towards a partnership in SMR projects?

We are going to seek a partnership with Argentina in the SMR area, as our abilities complement each other. Starting with the co-operation to construct the BMR, we can expand to include projects in the areas of fuel elements, complementing the production chain and SMRs.

Could the research areas of doctoral programmes be geared towards final projects like these?

Once the country has a medium and long-term nuclear programme, we will be able to create a programme to meet the demand for professionals within the sector's production chain, both in the public and private sectors. But there are already postgraduate courses in the various fields of nuclear applications, as is the case with the CENTENA project which collaborates extensively with the Federal University of Minas Gerais (UFMG, acronym in Portuguese) to develop

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academic work. There is a group of postgraduate students developing master's and doctoral theses in the areas of materials, processes and methods of analysis that will enable the development of a process for treating, securing and insulating material. This is what I call an innovation chain.

Is there any planning in relation to replacing the ageing workforce of the nuclear institutions?

We are drawing up a plan that includes economic, managerial and administrative aspects. One thing is certain: we won't be carrying out a huge recruitment drive in the public sector. The 1,800 existing vacancies will be filled progressively but we are also assessing future retirements, which will increase the need for staff. This is what we are putting on the agenda to discuss with the MCTI.

What is the importance of the International Nuclear Atlantic Conference (INAC), the largest and most important event in the nuclear sector in the Southern Hemisphere, in promoting academic research, especially that linked to CNEN?

I have had the opportunity to take part in all of the editions of the INAC and I consider it to be fundamentally important because it offers a week-long experience with several simultaneous events: the National Conference of Nuclear Applications (ENAN, acronym in Portuguese), the National Conference of Reactor Physics (ENFIR, acronym in Portuguese), the National Conference of the Nuclear Industry (ENIN, acronym in Portuguese), the ExpoINAC and the Junior Poster exhibition. This facilitates the interaction of professionals from diverse segments of the nuclear sector, academics, and students. One of the characteristics of the INAC is that it attracts young professionals or potential professionals from the sector. More than once, I've heard foreign professionals say that it's the event within the nuclear sector where we see the greatest number of young people taking part.

In your view, how can ABEN, which celebrated its 40th anniversary in 2022, continue to contribute to the development of the Brazilian nuclear sector?

ABEN is an organisation that brings together professionals from the sector and also has participation from some of the sector's public institutions. I think the organisation needs to do more work to reach out to new professionals. CNEN has always supported ABEN, which must continue in its purpose of supporting the communication process of the institutions and clarifying the issues raised by society, as well as putting forward suggestions for our nuclear programme. It brings together a great number of professionals and is well respected within the sector. As a non-commercial organisation, it is sufficiently neutral to do this.

What is your outlook for the future of the Brazilian nuclear sector? What recommendations can you provide?

Brazil has great potential in the nuclear area because it has mastered the technology of the fuel cycle. This is extremely important. Secondly, it has a history of developing applications in the nuclear sector. And despite all the difficulties, it maintains training programmes in the area. I see a positive outlook for the medium and the long term. And my recommendation is for the government to look at the Brazilian nuclear sector to identify its contributions to society, and create a Brazilian nuclear programme, with objectives and targets.

Would you like to make any further comments?

Brazil needs to continue to make progress in expanding its nuclear programme for generating electricity. The country needs energy security and, to achieve this, it needs to have a balanced matrix, with renewable and dispatchable sources. As renewable sources have a degree of instability, we need to add a dispatchable component to the energy matrix. It is this component that will ensure that, when renewables fluctuate, the country has a source that continues to deliver energy. The dispatchable sources are thermal, natural gas, biomass and nuclear. Today, the Brazilian nuclear sector would be able to deliver, to the grid, the equivalent of Itaipu in terms of electricity generated. Let's remember the old maxim that "the most expensive energy is the energy you don't have". We're not talking about building nuclear power plants all over the country, but about exploiting the potential we have today, which will minimise costs and optimise electricity generation.

The light at the end of the tunnel for the BMR

Project receives new funding from the FNDCT

Vera Dantas

On the 3rd of September 2008, the inaugural meeting of the Brazilian Multipurpose Reactor (BMR) project was held, a venture designed to produce radioisotopes for applications in health, industry, agriculture and the environment, among others. The project also aims to test and classify materials and fuels for power reactors and for scientific and technological research on the use of neutron beams in materials. The event was attended by the president of the National Nuclear Energy Commission (CNEN), Odair Dias Gonçalves, directors and researchers from the commission and representatives from the Navy's Technology Centre in São Paulo (CTMSP, acronym in Portuguese). The reactor was scheduled to start operating in 2013. However, 10 years later, the project has advanced conceptually, but no construction work has started.

The inconsistency in the release of government funding has led to successive project delays. In 2022, the situation became critical due to the restrictions on the National Fund for Scientific and Technological Development (FNDCT, acronym in Portuguese), which meant that there would be no funding. The outlook for 2023 was not promising either. Contributing further to the climate of uncertainty was an initiative of the Ministry of Science, Technology and Innovation (MCTI), which consisted of carrying out a study with the aim of "revisiting" the BMR; this suggested, to those participating in the project, that it would be closed down. "Since the end of 2021, the ministry has been collecting information, but we had the impression that the real aim behind this move was to stop the project from going ahead," stated the BMR's current technical coordinator, Patrícia Pagetti.

In protest at the government's lack of political will to ensure the necessary financial resources, the technical coordinator and creator of the BMR, José Augusto Perrotta, retired from the National Nuclear Energy Commission (CNEN) and left the project in June 2022.

BMR opening meeting

At its 74th annual meeting in July, the Brazilian Society for the Advancement of Science (SBPC, acronym in Portuguese) unanimously approved a motion to support the BMR, aimed at the presidential candidates, members of congress and the presidents of scientific associations and societies. The initiative received the support of the Brazilian Society of Nuclear Biosciences, the Brazilian Society of Physics, the Brazilian Association of Collective Health and the Brazilian Society of Pharmacology and Experimental Therapeutics.

However, in the latter months of 2022, the Minister Paulo Alvim, who replaced Marcos Pontes, following his departure from the MCTI to run for the Senate, had been showing interest in the BMR and held a series of meetings with officials from CNEN, researchers and representatives from the field of nuclear medicine and the scientific community, to obtain further details about the project. In December, the MCTI authorised the release of R$ 172 million of funding from the FNDCT, through a new agreement between CNEN and the Research and Projects Funding Agency (FINEP, acronym in Portuguese), with December 2025 as the deadline for completion.

The change in the outlook was reinforced by the new government. During President Luis Inácio Lula da Silva's official visit to Buenos Aires, in January, the Minister, Luciana Santos, announced the MCTI's intention of moving forward with the construction of the BMR and resuming the partnership with Argentina in relation to the project. The Joint Presidential Statement issued, following the meeting, reaffirmed the strategic alliance between the two countries in the area of nuclear technology, emphasising the importance of the bilateral partnership in the construction of the BMR and the Argentinian Multipurpose Reactor (RA-10).

Currently, the new timetable envisages the completion of the main construction works and the reactor's commissioning in 2028, i.e. 20 years after the start of the project. The total estimated cost of the BMR is US$ 500 million (approximately R$ 2.5 billion), spread over five years, that is, annual contributions of US$ 100 million to complete the project. "This is a very small fraction of the resources available to the FNDCT which are around US$ 2 billion a year," observes José Augusto Perrotta - although retired, he continues to work on the BMR in a voluntary capacity.

However, since its launch in 2008, the BMR has received R$ 452 million, including the current funding agreement of R$ 172 million. "In 14 and a half years, the funding made available does not amount to 15% of the total estimated cost of the project. It's a very low figure," says Patricia Pagetti. "We need to define whether or not the BMR is a priority project for the country," says Sílvia Velasques, former president of the Brazilian Society of Nuclear Biosciences and SBPC representative on the nuclear medicine working group, set up by the GSI to draw up the Brazilian Nuclear Programme. She points to the incoherence between the discussions on the strategic nature of the BMR and the lack of resources for the project. "Having secured less than 15% of the project funding, in 15 years, shows that the project was never considered a priority by the government."

Planning

With the funding that has already been received it has been possible to finalise the detailed engineering project for the building that will house the nuclear reactor and the basic engineering project for all of the project's installations. So far, 17,000 technical engineering documents have been produced. Some of the funding, from the new agreement with the FINEP, will be used to contract the detailed design of the radioisotope processing unit, which will be built next to the reactor building. This is a highly complex project: the first-of-its-kind in Brazil. "Brazil has four research reactors, but no plant for the production of radioisotopes such as molybdenum-99, which is the main input in the production of the majority of the radiopharmaceuticals used in nuclear medicine," says Patrícia Pagetti.

The BMR coordinator also plans to start, in mid-2024, some of the building work at the 2 million square metre site, in Iperó, São Paulo, donated by the Navy and the São Paulo State Government. One of the projects is the construction of a bridge over the Ribeirão do Ferro river, which is necessary to open up access to the site where the reactor building will be constructed. The first earthworks are also planned, as well as the start of the construction of the main roads. However, funding has not yet been allocated to begin construction of the reactor building and the radioisotope processing unit. One possibility she has raised is to negotiate other agreements that will allow these works to be carried out in parallel. "We have resources guaranteed for the next two years, but as for the long term, we are always working with a lot of uncertainty," she says.

It is also planned to procure a company, specialising in the implementation of nuclear projects, that will provide advice for producing a strategic plan for the construction of the BMR.

CNEN's president, Francisco Rondinelli, estimates that the BMR will take another seven years to complete: two years will be spent finalising the detailed engineering design and some civil engineering works, and another five years on the construction.

Human resources

For Patrícia Pagetti, it is necessary to create a structure "commensurate with the complexity and magnitude of this project". Currently, only Pagetti, along with five technologists and Perrotta (as a consultant) are fully dedicated to the BMR. But they count on the collaboration of 75 researchers and technologists from the institutes linked to CNEN, who offer a portion of their time to work on the revision of documents, the drawing up of technical specifications and discussing the entire technical element of the BMR's design.

The project's organisational chart indicates that around 300 people will be needed for the various phases of the BMR's implementation. Some of them will have to be trained when work on the reactor begins. "It's important that the people who will operate the reactor also accompany its construction," explains Pagetti.

Research centre

"The BMR project is not just about a reactor. It is a research and development establishment that nurtures other technologies," says Francisco Rondinelli. One of the fruits of the BMR is the development of fuel technology for research reactors, carried out in partnership with CNEN, Indústrias Nucleares do Brasil (INB) and the CTMSP. Without giving away any names, he said that CNEN has already been consulted by some countries interested in the supply of fuel for their research reactors.

The BMR project financed the infrastructure of the CTMSP's Isotopic Enrichment Laboratory to enrich uranium to 20%, which will then be supplied to the BMR. It also structured the Nuclear Fuel Centre of the Nuclear and Energy Research Institute (IPEN, acronym in Portuguese) to produce the fuel elements and uranium targets for the operation of the BMR. Nineteen fuel elements, identical to those of the BMR, were produced and loaded into the core of the IPEN/

José Augusto Perrotta

Patrícia Pagetti

MB-01 reactor. This new core of the IPEN/MB-01 has been licensed and is in operation, simulating the core of the BMR reactor. This autonomous, fuel supply project, for research reactors, developed 100% domestically, is rare in the world. Perrotta often praises this fact when he says that "the neutrons in our research reactors speak Portuguese".

The project will have laboratories for processing radioisotopes, post-irradiation analysis, radiochemistry and neutron activation analysis. There are also plans to create a National Neutron Beam Laboratory to complement the activities carried out by the National Synchrotron Light Laboratory (LNLS, acronym in Portuguese) in Campinas. In the future, it may also include a high-powered laser laboratory and another dedicated to the study of nuclear fusion technology, as well as high-energy particle accelerators for the production of radioisotopes and research.

The laboratory for processing radioisotopes for use in healthcare will help to reduce the country's vulnerability in this area, which is starkly clear for all to see. Currently, Brazil imports the radioisotopes used in the production of radiopharmaceuticals, most of which are supplied by Russia. Due to the enormous distance between the two countries and the radioactive decay of the material, the operation is logistically complex, made even more difficult due to the conflict between Russia and Ukraine.

One example of the country's vulnerability is its external dependence on the molybdenum-99 radioisotope for the production of molybdenum-technetium generators, which supply the radiopharmaceutical used in most of the scintigraphy tests carried out in Brazil. Most of the generators are supplied by IPEN. Molybdenum-99 is imported weekly from countries such as Argentina, Israel, South Africa and Russia. "Any irregularity in its supply has an impact on the production of molybdenum-technetium generators, which are distributed throughout the country," states Rafael Willain Lopes, a consultant in nuclear medicine, with a special emphasis on cardiology, and president of the Brazilian Society of Nuclear Medicine (SBMN). In his opinion, the BMR project will bring about a series of changes in this context by guaranteeing the country's autonomy in the production of various isotopes, especially molybdenum-99. "The technetium generators will be produced with raw materials from Brazil, priced in Brazilian reals, which will facilitate their distribution and, above all, allow us to expand access and reduce the costs of nuclear medicine for the population," he explains. He believes that the BMR will be a hub for generating know-how that will make it possible to produce new isotopes and it will have the capacity to supply, not only Brazil, but also, other countries, in Latin America and beyond.

Every year, around two million medical procedures, in the area of nuclear medicine, are carried out in the country, both within the private healthcare sector as well as by the National Health Service (SUS, acronym in Portuguese). Myocardial scintigraphy scans account for half of all procedures. Radiopharmaceuticals are

Simultaneous operations

A multipurpose research reactor has the capacity to carry out several operations at the same time. So, the BMR can simultaneously irradiate targets for the production of radioisotopes, fuel elements, materials for the structure of the reactor core and materials for analysis by neutron activation. In addition, the high-intensity neutron beam generated by the reactor core can be used to analyse and research the structures of new materials. "It complements, for example, the country's capacity for research into new materials. The Sirius Project, which is very important, does research into new materials, but it doesn't have a neutron beam," says Francisco Rondinelli.

Patrícia Pagetti guarantees that carrying out several operations simultaneously does not involve any safety risk. "The multipurpose reactor is designed for this: it can be irradiating silicon or uranium targets, as well as carrying out fuel tests or using neutron beams for scientific research. And each of these activities follows the safety standards stipulated by the regulatory body," she explains.

also used in PET-CT diagnosis and traditional scintigraphy, as well as for the treatment of diseases such as thyroid cancer, with iodine-131, and neuroendocrine tumours, with lutetium-177, which, more recently, has also been used for patients with advanced prostate cancer. This number, however, should be double, according to the president of the SBMN. "In other Latin American countries such as Argentina and Chile, the possibility of a patient receiving a nuclear medicine examination, or treatment, is twice as high as the availability in Brazil," he states. "The difference is even greater if we compare the number of procedures carried out within the private sector compared to the public healthcare system," he emphasises. Around 94 per cent of nuclear medicine services are private - although the vast majority of clinics provide services to the SUS - and only 6 per cent are public. He estimates that, even with constant growth, it would take 30 years for the number of procedures in the public health service to reach those carried out in the private sector. "The BMR will be able to help to reduce this asymmetry in a shorter period of time, bringing the prospect of significant gains for the population, through access to these technologies and health benefits in general, as well as becoming a centre for teaching, research and scientific development for our country," he claims.

The three pillars of a major project

Although he has retired, the creator and former technical coordinator of the BMR, José Augusto Perrotta, continues to work on the project. "I took retirement as a protest, but I would never abandon the project and the ideals that Brazil needs in the nuclear area. I've always kept working," he says.

According to him, the implementation of a major project like the BMR must be based on three pillars: the first is sustainability and financial resources; the second, is what he calls HR, that is human resources. "You can't do anything without human resources. In recent years, Brazil has suffered, and not just in the nuclear area, a complete brain drain within the working groups. IPEN, which once had 1600 employees, now has just 500, of which half, or more, could retire," he decries. The third pillar is management. "There's no point in having money and human resources if there's no proper organisation to build, operate and maintain a system the size of the BMR," he states.

One of the difficulties, Perrotta points out, is that the activities within the nuclear area are conditional on the release of funding from the Treasury. He cites IPEN as an example, which supplies radioisotopes to more than 400 clinics but receives no payment, since the funds generated by the activity go into the government's single pot. "The institution has no control over the whole process, as its budget is often restricted. There's no money to increase production or carry out investments."

According to Perrotta, the BMR project proposes a change in this situation, with the creation of an institution subordinate to the CNEN to independently manage the enterprise. "The law that created CNEN allows for the creation of a public company that is not dependent on the government, which is able to independently manage the resources generated and has flexibility in hiring human resources," he explains.

The BMR's feasibility study shows that, the financial resources generated from the production of radioisotopes (just one of the multipurpose functions), could cover the cost of the operation and, what's more, generate additional resources for investment and hence, continuous growth. "As well as brilliantly serving society through its products, the investment will mobilise technological development. It will be a virtuous, winning circle," says Perrotta.

Partnership Brazil-Argentina

The BMR's nuclear systems were designed by Invap, an Argentinian company whose portfolio includes projects for the Open-Pool Australian light water research reactor (OPAL), inaugurated in 2007, and the RA10 Argentinian reactor, the BMR's "twin", which will be ready next year. Invap's participation stems from an agreement between CNEN and its Argentinian counterpart, the National Atomic Energy Commission (CNEA), within the framework of the Binational Nuclear Energy Commission.

Amazônia Azul Tecnologia de Defesa (Amazul), a Brazilian engineering company, also took part in the project, through a previous funding agreement with FINEP, where it carried out the critical analysis and developed conventional systems projects.

The BMR team is interested in resuming its partnership with Argentina through a new co-operation agreement focussed on the detailing phase of the radioisotope plant. "We're going to take advantage of the knowledge that both sides have. For example, Brazil has mastered several phases of the fuel cycle and is able to produce the low-enriched fuel that will be used in these reactors. Brazil can manufacture uranium targets to produce molybdenum. And Argentina has the technology to dissolve the targets to produce molybdenum," explains Patrícia Pagetti.

Nuclear and renewables: Partners in decarbonisation

Leonam dos Santos Guimarães*

Comparing the costs of different technologies for generating electricity has become one of the main arguments used by advocates of specific sources of energy as well as by those seeking to find the best approach for planning the expansion of electricity grids. However, this approach, taken in isolation, for formulating public energy policies, is far from simple and can lead to undesired and unexpected results.

How much does it cost? It seems like a simple question. However, when it comes to competing technologies for generating electricity, it is an extremely challenging question. Generation costs include many variables: capital, fuel, location, waste disposal, environmental impact, interconnection, reliability, intermittency and other external and systemic costs. No two technologies are the same.

System costs are generally divided into four broad categories, defined as follows: profile costs (also called operational or backup costs), balancing costs, grid costs and connection costs [1].

- Profile costs refer to the increase in the generation cost of the electricity grid as a whole in response to the variation in the production of Variable Renewable Energy (VRE).
- Balancing costs refer to the increasing requirements to guarantee the stability of the grid due to uncertainty in power generation (unforeseen interruptions at power stations or forecast generation errors).
- Grid costs reflect the increase in transmission and distribution costs due to the distributed nature and isolated location of VRE generation plants.
- Connection costs consist of the cost of connecting a power station to the nearest connection point on the grid.

External costs are based on the sum of three components: costs due to losses caused by climate change associated with greenhouse gas emissions (CO2 and others); cost of damages (such as impacts on health, agriculture, etc.) associated with other air pollutants (NOx, SO2, NMVOCs, PM10, NH3) and other non-environmental social costs for non-fossil electricity generating technologies. Environmental and social externalities are highly site-specific and therefore the results vary widely, even within a given country, according to geographical location.

For decades, analysts have proposed an approach that tries to integrate some of the main cost variables of generation technologies. It is called the Levelised Cost of Electricity (LCOE), taking into account the internal costs, including Capex and Opex, up to when a new power station is connected to the grid [2]. Analysing the LCOE [3] provides evidence for three main points:

- Despite the recent high-cost projects in Western countries, most new nuclear stations have a levelised cost of electricity (LCOE) comparable to any other generation source, including most VRE.
- The LCOE for VRE does not take into account the grid costs that consumers are obliged to pay, such as expansion of the grid to accommodate generation that is distant from centres of consumption, low balancing of predictability of VRE and control of frequency and backup and/or storage of electricity to compensate for this variability.
- The LCOE analysis does not include environmental and social externalities, such as waste disposal, air pollution and the greenhouse effect, material resources and land use; by excluding marginal externalities, the LCOE contradicts the main point for considering clean energy technologies, which is the impact of these very externalities.

Using LCOE to compare generation costs has become widespread practice. However, this approach, associated with different generation technologies or any other measure of total life-cycle production costs per MWh supplied, does not take into account the different costs of the system, effectively treating every MWh generated, regardless of source, as a homogeneous product, that is a commodity, governed by a single price.

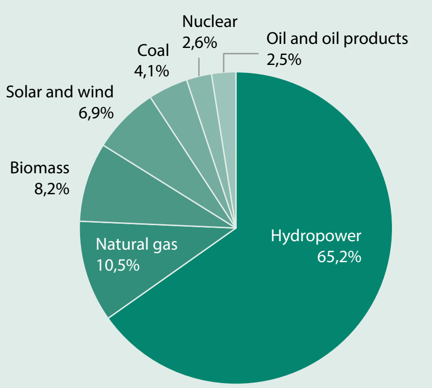
The criticism is technical and the fundamental objection is that cost does not measure value. Electricity generation takes place at different times and in different places, with different values at each time and at each place. It would be like saying that a car costs much more than a bicycle, so we should all buy bicycles. However, this disregards the fact that a car and a bicycle are each providing services of a different nature.

Analysing the NEA study on the costs of decarbonisation [1], COSTES [4] gives us some powerful insights

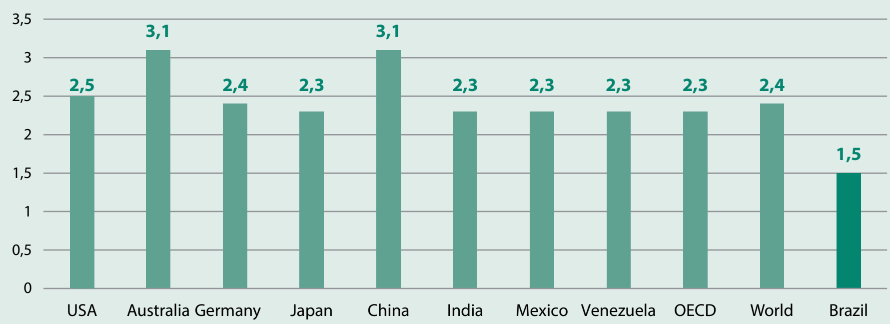
- Setting a price for carbon as an external cost seems obvious: US$ 35 per tonne of CO_2 emitted is considered sufficient to eradicate it from all scenarios. That's not so far off the US$ 20 already considered by some countries. The sooner this is achieved, the better, because everyone agrees that there is an urgent need to decarbonise the energy system.
- Ideally, policies should be developed to ensure that grid costs are well analysed and allocated to the source that generates them. The concept of "Equivalent Firm Energy" [5] has been proposed, according to which any VRE source must guarantee its production with some storage for which it would be responsible. In any grid, this would be very difficult to implement.
- The adaption of most existing electricity markets is questionable. The order of merit may have been justified in the past, when all sources had comparable LCOE and were fully exposed to the market. Today, electricity markets produce situations where prices are zero and there are no further economic signs consistent with an increasing share of VRE.
- In a market where any form of electricity generation is treated on its own merits, without subsidies or priority rights, there will be a need for new regulations that are clear. With a high share of VRE, existing markets will be very volatile and will present high risks for any long-term investment and financing. How can policies be designed to attract investment in this situation?
- There is clear evidence that, apart from hydropower with large reservoirs, nuclear is the only dispatchable, low-carbon technology and it is essential, together with VRE, to achieving a decarbonised electricity system. The cost-benefit ratio for the consumer leads to a balanced grid, in which the value of nuclear energy and of the VRE itself is not destroyed by the excessive participation of the latter. Instead of developing public policies that set targets for VRE participation, which will require capacity, flexibility and grid infrastructure, would it not be preferable to set carbon generation targets first and then identify which electricity system would provide the best cost-benefit ratio?

Considering the facts about the types of technology; their costs, including external and grid costs; public acceptance and assessing the potential for higher electricity prices, policymakers could create the market conditions and rules to find a suitable way forward.

Brazil's Electricity Matrix 2017 (BEN, 2018)



Energy sector carbon emissions* | Some countries and regions (tCO_2/toe)



Source: International Energy Agency (*)Assessed on the basis of domestic energy supply

A cost-effective low-carbon system

- **considerable portion of VRE;**
- **considerable portion of dispatchable zero-carbon technologies, such as nuclear power and hydropower with large reservoirs;**
- **additional amount of gas capacity for further flexibility, along with storage;**
- **management of the demand side and interconnections;**

The Brazilian system seems to be heading in this direction, already possessing some of these attributes.

Considering the facts about the types of technology; their costs, including external and grid costs; public acceptance and assessing the potential for higher electricity prices, policymakers could create the market conditions and rules to find a suitable way forward.

However, there are other important aspects for decision-makers to take into account:

- to accommodate a high share of VRE, the grid must develop not only transmission and distribution networks, but also incorporate new technologies that do not yet exist in order to accommodate the fluctuations that VRE generation entails; these costs can be taken into account, but what about the risks associated with these future technologies? And what about the reliability of this grid and its resilience?
- the use of material resources to generate electricity is a question that has not been sufficiently analysed; it is a question of energy and power density [6]; in essence, VRE has, in most areas, a limited load factor: to achieve the same generation in GWh, VRE needs to have about three times more capacity than any dispatchable source and would require a lot of storage capacity with a limited load factor; low energy density VRE implies more building materials (for example, cement, concrete, steel) and greater land use for a given amount of energy generated in the life cycle. Which policy would provide the most efficient way of using the planet's resources?

A cost-effective, low-carbon grid would probably consist of a significant share of VRE, at least, an equally significant share of dispatchable, zero-carbon technologies such as nuclear power and hydropower with large reservoirs. A complementary amount of gas-fired capacity would provide additional flexibility, along with storage, demand-side management and expansion of interconnections. Brazil's grid seems to be heading in this direction, and already has some of these characteristics.

Nuclear energy will play a fundamental role in the diversification strategies of the energy transitions so that countries achieve the decarbonisation of their electrical grids

Nuclear energy will play a fundamental role in the diversification strategies of the energy transitions so that countries achieve the decarbonisation of their electrical grids, bringing benefits and continuing to be an economically viable option. It produces huge amounts of dispatchable, low-carbon electricity but in many countries there continue to be doubts over its acceptability to the general public. The costs of generating VRE have fallen dramatically, but the overall costs of VRE to the grid are not fully accounted for because production is aggregated over a limited number of hours.

Electricity markets are evolving and nuclear energy is following suit, as for example, in the case of small modular reactors (SMRs), with many promising projects.

Nuclear power is a reliable partner for VRE in a collaborative model. Technical complementarity can be achieved by developing greater flexibility in the operation of the reactor, in order to minimise VRE's variable energy output. Systemic complementarity could be achieved through innovative technologies. Strategic complementarity in order to create a decarbonised energy mix should not be forgotten.

*ENBPar adviser and ABDAN technical director

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Nuclear sites and the expansion of nuclear energy in Brazil

Carlos Henrique da Costa Mariz*

In 2009 and 2010, Eletronuclear coordinated the selection of nuclear sites in Brazil, at a time when the National Energy Plan (PNE 2030, acronym in Portuguese) signalled the need to build new nuclear power plants in the country. Initially, two power plants in the Northeast Region, followed by two in the Southeast Region, were due to come on stream in the first half of the 2020s.

Coppe/UFRJ and international consultant Paul Rizzo were involved in this selection process, along with the Energy Research Company (EPE, acronym in Portuguese) a state-owned company under the Ministry of Mines and Energy (MME). The study culminated, initially, in choosing areas in the Northeast and Southeast and, subsequently, in 40 candidate areas, spread throughout the country, for the construction of nuclear power plants.

The process was underpinned by the US-based, Electric Power Research Institute's (EPRI) concepts and criteria, that were specifically developed for the selection of nuclear sites, in accordance with a proven, successful, methodology and which appear in the EPRI Site Guide.

At that time, two sites stood out: the Itacuruba site in the state of Pernambuco, which Paul Rizzo considered to be an excellent nuclear site; and the site located in the municipality of São Romão, in the state of Minas Gerais.

During the same period, Paul Rizzo also carried out studies related to the nuclear site in the United Arab Emirates, where the Barakah nuclear power plants stands today, with four APR-1400 nuclear reactors totalling 5,600 MW, the construction of which was the responsibility of a consortium led by the Korea Electric Power Corp (KEPCO) from South Korea. Construction was carried out sequentially, i.e. one reactor plant followed by another, without interruption, and is a notable success story within the nuclear sector, as it was completed on time and within budget. This was a pioneering experience by the United Arab Emirates, the success of which was partly due to this sequential construction method, following the example of France, which adopted it and continues to use it, having built 58 nuclear power plants: of which 40 were built in 10 years. Also the new Chinese programme plans to build 150 new nuclear power plants within 15 years.

What has Brazil lacked, or is lacking, that prevents it from making progress in developing its nuclear programme? Why are we so slow? The programme to construct renewables and the transmission lines are insufficient, and Brazil is heading towards high electricity prices and energy insecurity just when it needs to grow in order to develop. We have a very low per capita consumption of electricity at 2,500 kWh per inhabitant per year. We urgently need big investments in the generation of large blocks of electricity to get out of this appalling situation, which places us in an abysmal position in world rankings: seventy-fifth in the HDI - Human Development Index.

Electricity generated by nuclear energy offers a high-capacity factor that is independent of the climate and does not pollute the atmosphere. It is an essential alternative for our country's development, both in terms of guaranteeing energy security and from an industrial, technological, educational and regional socio-economic growth point of view. In addition, we have large uranium deposits and we master the entire nuclear fuel production cycle.

We need to quickly adopt new paradigms based on the successful experience of countries that have proven that standardising and building in sequence, following a construction programme at predefined sites, is the proven basis for success in the construction of new nuclear power plants.

The recent National Energy Plan 2050 (PNE 2050) signals the expansion of a further 10,000 MW in new nuclear power stations over the next 27 years. Achieving this goal means putting into practice this new paradigm by building 10 new nuclear power stations, each with a capacity of 1,000 MW, during this period. Time is short. Therefore, it is urgent to get approval for the new nuclear sites, which have already been studied, and start the construction process, adopting the new ways of building plants at low cost and within the pre-established deadlines.

Nuclear energy will be a great vector for getting Brazil back on the path to growth: something we all want. We need to take part in the new cycle of global expansion. We also need a major campaign to inform the population of the huge safety measures, offered by modern technology and which are employed in nuclear power stations, as well as, all of its benefits. It must be made clear to the population, using effective means of communication, that nuclear power plants are safe and offer enormous benefits, including the contribution they make to combating global warming and reducing air pollution.

Brazil, with more than 203 million inhabitants, is in the grim position of being ranked ninetieth in the world in terms of GDP per capita, which makes it even more urgent for the country's decision-makers to take the decisions to actually bring about Brazil's new and necessary nuclear programme.

*President of the Brazilian Nuclear Energy Association (ABEN) for the 2021-2022 biennium.

CENTENA – A centre of security and sustainability for Brazil

Clédola Cássia Oliveira de Tello*

In the current scenario, sustainability is an essential component of industrial development. The nuclear sector has a firm commitment to the principles of sustainability and the Sustainable Development Goals (SDGs), collaborating to achieve the targets set for 2030.

Brazil's energy matrix embraces measures against climate change through two nuclear power plants that are in operation, Angra 1 and Angra 2, and one under construction, Angra 3, which collectively make up the Almirante Álvaro Alberto Nuclear Power Plant in the municipality of Angra dos Reis, in the state of Rio de Janeiro. To contribute towards the other SDGs, Brazil has more than 2,500 facilities working across various areas such as medicine, industry, the environment, agriculture, etc.

In these activities, as in so many others, waste may be generated. The difference between other sectors and nuclear power is that, in the latter, waste is managed right from its source, with initiatives to prevent and minimise its generation, protect workers, the public and the environment.

Currently, waste is stored in initial deposits, located at the plants where it is generated, or in intermediate deposits. These facilities are totally safe but they are licensed for storage for a limited period of time. The CENTENA Project will operate at the end of the useful life of radioisotopes and material used in all the applications of nuclear energy, contributing to the sustainability of the sector.

The aim of the project is to build, license and operate the Nuclear and Environmental Technological Centre (CENTENA), whose main function will be to store low and medium level radioactive waste produced through the use of nuclear energy in Brazil. It will also carry out RD&I activities, not only for the treatment of radioactive waste, but also for other types of waste, such as chemical or mining waste, which may contain natural radionuclides.

CENTENA will be the first repository built, licensed and put into operation in Brazil for the disposal of low- and medium-level radioactive waste. Its concept is similar to other successful centres in Europe, specifically in Spain and France.

Challenges

Over the last decade, the CENTENA Project has faced many different challenges, including technical, political, financial, legal and social.

Destination of the waste generated: CENTENA

2 FOME ZERO E AGRICULTURA SUSTENTÁVEL — Pest control using nuclear techniques

3 SAÚDE E BEM-ESTAR — Nuclear medicine

6 ÁGUA POTÁVEL E SANEAMENTO — Aquifer quality control using isotopic techniques

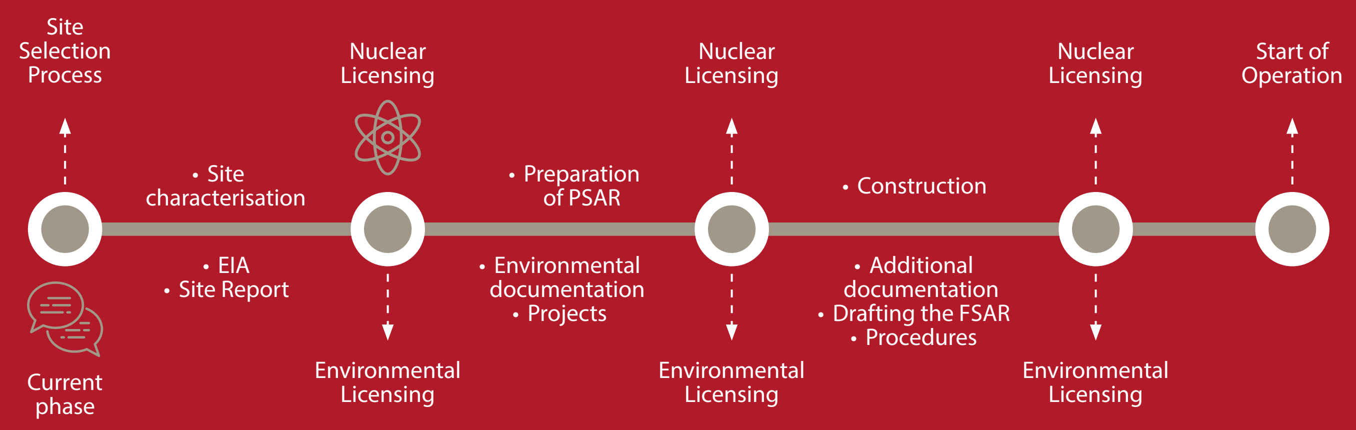
7 ENERGIA LIMPA E ACESSÍVEL — nuclear power plants with zero emissions

9 INDÚSTRIA, INOVAÇÃO E INFRAESTRUTURA — Process control using nuclear techniques

13 AÇÃO CONTRA A MUDANÇA GLOBAL DO CLIMA — Low-emission electricity generation

15 VIDA TERRESTRE — Isotopic techniques in agriculture

Project stages associated with licensing



Technical Challenges

When the project began, there were few licensed repositories worldwide for low and medium-level radioactive waste. In Brazil, there was the Abadia de Goiás repository, built to house the waste from the radiological accident that occurred in Goiânia in 1987. However, this repository was built for a single radionuclide and for a constant volume. CENTENA is planned to store all the low- and medium-level radioactive waste. It is a facility comprising of the disposal area and all the necessary infrastructure to guarantee the safety of people and the environment. Installations have also been provided for RD&I activities related to the performance of the multiple barriers and the very waste management activity itself.

The success of the project depends on a multidisciplinary team, coming together to work at the various stages, such as site selection, concept, basic and executive designs, construction and commissioning. In this sense, the challenge is to have sufficiently skilled human resources capable of meeting the technical and licensing requirements. A training programme is being developed for professionals with this profile. In the meantime, technical staff from the Nuclear Technology Development Centre (CDTN, acronym in Portuguese) and other institutes, as well as undergraduate and postgraduate students, are the project's main strength in terms of HR, which also has the support of other educational institutions.

Political Challenges

Since the start of the CENTENA Project (formerly known as RBMN), there have been five changes in the Presidency of the Republic, fifteen changes in the direction of the Ministry of Science and Technology and five changes in the direction of the National Nuclear Energy Commission (CNEN). All of these changes had internal repercussions and negatively affected the project. However, in July 2018 an inter-ministerial working group - GT-8 - was set up to work on resolving the project's issues. The most important result of this working group was to position CENTENA as a "project of the Brazilian state" and to be recognised as strategic for the nuclear area.

Financial Challenges

According to the International Atomic Energy Agency (IAEA), "the majority of low- and medium-level radioactive waste disposal facilities are surface or near-surface facilities. The disposal of this type of waste and very low-level waste in countries with relatively low generation is a challenge due to the relatively high initial fixed cost of designing, licensing and building a repository." Brazil has a nuclear programme that ranges from uranium mining to nuclear power plants, as well as various applications that use nuclear technology.

In comparison, the estimated budget for the project, around R$ 130 million, is relatively low. This amount is being analysed within the Ministry of Science, Technology and Innovation (MCTI) in order to identify the sources of funding available, as well as entering into partnerships, either with other state institutions, at a federal level, that work in the nuclear sector, or through potential partnerships with the private sector.

Social Challenges

"Public acceptance of spent fuel and radioactive waste management remains a challenge in most countries. This is especially true for disposal facilities and has had a negative impact on the progress of programmes," as stated by the IAEA. However, countries such as Finland, France and Sweden have successfully overcome these challenges.

This is a challenge that the project is working on, as it was found that, even in scientific circles, there is a great lack of knowledge about the nuclear area, and information on the subject for the general public is very diffuse. In most countries, this was the biggest challenge. An agency specialising in public communication, together with the project coordinator, drew up a Preliminary Stakeholder Communication Plan and produced publicity materials to explain to various audiences the nuclear area and CENTENA.

In addition, this project has some aspects that are unique to the Brazilian context, especially with regard to the time between its construction and the end of institutional use. This is a period of approximately 360 years, when the area will be released for unrestricted use. This means that the Repository must be safe for more than three hundred years, which is more than half of Brazil's entire history. This aspect is very new in the Brazilian social context, bringing a new dimension to public acceptance.

Commitment to future generations is one of the basic principles of sustainability and also of management CENTENA fulfils its commitment to future generations by giving visibility to how much radioactive waste is generated and how it is treated and stored of radioactive waste. In this sense, CENTENA fully fulfils this commitment, as it will give visibility to how much radioactive waste is generated and how it is treated and stored, allowing these generations to opt for the continued use of nuclear energy. The challenge is to manage the information and knowledge generated during CENTENA's implementation and operation.

> CENTENA fulfils its commitment to future generations by giving visibility to how much radioactive waste is generated and how it is treated and stored

In conclusion, the implementation of CENTENA is a milestone of transcendent importance for the consolidation of the Brazilian nuclear industry. International experience shows that the final storage of waste brings a positive image to the use of nuclear energy and that the better and more transparent its design, construction, operation and monitoring are in the long term, the safer and more confident the public feels about the various ways in which this energy can be used, whether in electricity generation, or in healthcare, or in industrial processes and other uses.

*CNEN technologist and CENTENA coordinator

Further information, videos and interviews are available (in Portuguese) on CENTENA's website:
https://www.gov.br/cdtn/pt-br/projetos-especiais/centena

Atoms

INAC 2024 will be **held in Rio**

The next edition of the International Nuclear Atlantic Conference (INAC), the traditional nuclear energy event in the Southern Hemisphere, will take place at the Naval War College (EGN) in the city of Rio de Janeiro, from 7 to 10 May 2024, with the theme "Nuclear Energy: Ensuring Energy, Health and Food".

Promoted by the Brazilian Association of Nuclear Energy (ABEN), the conference, which is in its 11th edition, will bring together the XXIII Meeting on Reactor Physics and Thermohydraulics (ENFIR), the XVI Meeting on Nuclear Applications (ENAN), the VIII Meeting of the Nuclear Industry (ENIN), the X Junior Poster Technical Sessions (poster session for undergraduate students) and the XI ExpoINAC. During INAC 2024, the winners of the 3rd edition of ABEN's Nuclear Ambassadors Project will also be announced.