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Russia Maximizes Radiopharma

This March, the radiopharmaceuticals production facility built by Rosatom in Bolivia began supplying fluorodeoxyglucose to Bolivian hospitals. In South Africa, Rosatom representatives spoke about actinium-225, which is already used in Russia to treat cancer. In this article, we tell you about Rosatom's achievements in the global market of radiopharmaceuticals.

On the way to radiopharma independence

"Fluorodeoxyglucose is rightfully called 'the molecule of the century.' It is used in positron emission tomography (PET) scanning of bodily organs and tissues, which is often combined with computer tomography or magnetic resonance imaging," says Evgeny Pakermanov, President of Rusatom Overseas.

Rusatom Overseas is building a nuclear research and technology center (NRTC) in El Alto, Bolivia. One of the NRTC facilities is a cyclotron designed to fabricate

radioisotopes (for example, fluorine-18) and radiopharmaceuticals (for example, fluorodeoxyglucose).

Fluorodeoxyglucose is a sterile, clear solution administered intravenously. Its function is to deliver a molecule analogous to natural glucose and labeled with the radioisotope fluorine-18 to the area under examination. Once in the body, the radioisotope, like a flashlight, illuminates formations in which glucose absorption is too intense. This characterizes malignant cells that are metabolically more active than healthy cells. Atypically low glucose accumulation also serves as a marker, for example, of scar formation after a heart attack.

The radiologist sees bright, dark and normal areas on his computer while the patient is in the CT scanner. The method allows detecting pathological foci as small as 4–5 mm in diameter. Such precision is very important for the success of a follow-up treatment.

"We now have this nuclear medicine center with the most advanced equipment and, instead of importing, can produce radiopharmaceuticals for cancer diagnostics by ourselves. This technology is so advanced that Bolivia can even export these radiopharmaceuticals to neighboring countries. From now on, we will be able to fight cancer even more efficiently!" Bolivian President Luis Alberto Arce Catacora said at the ceremony marking the start of production.

The line of radiopharmaceuticals that can be fabricated at the NRTC will expand. **"We have already test-produced three more medical radioisotopes and thus confirmed the possibility of commercially producing a range of radiopharmaceuticals based on**

them. Carbon-11 is used to diagnose brain tumors, technetium-99m for tumors in the liver and brain, and iodine-123 for the thyroid gland. We have made a launch, and now let's see which radiopharmaceutical will come next — this is left for the customer to decide," Evgeny Pakermanov commented.

The NRTC will produce radiopharmaceuticals sufficient to conduct over 500 diagnostic studies per year. In the future, all three Bolivian nuclear medicine centers will be fully supplied with locally produced radiopharmaceuticals.

Another NRTC facility, a multipurpose irradiation center (MIC), is in a pilot operation mode, with test batches of different types of produce irradiated. Its capacity is 70 tons per day. **"The MIC is being prepared for handover to the customer and planned to be put in operation in the near future. The decision on what kind of produce and goods will be processed at the center is, of course, up to the customer,"** Evgeny Pakermanov said. As international practice shows, they can be grain crops, vegetables, fruits, cosmetics, and medical products.

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The third and fourth NRTC facilities are currently under construction. These are radiobiology and radioecology laboratories, and a water-cooled water-moderated pool-type research reactor with a thermal power of 200 kW. The facilities are planned to be commissioned in 2025.

Meet actinium-225

Rosatom expands the range of radiopharmaceuticals it produces, and the most interesting of them are based on actinium-225. This radioisotope is used to treat inoperable metastatic cancer, primarily of the prostate gland.

In late February and early March 2023, representatives of Izotop (Rosatom's isotope supplier) and the Institute of Physics and Power Engineering (IPPE, one of Rosatom's producers of medical isotopes) made poster presentations at the 12th International Symposium on Targeted Alpha Therapy in Cape Town, South Africa. They told the audience about the trends in clinical trials of actinium-225-based drugs and production optimization that helped IPPE significantly increase the fabrication of isotopes.

"It is the preferred choice among alpha emitters today. The Russian nuclear corporation is a Top-3 supplier of actinium-225 worldwide and has plans to expand production. It was important for us to underline this fact in our presentation and share our success in producing and supplying actinium-225 as well as to contribute to the development of its consumption in Russia and globally," says Olga Walsdorf, Head of Marketing at Izotop.

According to her, many medical institutions all over the world use actinium-225, but only for the treatment of certain diseases, and have no idea of its potential uses. Rosatom studies this matter comprehensively and consistently analyzes international practice. This helps build sales and advise potential buyers of actinium-225 on other areas of application of radiopharmaceuticals. **"The more areas of application there are and the more clinical trials are conducted, the more sustainable demand for actinium-225 is guaranteed,"** says Olga Walsdorf.

Several US companies, such as Terra Power, Cardinal Health and Northstar, are investing in the production of actinium-225. It should be noted that the symposium, which used to be of interest mostly to scientists, was attended by representatives of major companies, such as Bayer, Curium, Cardinal Health, Siemens and others. **"It may well sound paradoxical, but we benefit from competitors' ambitions because their activities shape a consumer environment and make the isotope popular. They may even buy our actinium-225 for backup supplies,"** Olga Walsdorf stressed.

Isotope of Cooperation

Novosibirsk Chemical Concentrates Plant (part of Rosatom's TVEL Fuel Company) will supply the Brazilian company Eletronuclear with lithium-7 hydroxide for the cooling system of the Angra NPP reactors. The shipment expands cooperation between the Brazilian and Russian nuclear companies.

Isotope for membranes

Lithium-7 hydroxide (hereinafter lithium-7) is a light-colored, fine crystalline substance with an atomic fraction of lithium ranging from 99.95% to over 99.99% relative to the sum of lithium isotopes (depending on the specifications). Lithium-7 is added to the primary coolant of pressurized water reactors to adjust its chemistry. Lithium-7 is also the main component needed for the preparation of reactor-grade ion exchange membranes that are used to treat coolant for pressurized water reactors.

Bidding for a contract to supply lithium-7 was initiated by Rusatom International Network. Part of Rosatom, the company represents its interests in international markets. **"This business opportunity came about thanks to our efforts aimed at promoting this product. We contacted Brazil's nuclear operator Eletronuclear and presented our new product. After that, we were invited to compete in a supply tender with Eletronuclear's current suppliers. Well-coordinated teamwork between Rosatom Latin America and Rusatom International Network's head office helped us win the contract,"** Gonçalo Castillo, Business Development Manager at Rosatom Latin America, commented on the event. Over 100 kilograms of lithium-7 will be shipped to Brazil. The contract will be signed shortly, and the customer is expected to receive the shipment during this year.

"Rosatom is a leading player in the global market of lithium products and a reliable supplier. Novosibirsk Chemical Concentrates Plant has specialized in the production of lithium compounds for more than 60 years. Its advanced production facilities make it possible to achieve a high degree of chemical purity in accordance with customer requirements," says Mikhail Metelkin, Director of Specialty Chemicals at TVEL.

Enriching cooperation

The supply of lithium-7 expands Rosatom's cooperation with the Brazilian nuclear sector.

Last December, Internexco GmbH, a subsidiary of TENEX (part of Rosatom), signed a contract with the Brazilian state-run company Industrias Nucleares do Brasil (INB)

to fully supply the Angra NPP with enriched uranium in 2023–2027.

The contract was awarded following an international public tender held in August 2022 that was won by Internexco GmbH. This is Rosatom's first long-term contract for the supply of enriched uranium products and a result of the agreement of intent concluded in 2019. The agreement provides for the implementation of joint projects in the nuclear fuel cycle segment.

In addition, the supply of lithium-7 expands cooperation in the segment of isotope products. It should be noted that the Russian nuclear corporation currently meets up to 50% of Brazil's demand for medical isotopes and is one of the largest suppliers of isotope products for the country's nuclear medicine.

Next steps

In September 2022, Rosatom signed a memorandum of understanding with the Brazilian holding company ENBPar. Acting through Eletronuclear, the company supervises the operation of the Angra Nuclear Power Plant and runs hydro power projects. It also plans to engage in uranium mining and nuclear fuel production.

The memorandum provides for the cooperation between ENBPar and Rosatom in the construction and operation of large and small nuclear power plants and the nuclear fuel cycle. In addition, the parties agreed on technology transfer to form a cluster of companies specializing in the provision of services and supplies of products for the nuclear industry, and to join efforts in operating, repairing and upgrading hydro power plants and raising public awareness.

Rusatom International Network represents Rosatom State Nuclear Energy Corporation abroad. Its network of 14 foreign regional centers, country offices and business representatives allows Russian nuclear industry enterprises to interact with partners around the world efficiently, meeting the highest standards of international activities of a modern technology leader.

TechSnabExport (TENEX) is a Rosatom company supplying nuclear fuel cycle goods and services. Its key activities are uranium production, international supplies of Russian uranium products, nuclear fuel cycle back-end services, and logistics. TENEX is also engaged in lithium mining and biofuel production.

"We want to take advantage of Rosatom's experience, learn more about the end-to-end production cycle in nuclear power and implement the best practices in Brazil," said ENBPar President Ney Zanella dos Santos.

Rosatom and ENBPar continued their collaboration in November 2022. Speaking at the plenary session of Atomexpo, Ney Zanella dos Santos said that small modular reactors could be used extensively in Brazil's remote regions. The country also plans to complete the third unit of the Angra NPP (commissioning is scheduled for 2027) and build new units. Brazil is expected to commission another 10 GW of nuclear capacity over the next 30 years.

"Eletronuclear also invited us to participate in a market study that will result in a tender for maintenance services for Angra 1 and Angra 2," Gonçalo Castillo concluded.

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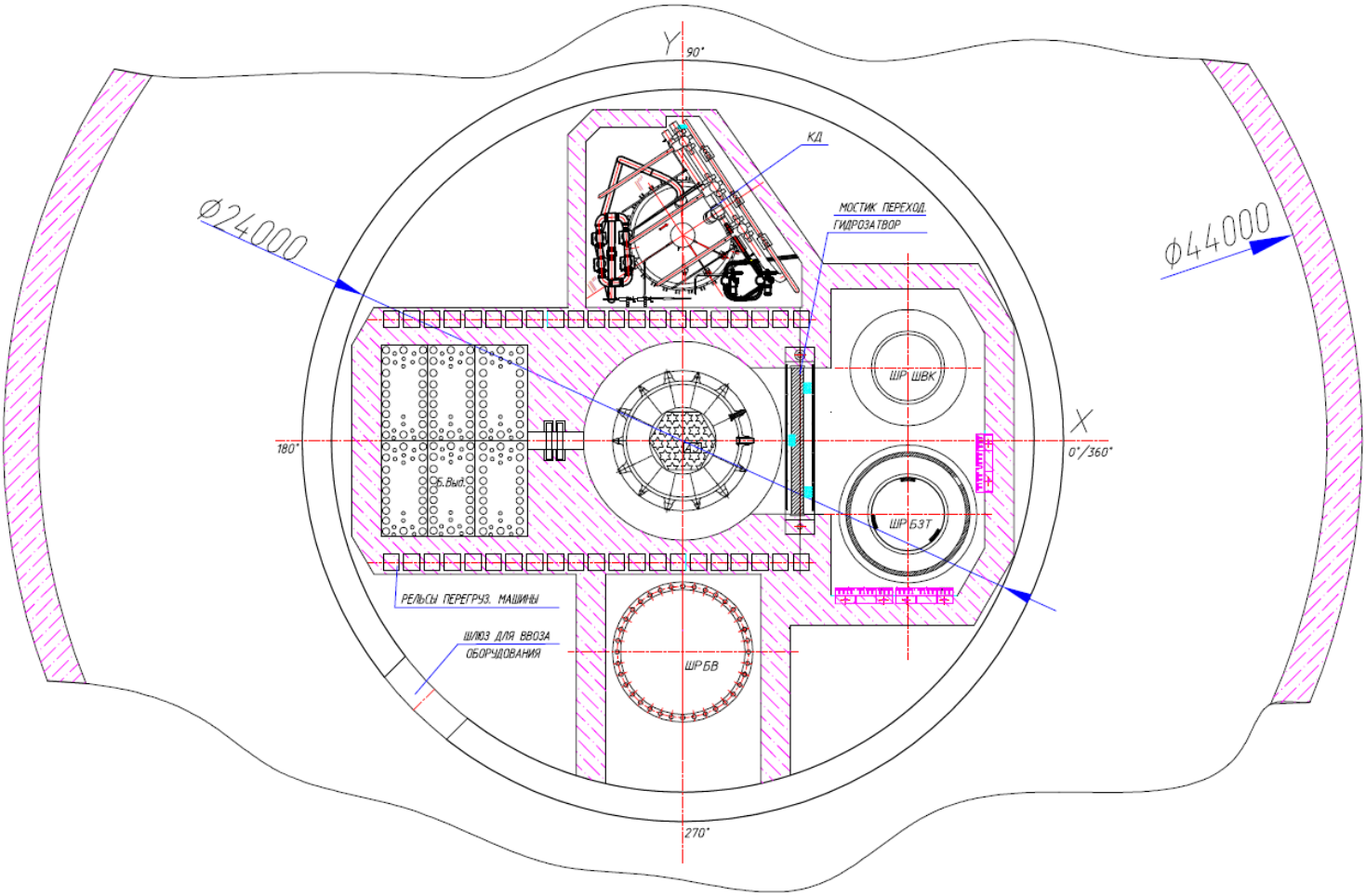


As Natural As Water

In this issue, we tell you about a new small nuclear power plant with a VVER-I reactor. Designed at OKB Gidropress, it is an integral modular reactor with natural coolant circulation.

Distinctive internals

The VVER-I reactor pressure vessel (RPV) houses a core, a riser tube unit, steam generation modules, and other necessary internals. Water, which serves as a coolant, circulates inside the RPV only. Having a higher temperature and a lower density, it goes from the reactor core into the shell side of the steam generators, gets cooled there and returns into the core through the downcomer tubes. Location of the steam generators and the reactor core at different heights ensures natural circulation. Overheated steam with the pressure of 3 MPa and temperature of around 290 °C goes from the steam generators into the turbine, circulating through heat exchangers. The primary coolant loop is therefore integrated into the reactor pressure vessel. The reactor in its basic version is capable of generating 250 MW of thermal power. Estimates show, however, that its thermal output can be increased to 400 MW without material changes in the design by simply raising the height of the RPV and steam generation

modules by 1.5–2 meters. This will help to easily meet customers' requirements.

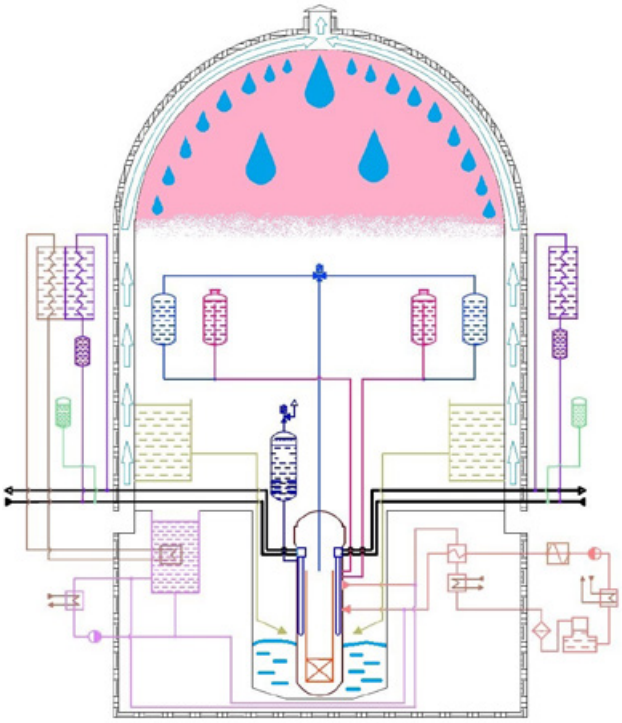
Advantages of integral layout

The reactor's integral layout reduces the inventory of equipment needed and size of the nuclear island. It also makes large-diameter pipes unnecessary. The largest high-pressure coolant pipe in VVER-I has a diameter of less than 100 mm. As a result, fewer safety systems are needed and all of them can be passive, which is another indisputable advantage of the new reactor. Its design does not provide for any active, human-triggered safety systems.

The principle of modularity applies to the entire reactor. The RPV houses seven modular steam generators that are easy to maintain, repair and even replace when needed. The reactor itself is also modular, which allows placing two or three reactors in a single containment.

Advantages of natural circulation

When in a natural circulation mode, more powerful VVER reactors are capable of producing more than 10% of their nominal power, or around 300 MW of thermal power. This has been confirmed by tests. Having taken this into account, engineers plan to achieve more power with the same RPV by reducing hydraulic resistance in the circulation loop and creating other conditions for continuous natural circulation. Correctness of this solution has been confirmed by Computational Fluid Dynamic (CFD) modeling. **"In fact, there is no need to invent how circulation pumps can be integrated into the RPV, and so there is**



OKB Gidropress provides comprehensive services in design engineering, computation, experimental testing, research and development of nuclear reactors for various-type power plants. The company also provides engineering supervision services throughout the service life of the equipment designed.

no need to feed or maintain them. In my opinion, the less complex equipment is and the simpler design, the more reliable it is," says Mikhail Bykov, Head of Thermal Physics Department at OKB Gidropress (part of Rosatom).

Proven approach

Many reactor design proposals were considered and analyzed at OKB Gidropress during the engineering process. In the end, engineers settled on the time-tested technologies but still had to find many new solutions. **"The RPV is similar to that of VVER-1000 reactors which have been in operation for over 1,000 reactor-years. We had to fit the steam generators and the core into it and faced a dilemma: should the coolant flush the steam generator tube or, on the contrary, should the secondary loop be arranged in the shell side? How to make a riser tube unit to ensure continuous natural circulation? We faced such dilemmas and problems now and then. And it was great that young people were involved in our work from the very beginning,"** Mikhail Bykov says.

Young professionals proposed bold ideas, analyzed the options, and chose the best solutions. More experienced colleagues were guiding them and prompting the way. The technical proposal for a VVER-I reactor was finally elaborated even more than this development stage requires. Based on that document, the team prepared terms of reference for the VVER-I draft design, which will be the next stage of the reactor development process.

The draft design will be developed in close collaboration with the chief designer and the R&D supervisor to obtain the concept of the entire nuclear power plant and the scope of the equipment and systems needed. **"I believe that together we are capable of developing a VVER-I-based small nuclear power plant that will be cost effective, attractive to international customers and compliant with all applicable safety requirements to further strengthen Rosatom's leadership in this market segment,"** Mikhail Bykov concluded.

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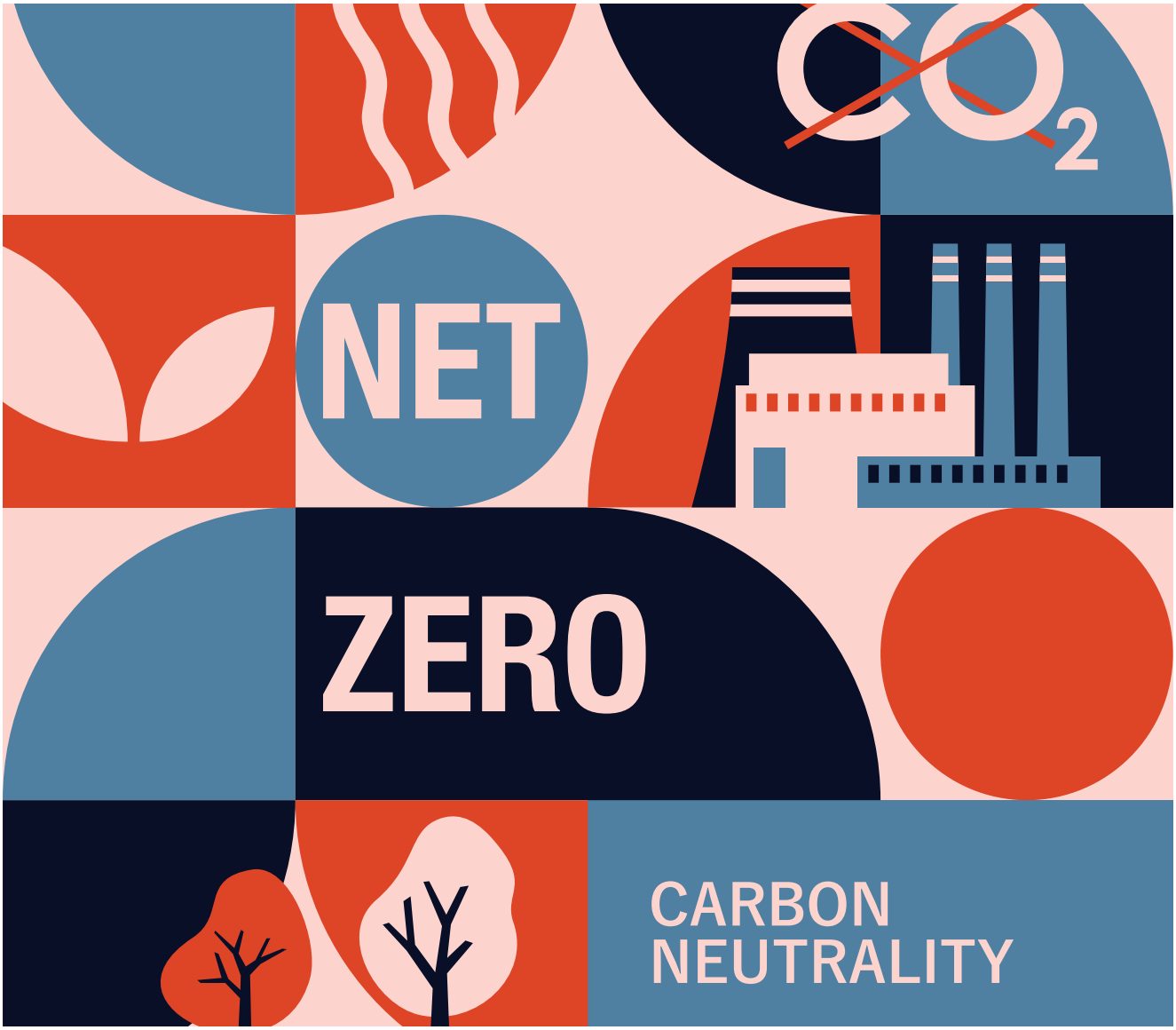


New Does Not Mean Advanced

In mid-March, the European Commission proposed the Net Zero Industry Act (NZIA) providing for the use of advanced reactor technologies for decarbonization. In Europe, such technologies are developed by startups. Although heavily invested, they exist only on paper — in contrast to those already at advanced stages at Rosatom.

Partial inclusion

The new bill aims "to scale up manufacturing of clean technologies in the EU and make sure the Union is well-equipped for the clean-energy transition." According to its drafters, decarbonization might be achieved to a greater extent through solar photovoltaic and solar thermal, onshore wind and offshore renewable energy, batteries and storage, heat pumps and geothermal energy, electrolyzers and fuel cells, biogas/biomethane, carbon capture, utilization and storage, grid technologies, sustainable alternative fuels

technologies, advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle, small modular reactors, and related best-in-class fuels.

The act is intended to cut the red tape in launching new projects, shorten timelines, and expedite licensing procedures. It also requires that sustainability criteria for zero-emission technologies be taken into account in public procurement, thereby ensuring future sales, and calls for the creation of Net-Zero Industry Academies to improve employee qualifications.

However, the Brussels-based trade association for the nuclear energy industry, Nucleareurope, believes that the future contribution of nuclear technologies to the decarbonization in Europe is being underestimated. The association pointed out in a statement that the European Commission had decided to partially include nuclear by referencing Small Modular Reactors (SMRs) and advanced reactors under its Net Zero Industry Act (NZIA). Whilst a step in the right direction, Nucleareurope believes that much more could still be achieved by including the nuclear sector as a whole and treating nuclear in the same way as other strategic technologies. **"We understand that the discussions around the inclusion of nuclear under the NZIA have proved challenging, and so it is positive to see at least some reference to nuclear technologies in the text. But unfortunately, this is not enough,"** Nucleareurope Director General Yves Desbazeille said.

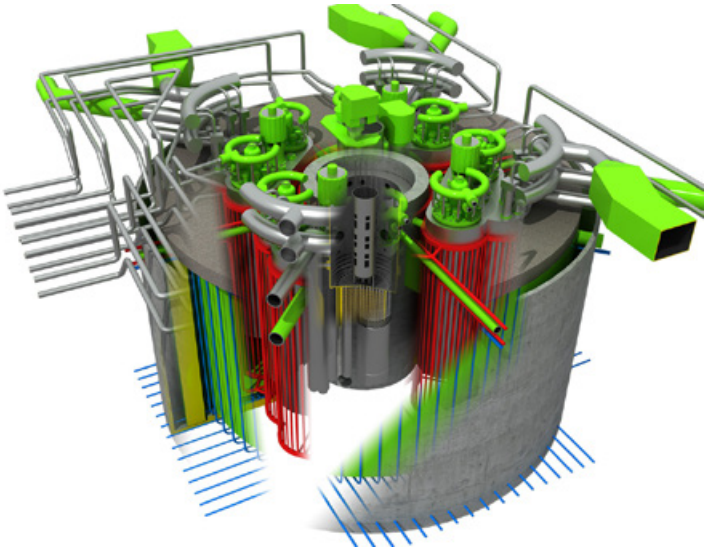
The statement by Nucleareurope also says that the NZIA will set the scene for industrial players in the years to come and determine the degree of EU strategic autonomy in terms of key technologies needed for the energy transition. In this respect, the nuclear industry stands ready to deliver what is needed to reach Net Zero by 2050, ensure security of supply, strengthen European resilience and tackle affordability.

It seems, however, European officials believe that only advanced reactors and SMRs — that is, completely new projects — can "ensure security of supply, strengthen European resilience and tackle affordability."

This March alone, there were three new nuclear startups reported in Europe.

Startup highlights: United Kingdom

Italy's Enel will acquire a stake in the first small nuclear power plant to be built by the UK startup Newcleo. It develops small modular fast-neutron reactors with lead coolant. However, the company's website contains no 2022–2023 news about the progress in the reactor development. The only thing known is that the company plans to build an electric prototype in 2026 to test the company's solutions "for the well-known



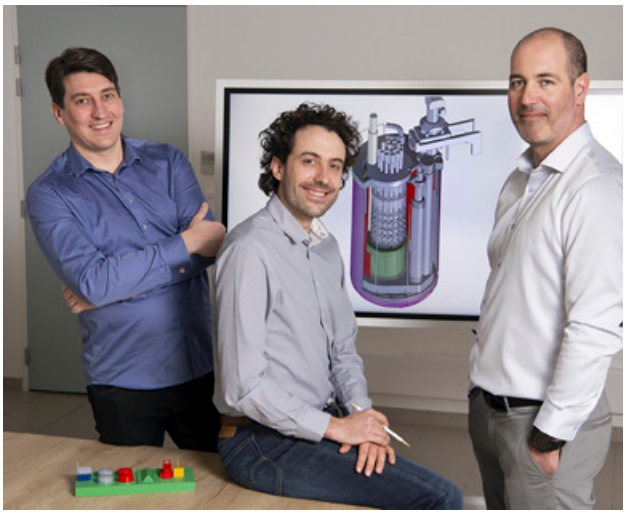
challenges related to liquid metal and in particular lead." A 30 MW mini-reactor is planned to be launched in 2030. At the same time, the company plans to invest in a MOX fuel fabrication plant. The plan for 2032 is to build a 200 MW lead-cooled SMR.

By contrast, Russia is already building a small nuclear power plant with a lead-cooled BREST reactor that will use mixed uranium plutonium nitride fuel. First concrete was poured for the foundation of a BREST-based pilot power unit in June 2021. The unit is being constructed in Seversk as part of the Proryv (Breakthrough) project. We will tell you more about the BREST reactor and construction of the power unit in our Reactor Technologies column in one of the next issues.

Startup highlights: France

France's Alternative Energies and Atomic Energy Commission (CEA) has founded two startup companies to develop small modular reactors.

One of them is Hexana. This startup will develop a small sodium-cooled fast-neutron reactor operating in conjunction with a high-temperature thermal energy storage unit. The plant will have two SMRs with a thermal power of 400 MW each and a thermal energy storage unit capable of converting heat into electricity. The reactors will use mixed uranium plutonium oxide fuel.



The plant should be flexible to operate in a load-following mode (adjust its power output as demand for electricity fluctuates) and be able to compete with gas-fired plants. It should also be able to supply heat to industrial consumers.

In Russia, sodium-cooled fast-neutron reactor technologies have been studied and developed almost from the very inception of the nuclear industry. Both research and power reactors have been built, but the focus in the power generation segment was on large reactors with their capacity gradually increasing from 350 MW (BN-350) to 800 MW (BN-800) rather than on small ones. The next step is the construction of a 1,200 MW reactor unit BN-1200. Engineering surveys for the new unit have already begun on the site, including environmental studies, analysis of nearby flight routes, assessment of water management conditions, and so on.

The other French startup is Stellaria developing a power unit with a molten chloride reactor. This molten salt reactor has a thermal output of 250 MW and an electric output of 100 MW. The volume of its core is 4 cubic meters. It is assumed that the reactor will be able to use different types of fuel, including uranium, plutonium MOX, minor actinides and thorium.

Rosatom is also developing molten salt reactors but those using fluorides. In December 2022, Dollezhal Research and

Development Institute (part of Rosatom) presented a draft design for a molten salt research reactor (MSRR). We wrote about it in the previous issue.

The both companies are expected to participate in the Innovative Nuclear Reactors competition under the France 2030 development plan. The French government earmarked EUR 500 million for the program.

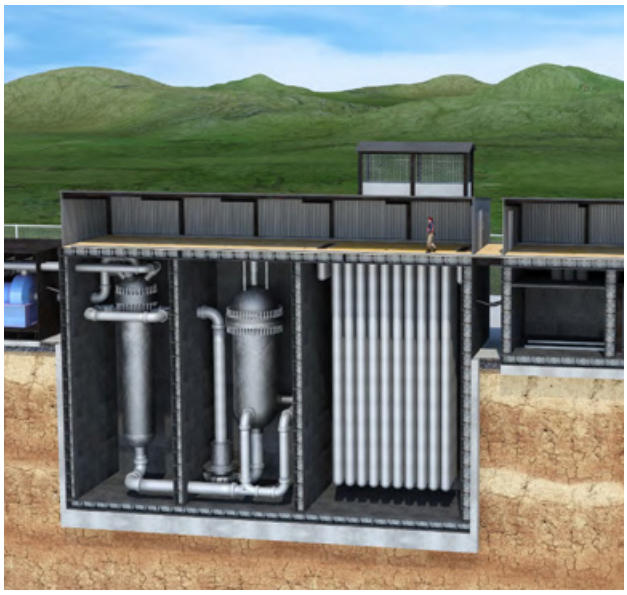
Complexities of advanced reactors

If the European Commission does not change its position, no regulatory, human resource or marketing support will be given to the facilities that use existing reactor technologies. This applies, for example, to the yet-to-be built Sizewell C nuclear power station where Framatome plans to build two power units with EPR reactors. The NZIA will also leave out large power units that Poland hopes to build in partnership with the US-based Westinghouse.

A quick look at the French and UK startups shows that their reactors are at a very early stage of development. They have an immense amount of material studies, calculations, adjustments, tests and feasibility studies ahead. This will require much money, let alone time and competent professionals.

In addition, feasibility of some projects raises doubts. This is especially true for molten chloride reactor projects. Russian engineers do not plan to use them because chloride acts on structural materials like mercury quickly corroding structures. Therefore, the idea was abandoned at the dawn of nuclear technology development in the USSR.

Since the chloride technology is still in its infancy, investors face a high risk of overspending or even project cancellation. For example, in March, Urenco stopped supporting the U-Battery project developing a 4 MW high-temperature gas-cooled microreactor “due to necessary re-prioritization under its strategy.” Another example is the US-based NuScale: the cost of its CFPP project has risen to USD 9.336 billion, and the target price for power from the plant was USD 89 per megawatt hour, up 53% from the previous estimate of USD 58 per MWh.



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We should develop reactor technologies, look for new solutions and try new designs, but we should not label every new project as 'advanced.' 'New' does not necessarily mean 'better' — let us not substitute one for another and confuse technology with marketing. A reactor is 'advanced' if its technology has proved efficient and is sought-after by customers. VVER-1200 in the large reactor segment and RITM-200 in the SMR segment can be rightfully considered advanced. VVER-1200 reactors are being constructed or prepared for construction on three continents. RITM-200 reactors are installed on Russian nuclear icebreakers. In the next few years, RITM-200 reactors will also be installed on the floating power units to supply power to Baimsky GOK mining and processing facilities; their onshore version will be built in Yakutia. NL

We have analyzed publications on the World Nuclear News website to see that the first mentions of 'advanced reactors' date back to 2014 and that the term was first used in the United States. That August, South Korean engineers and the Argonne National Laboratory agreed to jointly develop an EBR-II prototype reactor. In November the same year, five R&D projects received USD 13 million from the US Department of Energy.

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