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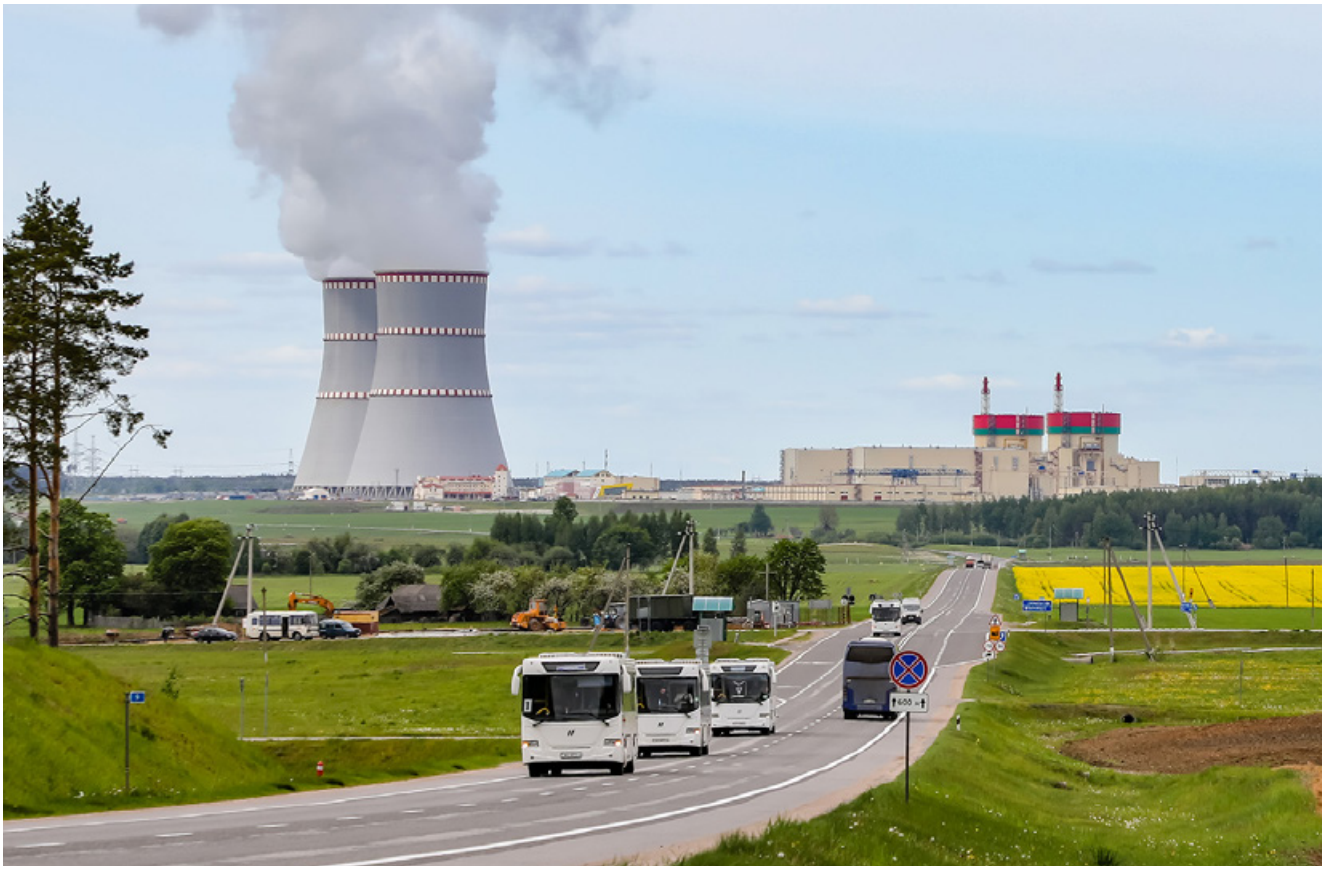

Second Reactor Goes Online in Belarus

On May 13, the second unit of the Belarus Nuclear Power Plant was brought online and supplied the first kilowatt-hours of electricity to the national power grid. From that moment on, the reactor unit has been considered operational according to the IAEA rules. The plant is clearly not the only example of cooperation between Rosatom and Belarus in nuclear technology.

The reactor was connected to the grid at 40% of nominal power, increased to 50% six days later. The reactor will gradually be taken to 100% while conducting dynamic tests in various operation modes, including complete de-energizing of the power unit. During the power ascension process, the plant engineers will compare operating parameters of the nuclear and turbine islands against rated performance.

“The start of power ascension tests means the entire Belarusian NPP construction project has entered the homestretch. The first nuclear power site in brotherly Belarus has laid a foundation for Russia and Belarus to continue their collaboration in the power sector and other economic sectors, including nuclear medicine and digital technology, taking it to new heights,” said Rosatom Director General Alexey Likhachev at the start of power ascension.

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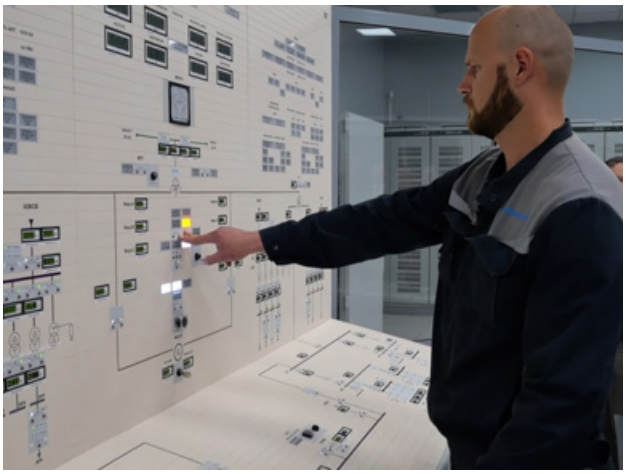


Russia and Belarus maintain close contacts across the entire spectrum of civil nuclear operations. Rosatom's fuel division TVEL supplies fuel for the Belarus NPP. Currently, the plant operates in a four-year refueling cycle with one partial reload every 12 months. However, there is a good chance that the refueling interval will be extended to 18 months. TVEL and the Belarusian NPP have also signed an agreement on scientific and technical support during decommissioning.

Rosatom helps Belarus in training staff for the nuclear industry. As of early 2023, over 20 Belarusian students were enrolled in Rosatom's backbone universities, majoring in nuclear-related professions sponsored by the Russian nuclear corporation. During the 2022/2023 academic year, another five Belarusian students received scholarships from Rosatom and were enrolled in the National Nuclear Research University (MEPhI) and the Moscow Institute of Physics and Technology (MIPT). Retraining and advanced training programs have also been implemented. In addition, MEPhI and the Belarusian State University of Informatics and Radioelectronics offer joint Master's programs. During Atomexpo 2022, the Moscow State University Faculty of Chemistry and the Belarusian State University signed an agreement on strategic cooperation in science and education. The priority lies in developing a curriculum focused on spent nuclear fuel management.

Cooperation in nuclear medicine is also expanding. In May, an agreement for the supply of medical equipment and radiopharmaceuticals to Belarus was signed at the Nuclear Medicine in Belarus and Russia: Prospects and Opportunities seminar. The seminar participants also shared their knowledge about the cancer treatment equipment and the use of radiopharmaceuticals.

In April, Rosatom group companies signed three agreements with Belarusian partners at the TIBO 2023 forum. The first agreement was made between JET Engineering and Technical Center on one side, and Belenergo and BelenergoRemNaladka on the other side. The agreement aims to deploy full-scale simulators and promote digital twins at the power generation facilities in Belarus, while also training personnel and implementing best practices in power equipment operation and maintenance.

The second agreement signed by Rusatom Infrastructure Solutions and Giprosvyaz, focuses on the development of Smart City solutions to optimize and digitalize the urban environment, utilities, and transport infrastructure management. For instance, the Digital Water Management system reduces losses in water supply networks and electricity costs, while simultaneously increasing productivity. Earlier, during a visit to Rosatom, the Belarusian delegation was shown how the Navigator nuclear industry management system worked. The system brings together 25,000 users

from 328 companies. Neural network models gather and process data to generate predictive analytics and recommendations.

The switchboard equipment manufacturer T-Com and the Belarusian company Promsvyaz signed an agreement on strategic cooperation in the field of telecommunications equipment. The partners plan to develop and test new products and solutions.

RENERA, a lithium-ion storage systems manufacturer, is discussing deliveries of storage batteries for stationary energy solutions. RENERA already supplies the Belarusian company BKM Holding with storage batteries for Olgerd trolleybuses with an increased travel range, including those produced by the Belarusian company for Gorelectrotrans in Saint Petersburg.

Another area of joint interest is additive technology. The parties are considering the possibility of using 3D-printing to create repair parts for the Belarusian power generation facilities.

Finally, Rosatom and Belarus are discussing the prospects of building a research reactor at the Joint Institute for Power and Nuclear Research in the town of Sosny. The terms of an intergovernmental agreement to this effect are currently being negotiated.

Belarus Unit 1 with a VVER-1200 reactor was connected to the national grid in November 2020. In 2022, it produced nearly 4.7 billion kWh of electric power.

Rosatom Director General Alexey Likhachev and China Atomic Energy Authority Chairman Zhang Kejian

Strengthening Partnerships with China

Rosatom maintains extensive business contacts with China. The Russian nuclear corporation presented its capabilities at the 15th China International Exhibition on Nuclear Power Industry (CIENPI) 2023 in late April and participated in Russian Premier Mikhail Mishustin's official visit to China a month later. The key areas of nuclear cooperation between the two countries comprise the construction and manufacture of equipment for the four Russian-designed reactor units at two Chinese nuclear power plants.

At the exhibition

Rosatom presented its latest technologies and solutions in the design and construction of large and small nuclear power plants, as well as nuclear fuel at CIENPI 2023. For instance, Rosatom's fuel division TVEL demonstrated TVS-K fuel assemblies, the only nuclear

fuel in the global market that is completely independent of the developers of the original PWR technology.

Visitors to the exhibition also had an opportunity to learn about Rosatom's solutions for nuclear decommissioning and radioactive waste management. "Rosatom has unparalleled time-proven solutions and extensive expertise in managing the back end of the nuclear fuel cycle. China also pays special attention to the development of advanced back-end technology, given the rapid growth of its nuclear power industry. Strategic cooperation between our countries in the back-end management sets long-term trends for the global nuclear power sector," said Eduard Nikitin, Director of Decommissioning Programs at TVEL.

In addition, visitors could take a virtual tour of the fuel assembly factory in Zarechny, which is a host town for the Beloyarsk Nuclear Power Plant with an operating BN-800 fast neutron reactor. With an interactive application, they also could take an in-depth look at a nuclear power plant with VVER-1200 reactors. These are the reactors that will be installed in the four units currently under construction at the Tianwan and Xudabao nuclear power plants.

Rosatom's booth at the exhibition was attended by China Atomic Energy Authority Chairman Zhang Kejian, IAEA Deputy Director General Liu Hua, Chinese Nuclear Society Secretary General Zhang Thinke, and heads of other companies and organizations in the global nuclear industry.

"Russian-Chinese cooperation has never been more intensive and keeps gaining momentum across every segment of nuclear power. Russia is a global leader in constructing nuclear stations abroad, while China is a global leader in the construction of nuclear reactors domestically. We are confident that the strategic partnership between Russia and China will bring the world's nuclear power industry to a fundamentally new level of technology development," said Boris Arseev, First Deputy Director General for Corporate Development and International Business at Rosatom.

On the official visit

Rosatom Director General Alexey Likhachev met with Zhang Kejian in Beijing during Russian prime minister Mikhail Mishustin's official visit to China. Industry colleagues discussed approaches to achieving the goal outlined in the Comprehensive Long-Term Cooperation Program for Fast Neutron Reactors and Closing the Nuclear Fuel Cycle. This program was signed on March 21, 2023. Alexey Likhachev and Zhang Kejian also agreed to hold a subsequent meeting of the Russian-Chinese Sub-commission on Nuclear Issues.

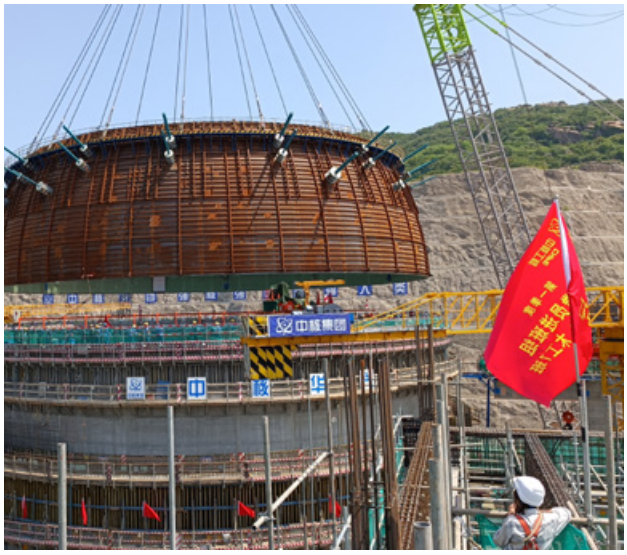
Representatives of Rosatom group companies participated in a business forum held as part of the official visit. Speaking at the Energy as a Driver of Russia-China Cooperation

round-table discussion, Anton Moskvin, Vice President for Hydrogen Energy at Rusatom Overseas (Rosatom's integrator for commercial hydrogen projects) noted that the hydrogen project in Sakhalin opened up more opportunities for the Russian-Chinese partnership in the production and transportation of low-carbon hydrogen. TVEL CEO Natalya Nikipelova spoke about the advantages of TVS-K fuel assemblies produced by Rosatom. Vladimir Panov, Rosatom's Special Representative for Arctic Development, said at the Russia-China Transport Cooperation: Development Scenarios round table that Russia and China could collaborate in sea logistics, port infrastructure, and shipbuilding.

Progress at Tianwan and Xudabao

Construction and installation work is going at full speed at the four units at the Tianwan and Xudabao nuclear power plants. In mid-May, the lower tier of the airtight internal containment shell was lifted and installed in place at Tianwan Unit 7. This structure, weighing 391 tons and with a diameter of 44 meters, is made of steel. After that, the top tier of the containment shell will be assembled and put in place, followed by the installation of equipment and pipelines, with a total weight of 214 tons.

In late May, a personnel training simulator was shipped to the Tianwan NPP. The simulator is an exact replica of both the main and backup control rooms. Utilizing mathematical modeling, it replicates the operation of a reactor unit in different modes of operation and in accidents.



The Central Design Bureau of Machine Building (CDBMB, part of Rosatom's power engineering division AtomEnergoMash) manufactured and shipped three aerosol filters for Tianwan Unit 7. They are required for the fine-cleaning of condensate in the gas purification system. The filtering elements are made of superfine glass fiber sheets. The same filters are also being produced for Unit 8. Also in May, CDBMB manufactured and shipped four (two primary and two backup) zeolite filters for Xudabao Unit 3. They are used to deep-dry the gas stream.

Construction of the Russian-designed power units, equipped with VVER-1200 reactors is proceeding on schedule. "We will continue to expand our successful cooperation in nuclear power," comments Alexey Bannik, Vice President for Chinese and Advanced Projects at AtomStroyExport.

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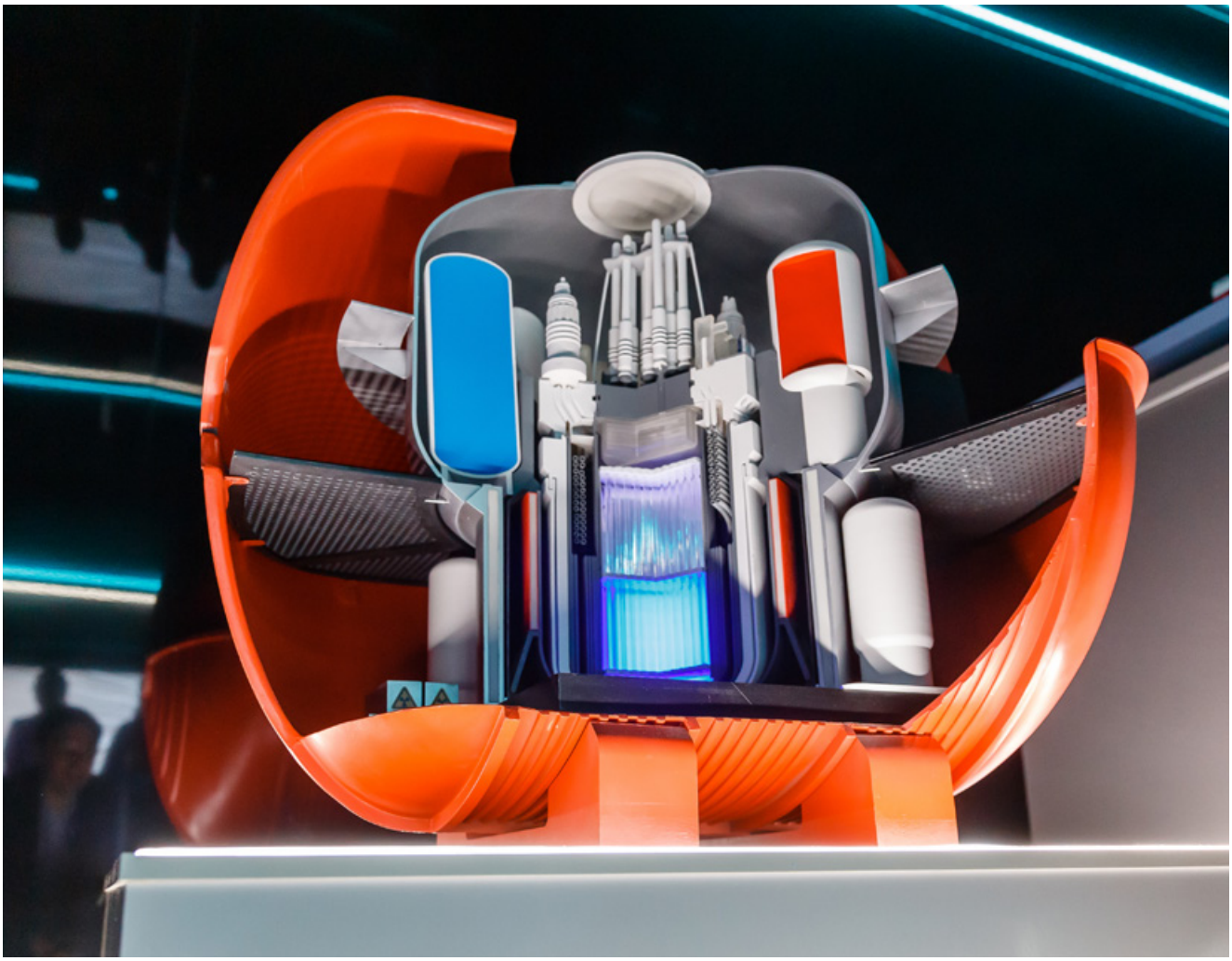


In Focus: SHELF-M Reactor

Along with small modular reactors, micro reactors are at the center of Rosatom's attention. SHELF-M is the closest among them to become tangible. Here is our story of the reactor specifics and construction prospects.

Structural highlights

With a thermal capacity of 35 MW and an electric capacity of 10 MW, SHELF-M is a water-cooled, water-moderated reactor that will be fueled with uranium dioxide dispersed in a silumin (aluminum-silicon alloy) matrix. The refueling interval will be eight years. The fully assembled reactor module will be 11 meters long and 8 meters in diameter. Weighing 370 tons, it will have a service life of 60 years. If necessary, the reactor can be transported from one site to another, for example, on a barge.

Working groups established by Rosatom and local authorities of Russia's northern communities have identified potential installation sites for the pilot SHELF-M unit. "We are working on the concept and

front-end engineering design for the nuclear power plant in relation to one of the possible sites," says Denis Kulikov, chief designer of reactors for small nuclear power plants at the Dollezhal Research and Development Institute of Power Engineering (NIKIET, part of Rosatom).

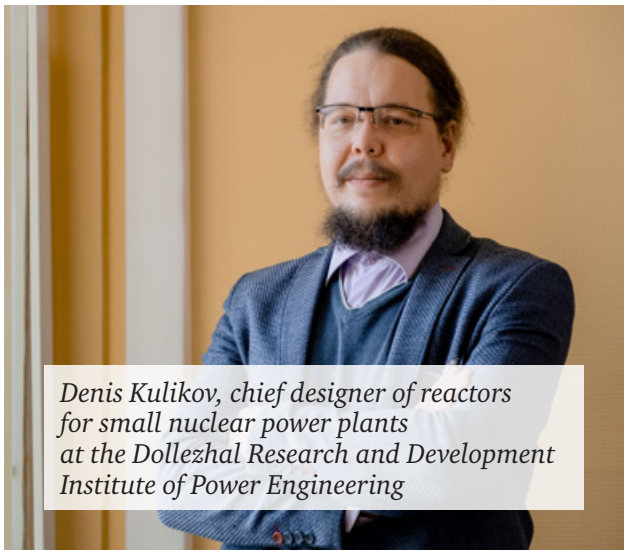
SHELF-M is a channel-type reactor. The layout of its core and fuel composition is similar to that used in nuclear-powered icebreakers.

The fuel rods for the pilot reactor are made of components that have been tested and proven before. For example, the cladding material is a time-proven chromium-nickel alloy 42KhNM, while the geometry of the cross-shaped fuel rod is similar to those used in the SM-3 and PIK research reactors. The chief designer and technologist of the basic fuel rod modification is the Bochvar Russian Research Institute of Inorganic Materials (VNIINM, part of Rosatom).

SHELF-M can operate in a natural primary coolant circulation mode at approximately 30% of its rated power. NIKIET sees no need in making the reactor cooled entirely through natural circulation since the reactor is planned to be transported fully assembled and must have limited dimensions for this purpose. However, some of the SHELF-M safety systems operate on natural laws alone: for example, the emergency reactor cooling and cooldown systems do not require power supply or pumps to perform their functions.

Solutions for the future

NIKIET is working on the concept design of the reactor unit and plans to finish it by the end of this summer. Then, they will proceed with the development of materials for the primary systems and equipment of the power unit.



Denis Kulikov, chief designer of reactors for small nuclear power plants at the Dollezhal Research and Development Institute of Power Engineering

At the same time, research studies are carried out to provide experimental evidence for the technical solutions adopted for the reactor. For instance, engineers are analyzing whether the equipment components made with additive technology or composite materials can be used in the reactor. "We are looking, among other things, for a solution to replace the structural material of the quite massive external tight-proof protective shell with a composite material. This should decrease the weight of the module by several dozens of tons while maintaining the mechanical and strength properties of the capsule," Denis Kulikov comments.

In addition research is conducted to develop a new type of fuel rods for the serial reactors. This is a bimetallic fuel rod developed at NPO Luch (part of Rosatom). The structure of the core, the type of fuel assemblies, and even the geometry of the fuel rods will remain the same while the

Plans for Shelf-M

2024 — Completion of the engineering design for the reactor and basic equipment of the nuclear power plant; start of on-site works

By 2026 — Completion of endurance tests on the main assemblies and structural elements

By 2027 — Start of equipment delivery to the deployment site

2030 — First criticality, first power, and commissioning

2032 — Start of production of the second and subsequent SHELF-M power units

fuel composition will be uranium metal filaments placed in a niobium alloy. The fuel rods, made to a similar design but using zirconium, are used in the core of the Kazakhstan research reactor IVG.1M.

Remote control

Robotic automation is another concept developed for the new reactor. Since personnel will have no access to the reactor containment during operation, many operations will have to be performed by robots.

"We plan to make mock-ups of critical robotic units and test them in a working environment. The most interesting task, in my opinion, is the development of a remote control system. We won't be able to fully deploy it at the pilot nuclear plant — it will be operated from a conventional control panel. But after the system is tested in backup mode and its reliability and safety are confirmed at the pilot unit, we hope to make the remote control a standard feature," Denis Kulikov says.

Market niche

There is a vast market for modular reactors with a capacity of up to 10 MW per module. They will replace obsolete generation capacity, both nuclear and fossil-powered, in the medium term and serve as local power sources for new industrial facilities in remote areas with decentralized power supply.

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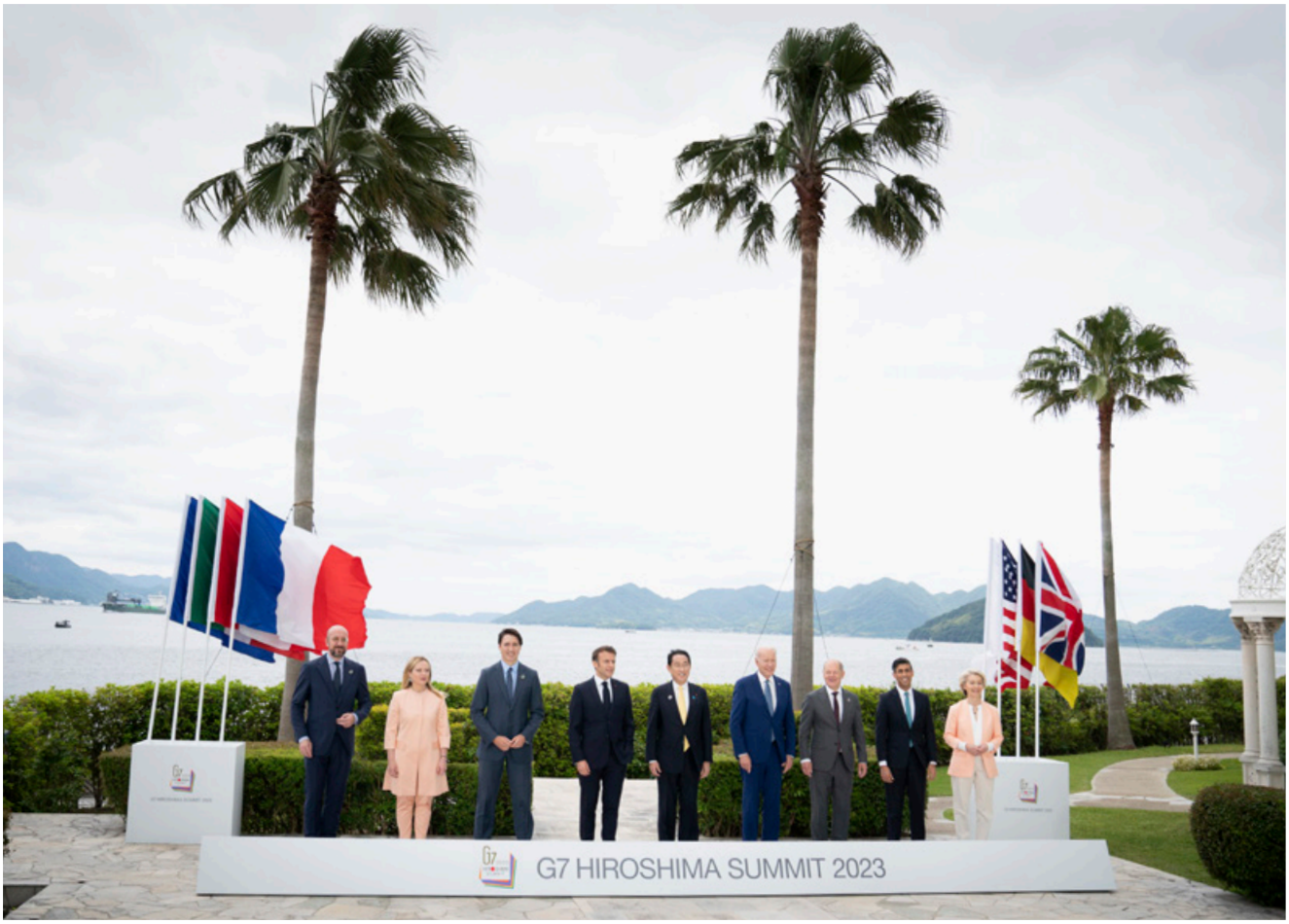


The Five Against Rosatom

Five nations agreed to counter Russia in the nuclear sector at the G7 Nuclear Energy Forum held in Sapporo, Japan. The alliance does not appear to be strong since the nuclear fuel supply chain is distributed between several countries. Their efforts will backfire, harming themselves and their willing and coerced allies as restrictions on competition will drive prices up.

The trend of countering Russia in the nuclear market continues. “Canada, France, Japan, the United Kingdom, and the United States have identified potential areas of collaboration on nuclear fuels to support the stable supply of fuels for the operating reactor fleets of today, enable the development and deployment of fuels for the advanced reactors of tomorrow, and achieve reduced dependence on Russian supply chains,” says a joint statement by the member countries of the new agreement.

Disrupted supply

Why did these countries join the agreement? “This multilateral effort would aim to recognize and leverage the unique resources and capabilities possessed by each country’s

civil nuclear sectors to establish a global commercial nuclear fuel market," the statement says.

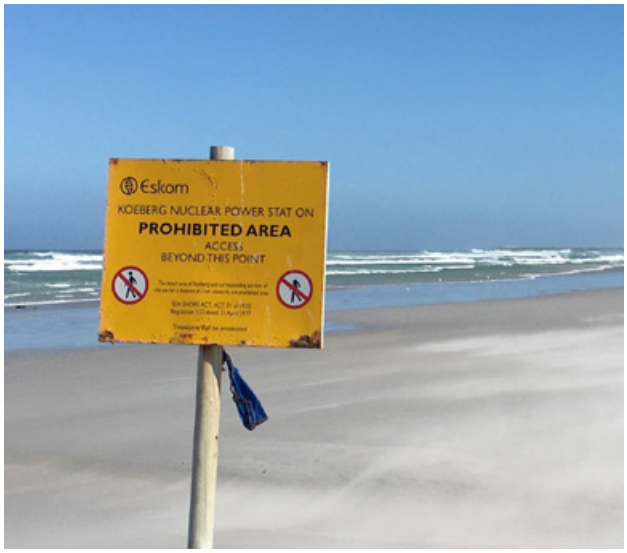
What does it really mean? It means that, unlike Rosatom, neither country has control over all the links in the nuclear fuel production chain. France, the UK and Japan do not produce uranium at all, while the output of uranium in the US is neglectable, at least for now. Neither Japan nor the US has conversion operations yet. Canada has no enrichment capacity. Fuel assemblies for Canada's CANDU and UK's gas-cooled reactors are not suitable for pressurized water reactors because the former use natural, not enriched uranium and have a different geometry of fuel assemblies. And, strictly speaking, the USA has no fabrication capacity because fuel assemblies are manufactured in Sweden.

Thus, the agreement looks like an attempt at creating Frankenstein's monster in the nuclear fuel segment. In the future, this situation is likely to persist, as building an entire supply chain within a single country is either impossible (due to the unlikelihood of France or the UK producing uranium) or extremely expensive (such as constructing new enrichment capacity in the USA).

But is the comparison with Frankenstein's monster appropriate? After all, a supply chain distributed across multiple countries is common in international manufacturing and trade.

History shows that only individual parts of this 'supply chain monster' have been functional so far. For example, yellowcake deliveries from Canada to the US, US-Japanese cooperation in the PWR fuel production (Mitsubishi Metal Corp. has been manufacturing zircaloy tubes with Westinghouse Electric technology since 1958, etc.), a contract signed last summer between France and Japan to reprocess spent nuclear fuel from Japanese reactors, and so on. However, even if we assume that a single supply chain comprising each of the parties to the agreement is built, it is safe to say that such a chain will be fragile since its every 'link' will pursue not only the common goal but also, as much as possible, the best deal for itself.

Another reason why the chain will be fragile is due to the unreliable or unpredictable behavior of the links. For example, the US did not renew uranium purchase contracts with Canada in 1959. Similarly, the UK refused to buy uranium, as it believed it would require less of it. The Canadian government was forced to purchase uranium for its reserves at an annual average of 500 tons until 1974 compared to 12,000 tons per year before the curtailment of supplies. A more recent example is Westinghouse: the company went bankrupt due to poor management, nearly dragging down its majority shareholder, Toshiba of Japan, which then had to restructure its business and sell some of



its assets. The most recent example of this detrimental attitude towards partners is Australia's cancellation of a contract with France for the construction of diesel-electric submarines. Subsequently, Australia entered into a new agreement with the United States to build nuclear submarines.

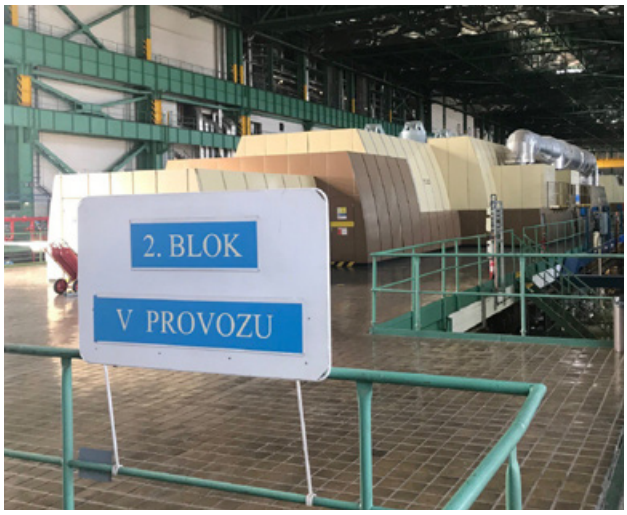
South Africa's Koeberg nuclear power station suffered a mishap. Its two reactors were built, and supplied with fuel, by the French Framatome. In the 1990s, Westinghouse decided to bid for the supply of fuel to Koeberg. The first fuel delivery from the American manufacturer arrived at the station in 2000. The fuel supply license expired in 2020, and so did the intergovernmental agreement between South Africa and the United States last December. Attempts to extend it failed. The license was renewed on a provisional basis, but the current situation cannot be called stable. Koeberg can only hope that the fuel deliveries will not be suspended because otherwise the nuclear station will be shut down and the energy crisis in the country will intensify causing rolling blackouts. This poses a significant problem not only for the local residents but also for the Western owners of local mining companies. The energy crisis contributed to the growing shortage of platinum on the market this year as South Africa is one of its largest suppliers.

Rising prices

The agreement, of course, benefits nuclear fuel companies in the member countries. They will receive political support and, potentially, business development subsidies and new contracts. Such contracts, however, will be disadvantageous to the buyers of nuclear fuel, including those from the same member countries and their political allies.

We wrote in this year's first issue that the price of Russian uranium in the US market was half that of the US producers and one and a half times lower than the market average. Refusing to buy Russian uranium increases nuclear fuel prices, making nuclear power generation in the United States less competitive. Naturally, this is well understood in the United States, which is why pragmatic cooperation between Rosatom and US utilities continues despite concerns in the media.

Higher prices quoted by Western suppliers, as compared to those of Russian uranium are also a concern in Bulgaria. "The suspension of the Belene NPP project and the impossibility of delivering it with potential Russian investors will freeze almost EUR 4 billion of Bulgarian taxpayers' money, won't it? How much would it have cost to build Belene with the participation of both European and Russian investors? Around EUR 10 billion. And how much would the possible cooperation with Westinghouse cost, which the previous parliament voted for? About EUR 30 billion. The difference is obvious … I ask for the umpteenth time whose interests are we protecting — Bulgaria's or someone else's?" says Borislav



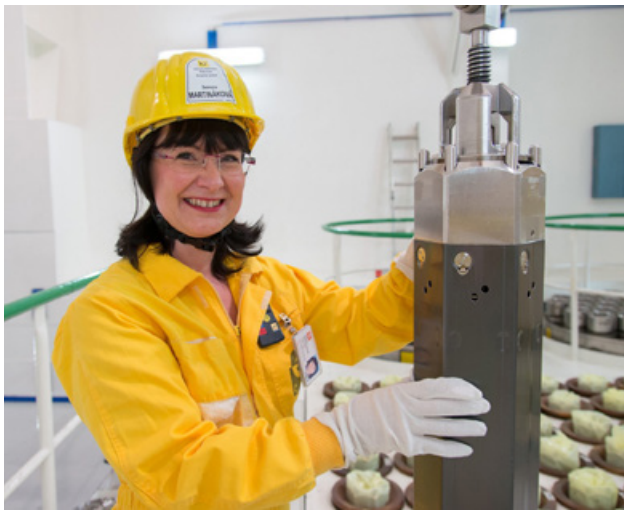
Gutsanov, Secretary of the Executive Bureau of the Bulgarian Socialist Party.

Price growth is therefore driven by a combination of market and political factors. Restricting a key supplier from the market creates a shortage in relevant market segments; as a result, buyers will purchase more, and the remaining suppliers will raise prices as competition decreases. What can hold them back? The entire world saw the effects of such restrictions in the hydrocarbons market in 2022 after the supplies from Russia were sanctioned. However, the nuclear fuel market also experienced a frenzy and an increase in demand. Urenco CEO Boris Schucht stated that orders were up 24% in 2022 and more than 10% in the first quarter of 2023.

Specifics of market behavior

How do member countries plan to isolate Russia? "The supply of civil nuclear technology, equipment, or materials would be subject to applicable domestic laws, regulations, and international agreements," the authors of the agreement suggest. The agreement also provides for deliveries to 'third countries'. It is clear, even without loud yet vague statements, that these primarily refer to countries of Eastern Europe. These include Ukraine (which signed a ten-year contract with Cameco in February for the supply of unenriched hexafluoride), Bulgaria (it signed contracts with Cameco, Urenco, and Westinghouse in April for the supply of nuclear fuel to the Kozloduy NPP), and the Czech Republic (Westinghouse and ČEZ signed a contract in March).

It should be made clear, though, that there is no alternative to Rosatom as a supplier of fuel



for VVER-440 reactors, despite Westinghouse's statement that the fuel deliveries would begin next year. However, even the US company has admitted it would take seven years to substitute the Russian fuel. Fuel reloading may, therefore, begin in 2030 at the earliest. For the record: it took Westinghouse 14 years (counting from the moment when the decision was made on the alternative fuel until the first fuel batch was reloaded) or 10 years (counting from the start of engineering studies) to launch the fabrication of VVER-1000 fuel assemblies in Ukraine. Another five years were spent to remedy the flaws that affected the safety of fuel assemblies.

It should also be stressed that VVER-440 reactors were built in Europe in the 1970s and the 1980s. These are very good reactors of Russian design; their service life has been extended, but it is not infinite. They will be decommissioned in 2030–2045. This means the alternative fuel will be supplied for a maximum of 5 to 15 years. During this time the supplier will have to recover its development costs and earn the planned profit. We can only sympathize with the consumers who have refused to buy the more affordable, reliable, and easy-to-use Russian fuel for political reasons.

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The biggest concern is, of course, how safe the alternative fuel will be, especially in combination with the Russian fuel assemblies (the fuel in the core is replaced in batches, not all at once). The fuel manufacturers and plant operators will have to recalculate the reactor core parameters for each reactor. This is not an easy process: only a few people can do that, and the risks are significant. It is obvious that the blame will lie with the alternative fuel manufacturers should an accident occur. For this reason, politics and market competition should by no means take precedence over nuclear safety.

Rosatom is aware of the risks the alliance poses and will protect its interests. The Russian nuclear corporation is growing, building relationships, forming partnerships, deepening and expanding cooperation with various countries by offering them the best solutions that have already been tested, and developing new solutions for the nuclear power, non-power, and non-nuclear segments. Rosatom builds clean and reliable nuclear plants powering their host economies, creates and equips nuclear science centers, fabricates medical isotopes and radiopharmaceuticals, and takes care of the environment by decontaminating legacy sites and facilities. This is what should normally be done for the good of this planet and the people living on it. And there are many who want to join us in this work. NL

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