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Representatives of TVEL, ENUSA, ENSA and IDOM signing the Memorandum

TVEL Joins Spanish Trio

TVEL agreed to collaborate with Spanish ENUSA, ENSA and IDOM on the decommissioning of nuclear facilities and management of radioactive waste. Rosatom's nuclear fuel company plans to enhance its technical and commercial capabilities on the market, which will inevitably grow in the coming years.

Rosatom's TVEL Fuel Company signed a memorandum of understanding on the development of cooperation with Spanish companies ENUSA, ENSA and IDOM (for details see TVEL Partners below). The first area of collaboration involves decommissioning and dismantling of nuclear and radiation facilities. The second area is radioactive waste management and related engineering and consulting services. The parties also signed a roadmap on joint projects to be agreed upon in the near future.

Market interest

According to IAEA PRIS, there were 187 shutdown reactors with the total net capacity of 83,018 MW as of 10 March 2020. Nine power units with the total capacity of 5,976 MW were shut down in 2019 alone. To compare, there were 442 operating reactors with the total capacity of 390,468 MW as of the same date. Since their service life is expiring gradually, the number of shutdown reactors will inevitably increase with years. **"Around one quarter of the current nuclear capacity in advanced economies is set to be shut down by 2025 – mainly because of policies to reduce nuclear's role. The fate of the remaining capacity depends on decisions about lifetime extensions in**

the coming years," the IEA's report entitled Nuclear Power in a Clean Energy System (May 2019) said.

TVEL sees great commercial opportunities in the growing number of shutdown nuclear power plants and other facilities. According to the company's estimates, the market for nuclear decommissioning services will exceed EUR 100 billion by 2030.

This applies not only to power plants, but to other nuclear facilities as well. TVEL plans to take part in the decommissioning of research reactors and rehabilitation of nuclear sites, including uranium mines. The company is also interested in similar projects in other areas.

"We plan to work both independently and in partnerships with foreign companies. The form of participation can be different – a consortium, a contract, a subcontract or anything else. The specific form will depend on the market conditions, local regulations, customer needs, and so on," the company's press service explained.

In 2019, Rosatom made its subsidiary TVEL an industry integrator for the decommissioning of nuclear facilities (including reactors, reactor internals, and primary loop components) and management of associated nuclear waste. As an integrator of decommissioning services, TVEL sees Spain and other nuclear countries as its potential market.

Experience gained

In 2008–2015, Rosatom Group companies completed 37 projects on seven sites in Russia. All of them were launched as part of

the Nuclear and Radiation Safety national program. A total of 57 facilities were decommissioned, and 13 more were prepared for decommissioning.

The projects covered by the program were diverse; each required an individual approach and unprecedented solutions. TVEL and its subsidiaries were engaged in the deactivation of highly enriched uranium processing, radiochemical, gas diffusion and fuel fabrication facilities and mothballing of radioactive waste storage sites. They also decommissioned a nuclear reactor at Chemical Metallurgical Plant in Krasnoyarsk and a uranium graphite reactor at Siberian Chemical Plant in Seversk.

At present, Rosatom is carrying out the second Nuclear and Radiation Safety national program that will last until 2030. TVEL's competency centers, including Bochvar Russian Research Institute of Inorganic Materials, Central Design and Technology Institute, Angarsk Electrolysis Chemical Plant, and Siberian Chemical Plant, are involved.

Rosatom is already participating in international decommissioning and dismantling projects in Germany and Bulgaria. Rosatom's subsidiary NUKEM

has developed a detailed concept for the dismantling of a steam dryer and water separator at the Mühleberg Nuclear Power Plant, a concept study for the treatment of radioactive materials generated during the decommissioning projects for EnBW Kernkraft GmbH, and a design for the dismantling of equipment in the controlled areas of Kozloduy NPP Units 1–4.

In 2019, a consortium of NUKEM Technologies and German Uniper Anlagenservice won a contract for the dismantling of four reactor vessels at the Swedish nuclear power plants Oskarshamns and Barsebäck. Another international consortium involving NUKEM is engaged in the decommissioning of Biblis and Philippsburg Nuclear Power Plants in Germany and construction of a spent fuel storage facility at the Kozloduy NPP.

TVEL partners

- **ENUSA** is a Spanish state-owned company specializing in the development and fabrication of nuclear fuel and providing engineering services for the management of fresh and irradiated nuclear fuel.
- **ENSA** is a Spanish state-owned company manufacturing machinery and equipment for nuclear power plants and providing nuclear fuel management, maintenance, deactivation and decommissioning services. ENSA also develops and manufactures flasks and racks for the transportation and storage of nuclear fuel.
- **IDOM** is an international company headquartered in Spain and providing engineering and consulting services in such areas as industrial design, nuclear synthesis, fissile materials and nuclear fuel cycle.

"TVEL Fuel Company and its subsidiaries have gained extensive experience in the delivery of such high-tech complex projects. As an industry integrator of these competencies, TVEL can act as a one-stop-shop contractor. Alliances with international vendors will supplement our competencies and make us more efficient in the overseas markets," TVEL Director for Global Development Dmitry Bazhenov said.

Umatex Playing Hockey with Composite Sticks

Rosatom's composite materials division Umatex had announced that its products would be showcased at the world's largest composites industry event JEC World in March, but the show was later rescheduled for May because of coronavirus. We at Rosatom Newsletter have decided that the announcement was a good reason to talk about the composite materials business.

Umatex is Rosatom's division and an umbrella brand for a number of R&D institutes, production facilities and trading companies dealing with carbon composites, from feedstock to end products. For the history of the group, see the Umatex-Branded Assets below.

Umatex-branded export products include carbon-fiber fabrics and prepregs. Apart from composite materials, the company also exports products made of them, such as hockey sticks and vehicle body kits. **"In 2019, we exported RUB 99 million of carbon fibers and RUB 92 million of fabrics and prepregs. We also export composite sticks for professional hockey players, selling 3,000 pieces per annum for RUB 15–20 million. This is 10% of what we sell in the Russian market,"** an Umatex representative said. The group believes that these results are only the beginning and plans to increase exports both in physical and financial terms.

> **Prepregs** are 'pre-impregnated' composite materials consisting of a woven or non-woven fabric impregnated with a thermoset polymer matrix.

Construction and repair

Umatex products and materials for construction applications, such as pontoons, temporary road surfaces, reinforcement bars, shapes and external reinforcement systems, are popular on the Russian market.

FibArm carbon tapes were used to reinforce steel pipes at the Ezmi Hydropower Plant (a subsidiary of Russian hydroelectricity company RusHydro). Some of the water pipes were damaged by corrosion; the thickness of walls decreased, and there was a risk of leakages and ruptures. In order to prevent accidents and increase the wall thickness, the pipes were wrapped with carbon-fiber tapes pre-impregnated with an epoxy matrix. Then a coating was applied to protect them against UV radiation and fire. The result is a safe and reliable operation and an extended maintenance interval.

Russian power distribution company Rosseti used Umatex materials to reinforce transmission towers in the Urals. Their concrete pylons and foundations had been damaged with time: reinforcement bars inside the structures were corroded, so the actual area of reinforcement shrank. The pylons were repaired with the use of FibArm external reinforcement system. The repair process took little time and did not require putting the towers out of operation. What is more, the use of composite materials reduced repair costs as compared to conventional technology.

"Conventional methods of reinforcement using concrete and steel are relatively expensive and labor-intensive and often require putting the structures out of use. Composite materials solve these problems," Nikolay Kravchenko, CEO of Kompozit (Ural company, Rosatom's partner) said.

Power engineering

In power engineering, Umatex targets three major areas: nuclear generation, wind generation, and power grids. The group supplies nacelles for Rosatom's wind turbines. A nacelle is a cover that is installed on top of the tower and housing all of the generating components in a wind turbine. By now, Umatex has supplied 150 out 388 nacelles provided for in the contracts with all Rosatom wind farms. Some of the wind turbines with Umatex-made nacelles are already in operation: Rosatom's wind farm in Adygeya fed its first kilowatts into the power grid in early March.

Umatex also produces a new generation of gas centrifuges for the companies fabricating nuclear fuel. Another product for the power engineering segment – composite core conductors – can be used in power grids.

Sport victories

Toprak Razgatlıoğlu from Kawasaki Puccetti Racing won the WorldSBK race in September aboard a bike in a carbon fiber reinforced plastic body kit. The kit was made at the Umatex R&D Center.

High rigidity and low weight of the carbon fiber reinforced plastic body kit enabled the rider to accelerate the motorbike to above 300 km/h and corner more precisely. Bikes with composite body kits vibrate less and are more stable on the track.

"An advanced aerodynamic design of the body kit had a positive effect on the bike's speed, having increased it by 3–4 kilometers per hour," Umatex CEO Alexander Tyunin said.

Visitors to JEC World, which is now scheduled to take place on May 12–14 in Paris, will have an opportunity to make selfies with the 'victorious' motorbike.

The Umatex team has also decided to bring ZaryaD hockey sticks to the show in France and play hockey right there. **"Sticks will be the main prize of the tournament,"** they promised.

Umatex-branded assets

Argon is one of the oldest plants of Rosatom's composites division. Commissioned in 1976, the plant has been producing carbon fiber for the nuclear industry since the 1980s. At present, Argon manufactures acrylic and carbon fiber and related products (tapes, textiles, etc.).

In 2009, one of Rosatom's subsidiaries acquired Chelyabinsk-based Carbon and Composite Materials Plant, which manufactures high-modulus carbon fibers, carbon-based heat insulating material, discrete carbon fibers, 3D reinforced carbon-carbon structural materials and carbon-fiber reinforced graphite composites.

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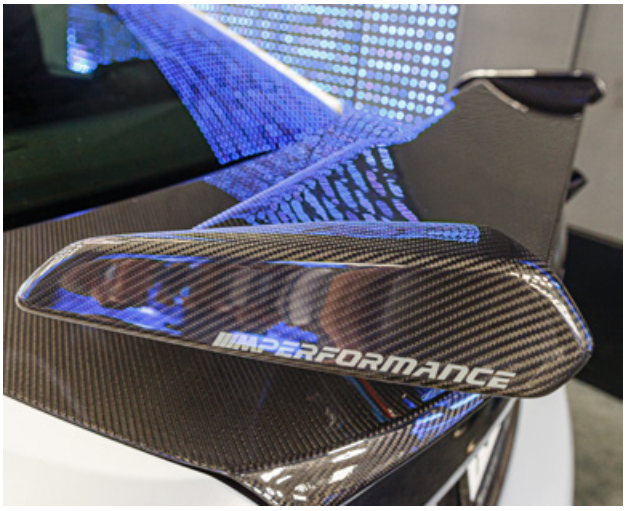

In 2011, Rosatom received control over KhimPromEngineering, which is now a holding company of the composites division.

In May 2015, Alabuga-Volokno plant built on commission from Rosatom produced the first batch of carbon fibers under the UMT trademark. It is planned to install four more production lines here to increase the output from the current 1,400 tons to 10,000 tons of fibers per annum.

In 2013, Umatex established a Research and Development Center at Technopolis Moscow. The R&D Center synthesizes polyacrylonitrile-based compounds and develops prepregs, PAN precursors (feedstock for more complex PAN-based compounds), carbon fibers, polymer matrices and new technology for the production of carbon-fiber structural elements, and studies new treatment methods for carbon-fiber surfaces.

In 2018, Rosatom acquired a 100% share in Prepreg-SKM. Prepreg-SKM is Russia's only mass producer of carbon-fiber fabrics and prepregs. The company also manufactures fabrics and prepregs based on glass and aramid fibers, which are used in marine, aircraft, construction and other applications.

The most recent acquisition in the carbon-fiber composite segment is a 50% stake in ZaryaD, a hockey stick manufacturer, purchased in July 2019.

Umatex Group also includes trading companies in Europe (Prague) and Asia (Shanghai). NL

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Mining and Chemical Plant bird's-eye view

Plant inside the Mountain

Rosatom Newsletter starts Rosatom Anniversaries, a series of articles dedicated to the 75th anniversary of the Russian nuclear industry. Our readers will learn about the greatest landmarks in its history and pace-setting nuclear companies. This issue will tell the story of Mining and Chemical Plant (MCP) celebrating its 70th anniversary this year.

The history of MCP dates back to 26 February 1950.

Settling down

The primary goal of the plant was fabrication of plutonium for nuclear weapons.

Considering international tensions the site for the plant had to be as safe as possible. **"The site on the bank of the Yenisei River in 50 km away from Krasnoyarsk is believed to be the most practicable. Compared to the other sites under consideration, it is the most distant from potential air bases of the enemy and allows for the construction of the plant's core facilities deep under the rock, with the distance from the roofs of the highest buildings to the surface being 200–230 meters. Water from the Yenisei is sufficient to meet the needs of the plant,"** reads the cover letter submitted together with the project documents.

The construction was a challenging endeavor in terms of technology. A side-hill cut was made along the Yenisei's right bank to accommodate railway and car roads. Rock taken out of the mines was used to build the roads.

Since the plant was located inside a mountain, it needed a complex ventilation system capable of supplying several millions of cubic meters of air per hour. In winter, the air supplied was pre-heated by special heaters installed inside the intake channels.

To protect the core facilities against shockwaves, expansion chambers were built in transportation and ventilation tunnels, followed by strong protective devices made of steel.

Functional transformations

Three plutonium breeder reactors had long been the 'core' of the plant. The reactor code-named AD was commissioned in 1958, ADE-1 in 1961, and ADE-2 in 1964. The first two reactors were shut down in 1992 after the collapse of the Soviet Unit and termination of defense contracts. ADE-2 remained in operation until April 2010 as it supplied heat and electricity to the neighboring town of Zheleznogorsk.

After the reactors were shut down, MCP has concentrated on providing spent nuclear fuel storage and transportation services.

Trials of a new transport and packaging set for spent nuclear fuel of the VVER-1000 and VVER-1200 reactors

It also processes spent fuel without creating liquid waste. Isotope Chemical Factory, a subsidiary of MCP, manufactured nuclear casks, flasks, ampoules and other equipment for spent nuclear fuel management and provided transportation and storage services for RBMK-1000 and VVER-1000 spent fuel. The factory operates wet and dry storage facilities.

Over the last fifteen years, MCP has been focusing its efforts on 'closing' the nuclear fuel cycle and fuel recycling. For this purpose, another subsidiary of MCP, Radiochemical Factory, has begun fabricating mixed oxide nuclear fuel (MOX fuel, a mixture of uranium and plutonium oxides) for fast neutron reactors, from pellets to assemblies. The factory's capacity is 400 fuel assemblies per year.

In August 2019, the first 18 fuel assemblies containing MOX fuel were loaded into the BN-800 reactor of the Beloyarsk Nuclear Power Plant. 180 more assemblies will be loaded in 2020. In 2021, all the assemblies in the reactor core will be replaced with MOX fuel.

The mixed oxide fuel allows for the use of depleted uranium in the fuel for nuclear reactors. Depleted uranium contains mostly U-238, which turns into plutonium in the fast reactor. What is more, the fabrication of MOX fuel allows for repeated use of irradiated fuel, burning it up and reducing the amount of nuclear materials in circulation 100-fold.

Also for the purpose of closing the nuclear fuel cycle, MCP has established a pilot center for the spent nuclear fuel (SNF) management. The first phase of the Pilot SNF Management Center was launched in 2015. The second phase is planned to be launched in 2020.

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Visit of Alexey Likhachev to the Mining and Chemical Plant

The Center operates several test chambers to develop a procedure for reprocessing any kind of spent nuclear fuel with a capacity of 5 tons of SNF per annum and an end-to-end reprocessing line for spent nuclear fuel from VVER-1000 reactors with a capacity of 400 tons per annum. Fuel assemblies are first crushed; then cladding and structural materials are separated from fuel and processed separately.

The resulting materials are powdered triuranium octoxide, a mixture of uranium, plutonium and actinide oxides, and solidified fission products. Powdered uranium and plutonium oxides will be used to fabricate MOX fuel, while fission products will be conditioned until safe, compacted and placed for long-term controlled storage.

The Pilot SNF Management Center will be supplemented with a molten salt research reactor that will be used to burn up minor actinides, toxic highly radioactive elements contained in spent nuclear fuel. The decision to build this reactor was made in November 2019; its design is now being finalized. NL

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SMR in the Making

Many nations believe small modular reactors (SMRs) to be a tool capable of ensuring reliable access to electricity, heat and fresh water without greenhouse gas emissions or a necessary connection to the centralized power grid. Governments have already made first steps in supporting SMRs and vendors in constructing them. Rosatom is the first company in the world to have commissioned a floating SMR. Discussions are now underway to build an onshore nuclear plant.

We are moving away from talking about the advantages of SMRs to actually doing things, several countries have already requested and analyzing concrete proposals.

Pioneering countries

ČEZ, a state-owned Czech energy company, a major electricity supplier in a number of Central European countries, sent requests for proposals to 11 companies developing SMR designs enquiring for technical details regarding the possibility of constructing an SMR in the Czech Republic. The potential suppliers include Chinese, Russian, French, UK, South Korean and Argentinean companies. In March 2020, ČEZ started analyzing the received proposals.

In February, Prague hosted the Small Modular Reactors 2020 conference. There are currently at least 55 SMR projects all over the world with too many differences – manufacturing materials, fuel and its types, fuel enrichment techniques, types of coolant, and other parameters. Josef Myšak, Strategic Development Manager at research company ÚJV Řež, believes that an in-depth analysis

of such a multitude of projects is impossible without competent experts and a consistent computer code to assess the designs. This is the problem that the Czech regulators and power generation companies will also have to deal with.

"We are talking about the designs rather than vendors. We have decided to focus on light-water reactors, most of which are pressurized water reactors. We have selected several companies, whose designs seem interesting, and want to study them in more detail. This does not mean, however, that the companies that are not on our list will be in a disadvantaged position," EDU II Executive Director Martin Uhlíř explained in his speech at the same conference.

According to local media, Czech Prime Minister Andrej Babiš said last spring that small modular reactors were the best option for new nuclear builds in the country.

Canada is another country that supports construction of small modular reactors. In December 2019, the premiers of three Canadian provinces – Ontario, Saskatchewan and New Brunswick – agreed **"to work together to explore new, cutting-edge technology in nuclear power generation to provide carbon-free, affordable, reliable, and safe energy, while helping us unlock economic potential across Canada, including rural and remote regions. We have signed a Memorandum of Understanding, committing to collaborate on the development and deployment of innovative, versatile and scalable nuclear reactors, known as Small Modular Reactors, right here in Canada."**

In January 2020, the King Abdullah City for Atomic and Renewable Energy (Saudi Arabia) and the South Korean Ministry of Information and Communications Technology signed a pre-project engineering contract for the construction of a small modular reactor in Saudi Arabia.

In the United States, the Department of Defense earmarked funds for the development of micro reactors. In two years, the department will select one of the three companies that received funding to finalize design documents and build a pilot reactor.

Russia's Rosatom is searching for a location to build its first onshore SMR.

Advantages of SMR

Small modular reactors have the same advantages that large capacity reactors do. First, they do not produce direct emissions. This applies to both greenhouse gases, which are believed to cause global warming, and soot and other harmful substances. Smog in Chinese cities where power stations run mostly on coal has become one of the powerful drivers behind the rapid development of nuclear generation in China.

Second, they are capable of generating electric power and, when needed, fresh water

and heat reliably and regardless of changes in weather. Susceptibility to such changes is considered to be the key weakness of solar and wind farms in the absence of cheap power storage systems.

However, small modular reactors have more to offer. They have their particular benefits mentioned on the World Nuclear Association website:

- Small power and compact architecture and usually (at least for nuclear steam supply system and associated safety systems) employment of passive concepts. Therefore there is less reliance on active safety systems and additional pumps, as well as AC power for accident mitigation.
- The compact architecture enables modularity of fabrication (in-factory), which can also facilitate implementation of higher quality standards.
- Lower power leading to reduction of the source term as well as smaller radioactive inventory in a reactor (smaller reactors).
- Potential for sub-grade (underground or underwater) location of the reactor unit providing more protection from natural (e.g. seismic or tsunami according to the location) or man-made (e.g. aircraft impact) hazards.
- The modular design and small size lends itself to having multiple units on the same site.
- Lower requirement for access to cooling water – therefore suitable for remote regions and for specific applications such as mining or desalination.
- Ability to remove reactor module or in-situ decommissioning at the end of the lifetime.

When people talk about disadvantages of small modular reactor, they often mention electricity cost, which is usually higher than the price of electricity produced by large reactors. This is true, but SMRs are cheaper than large stations in absolute terms. For example, the construction of a 342 MW onshore plant in Russia's north (currently discussed between Rosatom and interested parties) will cost around RUB 200 billion (approx. USD 2.7 billion), while the construction of Hinkley Point C in the UK is estimated at GBP 21.5–22.5 billion (USD 26.7–27.9 billion). Besides, not every nation needs so much new capacity because the demand is low or the existing grid infrastructure (substations, tower, etc.) is insufficient. In this context, an SMR could be compared to buying bananas. The price per banana will be lower if we buy a lot, but one needs only a few bananas to feed a family. And buying a kilogram will definitely hit your pocket less than buying a container.

Finally, a nuclear power plant contributes to the social and economic development, alongside with securing energy supplies. **"SMRs could be used in conjunction with other systems to address non-energy needs, such as providing thermal energy for desalination plants, industrial process heat, or for district heating systems. These non-electric functions are not available from most conventional renewable resources and could help developing nations meet other SDGs, such as SDG 6 (clean water and sanitation), SDG 9 (industry, innovation and infrastructure), or SDG 11 (sustainable cities and communities),"** Elina Teplinsky and Sid Fowler of Pillsbury Winthrop Shaw Pittman LLP, a US-based energy consulting company, said.

Talking to consumers

The SMR target audiences include large mining projects, armed forces, and remote communities relying on autonomous sources of heat and power. These are mostly unsustainable diesel and coal fired power plants. It is expensive to supply them with fuel, so the construction of SMRs is totally justified. **"SMRs could generate clean and low-cost energy for both on-grid and off-grid communities, connect more remote and rural areas of our province, and benefit energy-intensive industries, including the mining and manufacturing sectors. It could also drive economic growth and export opportunities as these technologies are further adopted across the country and around the world,"** the joint communiqué of the premiers of three Canadian provinces read.

Installation of a steam generating unit at Akademik Lomonosov

At the PDAC Convention, the world's largest mining industry event, the Canadian Nuclear Laboratories (CNL), Canada's top nuclear science and technology organization, did a seminar for mining industry companies and demonstrated advantages of small modular reactors.

Rosatom is doing the same. The Russian state nuclear corporation considers three SMR options based on the RITM-200 reactor. All three target industrial consumers, who need a stable and reliable power source located in the proximity of mining and production facilities and capable of generating electricity for several decades. The design is scalable, with the capacity ranging from 50 to 300 MW, so the consumers can choose an option that will meet their needs the best.

Rosatom's expertise

Russia's achievements in the development and operation of SMRs are remarkable. In late 2019, the Akademik Lomonosov floating nuclear power plant fed its first electricity into the power grid and has generated over 25 million kilowatts since then. Now it is a point of interest at every international event where Rosatom is present with experts from different countries wanting to visit the station.

"No one has built floating stations before, so experts are interested how it was built, transported and commissioned," Artyom Larionov, a product manager at Rusatom Overseas, shared his impressions from Small Modular Reactors 2020. He told the audience about the design and performance of the

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floating nuclear power plant and other details like mooring, staffing, protection systems, etc.

Participants of the conference in Prague were also interested in the onshore SMR design based on the RITM-200 reactor. Initially designed for nuclear icebreakers, the reactor has already been tested: in October 2019, two RITM-200 reactors onboard the Arktika icebreaker went critical. Four more reactors of the same design are installed on the Sibir and Ural icebreakers.

The conference participants were also interested in when the license for the construction of a Russian-designed onshore SMR would be obtained. Svyatoslav Pikh, a project manager of the SMR Group at Rusatom Overseas, said that Rosatom expected to obtain a site permit for an onshore SMR no later than 2023. Rashet Sharafutdinov, Deputy Director of the Russian nuclear regulator Rostechnadzor, announced earlier that the agency was analyzing the compliance of the RITM-200 based onshore SMR with the applicable standards and requirements. The construction license is expected to be granted in 2024. Construction will begin in the same year; the unit is scheduled to come online in 2027.

The world's only floating NPP Akademik Lomonosov

According to Rusatom Overseas President Evgeny Pakermanov, the case of the Czech Republic is exemplary, **"The Czech Republic has a long track record of using VVER technology and an extensive grid infrastructure and is earnestly interested in developing SMRs. It only goes to show that small modular reactors have very good prospects across the globe, Europe included. We already see that the competition from leading vendors is growing in the segment and are ready to offer cost-efficient and time-tested solutions."** NL

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