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No facility at the Akkuyu NPP site in Turkey was damaged by the earthquake. Construction of all four reactor units is continuing. The companies involved in the project have sent people and equipment to provide relief to the devastated regions.

Natural disaster

A magnitude 7.8 earthquake struck Kahramanmaraş Province in southeastern Turkey on the night of February 6. Then, at 1:24 pm Moscow time, the second magnitude 7.7 shock occurred, followed by the third one of magnitude 6 a few minutes later. President Recep Tayyip Erdogan said it had been the most powerful earthquake since 1939.

The epicenter was located less than 50 kilometers away from the border with Syria, which was also affected. As of February 20, the death toll in Turkey exceeded 41 thousand people, with more than 105.5 thousand wounded. In Syria, more than 5.5 thousand people were killed and about 10 thousand wounded. Turkey declared seven days of mourning for the victims.

What happened to Akkuyu

The Akkuyu site experienced earth tremors of about magnitude 3 on the 12-point MSK-64 scale. **“Our engineers have identified no**

damage to the structures, cranes or on-site equipment," says Anastasia Zoteeva, CEO of Akkuyu Nuclear. Construction and installation works are continuing.

Earthquake resistance margin

According to Turkey's Earthquake Map compiled by the Disaster and Emergency Management Presidency (AFAD), the Akkuyu site is situated in a Category 5 zone, that is, the least prone to earthquakes. There have been no devastating earthquakes on record within a 50-kilometer radius of the site. Nevertheless, the design of the nuclear power plant accounts for local seismic hazards.

"The location of the epicenter in this region and multiple aftershocks are associated with the large tectonic structures, the East Anatolian fault and the Dead Sea fault, and their junction. When we were working on design documents for the project, we analyzed seismic hazards in the region and those territories were considered prone to earthquakes. In different models we built, they were ascribed maximum magnitudes 8.4, 8.2 and 7.9. The magnitude of the earthquake that occurred on February 6 is lower than that taken into account in our assessment of seismic hazards," says Mikhail Ivanov, Director for Akkuyu Design at AtomEnergoProekt.

He added that the seismic resistance assessments had been validated by Russia's leading research organizations, CKTI Vibroseism and Construction Research Center.

In order to make the Akkuyu site resistant to earthquakes, loose soils were removed down to the rock base and replaced with concrete. There are two seismic stations at the site, and another 12 within a 40-kilometer radius. Data from them are transmitted to Turkey's Kandilli Observatory and Earthquake Research Institute. **"If the monitoring reveals changes compared to the design specifications, they will be promptly recalculated and, if necessary, measures will be taken to reinforce certain structures,"** a press release by Akkuyu Nuclear says.

The design takes into account the probability of a combination of several factors, such as an increase in the sea level, formation of wind waves, tide, storm surge, barometric effects, etc. The nuclear power plant remains protected even if the sea level rises by 8.63 meters or a 6.55-meter high tsunami occurs (the probability of such a tsunami is once in 10,000 years).

Aid for the victims

Recep Tayyip Erdogan declared a three-month state of emergency in 10 provinces. Aid is sent to the country from all over the world.

Akkuyu Nuclear's Department for Mobilization, Civil Defense and Emergency

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Centers provides support to AFAD. The companies involved in the construction of the nuclear power plant organized campaigns to collect winter clothes and basic necessities for the victims. Employees of those companies and local residents brought outerwear, shoes, blankets, heaters, sleeping bags, and more. As soon as the evening of February 7, more than four tons of humanitarian aid was handed over to the municipal authorities of Silifke. Money was also collected at the nuclear power plant construction site and the Akkuyu Nuclear offices in Ankara and Moscow. Additional blood donation points were opened at the Red Crescent branch in Silifke and the workers' neighborhoods in Büyükeceli.

Akkuyu NPP contractors sent more than 700 people and about 80 vehicles, including cranes, tractors, excavators and dump trucks, to remove debris. Over 60 buses

were provided to take the doctors arriving at Adana Airport and deliver them to the victims. Fifteen firefighters from the Akkuyu NPP Fire Department helped put out the fire in the Port of Iskenderun.

"It is impossible to remain indifferent to such a disaster, and we are grateful to our colleagues and all the construction site employees for their help. When every second is precious, people and resources must be mobilized instantly. We will, of course, go beyond the measures we have taken and provide all possible support to those affected. We mourn together with the people of Turkey, express our deepest condolences to the families of the victims, wish a speedy recovery to the injured, and hope that everyone who is still under the debris will be rescued," Anastasia Zoteeva said.

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Isotopes Become Radio-pharmaceuticals

On January 20, construction started to build Europe's largest radiopharmaceuticals factory. The new facility will be able to multiply Russia's production of highly sought-after substances for diagnostics and treatment of cardiovascular and neurodegenerative diseases and oncologies.

The factory is being built on the premises of Karpov Research Institute of Physics and Chemistry (NIFKhI, part of Rosatom) in Obninsk. As one of Russia's largest manufacturers of radiopharmaceuticals, NIFKhI is engaged in fundamental research and development of a wide range of diagnostic and therapeutic radiopharmaceuticals and improves radiochemical production methods and processes.

The new factory is planned to be commissioned as soon as 2025. Production processes will be fully compliant with the good manufacturing practice (GMP), an international quality control system for the production of medicines. **"We do a lot of construction work around the world, and we will use our best construction technology here. Beyond that, we have experience in building nuclear medicine centers. As an example, last year we built such a facility at the Dmitry Rogachev Center of Pediatric Hematology, Oncology and Immunology,"** Rosatom Director General Alexey Likhachev said when speaking at the factory foundation concreting.

Having 21 production lines, the factory will produce dozens of new radiopharmaceuticals and active pharmaceutical substances, Rosatom plans. They will include well-known and much-demanded substances containing isotopes of iodine-131, samarium-153, and molybdenum-99. The factory will also produce active radiopharmaceutical substances and medicines based on lutetium-177, actinium-225, radium-223 and other isotopes.

The Russian nuclear corporation was among the first in the world to set up commercial production of ytterbium-176 and lutetium-176, which are used as source materials for lutetium-177. Its employees also have developed and put into practice a number of production methods for lutetium-177. It is this isotope that is contained in most of advanced targeted radiopharmaceuticals for the treatment of inoperable tumors and metastases. Lutetium-177 is currently produced at two of Rosatom subsidiaries. Globally, about 30% of radiopharmaceuticals containing this isotope are produced from raw materials of Russian

origin. Actinium-225 is another isotope that, like lutetium-177, is considered the most promising for targeted therapy of inoperable metastatic cancers, such as prostate cancer.

In general, radiopharmaceuticals are used to treat neuroendocrine tumors, myeloid disorders, internal organ cancers, bone cancers, brain tumors, solid tumors, neuroblastoma, non-Hodgkin's lymphoma, etc.

"Today, the Russian nuclear corporation is one of the world leaders in the production of medical isotopes. But isotopes are only source material for medicines. We also produce about 10 of them, but their quantity should be much larger. This is the goal we want to achieve with the new factory in Obninsk," Alexey Likhachev said.

In addition to supplying products to the Russian market, Rosatom regularly ships over 20 globally sought-after medical radionuclides to more than twenty countries, and manufactures a number of ready-to-use medicines and radioisotope generators. In particular, Rosatom signed medium-term contracts for the supply of lutetium-177 and actinium-225 to Europe, Latin America and Japan in 2021. Overall, medical radioisotopes produced by Rosatom enable about 1 million diagnostic and therapeutic procedures in Russia and 1.5 million worldwide every year. In terms of certain isotopes, the Russian nuclear corporation accounts for 20% to 30% and even up to 100% of total deliveries on the global scale.

Rosatom has signed a cooperation agreement with the Russian Federal Medical and

How diagnostic radiopharmaceuticals work *(Source: NIFKhI data)*

Diagnostic procedures are based on the property of isotopes to be selectively accumulated in certain organs and tissues. Radiation emitted by attached radionuclides helps trace and localize the substance in the body with high precision.

• Sodium pertechnetate containing technetium-99m accumulates in the thyroid gland but does not affect the synthesis of thyroid hormones. For this reason, it is used in thyroid diagnostic procedures in patients taking antithyroid drugs. Besides, the blood clearance rate of sodium pertechnetate allows estimating blood flow dynamics in different organs (brain, heart, etc.).

• Due to the selective accumulation of iodine-131 in the thyroid gland, sodium iodide containing this isotope allows determining the functional state of the thyroid gland and visualizing it during radiometry and scanning.

• Sodium o-iodohippurate labeled with iodine-131 is rapidly excreted from the circulating blood by the kidneys. The degree and time of accumulation and excretion by the kidneys are used to determine their functional state.

• Ureacaps, a medicine containing carbon-14, is used to detect Helicobacter pylori bacteria in the human body with a breath test. This diagnostic method is based on the indirect measurement of urease, an enzyme secreted by the bacteria. Since urease is not normally present in human tissues and other urease-producing bacteria do not colonize the human stomach, the presence of urease in the stomach indicates the presence of Helicobacter pylori.

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Biological Agency (FMBA) with an intention to jointly develop radiopharmaceutical production methods and quality control procedures. Joint research programs will be aimed to confirm the efficacy, safety and quality of nuclear medicines. The agreement also provides for preclinical and clinical trials at FMBA's research and therapeutic facilities.

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MBIR: Lightweight, Fast, and Unparalleled

We continue a series of articles on innovative reactors designed and built by Rosatom. This article will tell you about MBIR. On January 18, a reactor pressure vessel was installed in its permanent position at the MBIR construction site.

What is MBIR

MBIR is a Russian acronym for a 'multi-purpose fast-neutron research reactor'. It stands out for its a large power capacity of 150 MW and will be the world's most powerful research reactor after commissioning. MBIR is built at the Research Institute of Atomic Reactors (RIAR, part of Rosatom).

Faster than planned

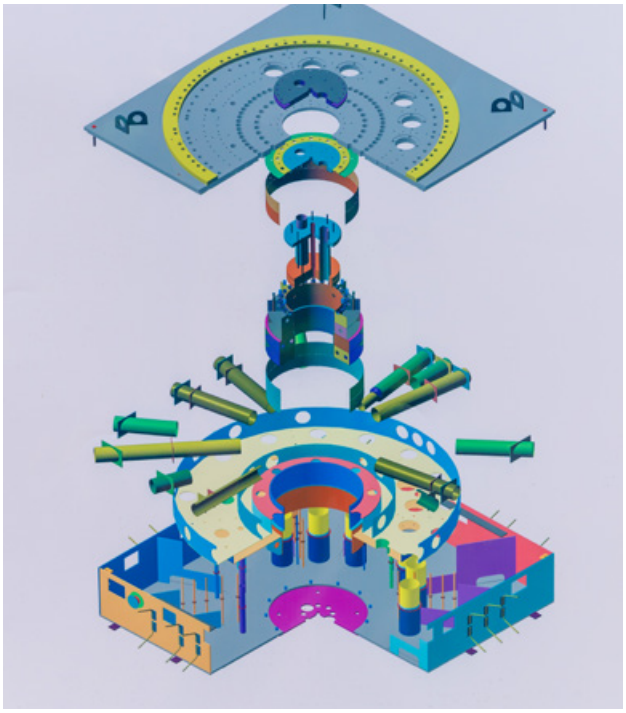
Construction works are going ahead of schedule. It was noted at a meeting of the construction management office in late December 2022 that the general contractor, OrgEnergoStroy Institute, had completed its 2022 work plan 130%. Last year, the company concreted the reactor pit, built a drainage pump station, laid a foundation for the turbine and was erecting a cooling tower. In January 2023, they installed the upper tier of the cooling tower, which now

reaches its planned height of 52 meters. The next step is to cover the tower frame with sheathing.

The reactor pressure vessel (RPV) passed a fit-up assembly test in January 2022 and was delivered to the construction site in April. In December, eight months ahead of schedule, the RPV was lifted vertically and placed onto the rig for strain gages, thermocouples and thermal insulation to be installed. Then the RPV was lowered into the reactor pit.

So thin, so rugged

MBIR has a different RPV — its walls are only 25 to 50 mm thick, or 6 to 12 times thinner than those of VVER. Weighing over 83 metric tons, the MBIR reactor is 12 meters long and maximum 4 meters in diameter. In order to comply with the dimensions as closely as possible, the RPV manufacturer Atommash (part of Rosatom's power engineering division) used proprietary devices designed for this purpose.



This January, an 8-ton protective cover was placed onto the reactor to protect the inside until the reactor internals are installed. Their installation is scheduled for the next year, but the workers hope to get started ahead of schedule.

"Installation of the reactor pressure vessel is a tangible result of the efforts made by a large team of like-minded people — researchers, engineers, designers, and builders. This is an important stage of the entire MBIR construction project and a step forward that brings us much closer to the project completion. It means that our country and also the global nuclear community will soon have a ground-breaking, technologically advanced research infrastructure," said Yuri Olenin, Deputy Director General for Science and Innovation at Rosatom.

MBIR role in global research

MBIR will replace a 60 MW fast-neutron research reactor BOR-60. Put in operation in 1969, it is approaching the end of its service life and needs replacement. As RIAR Director Alexander Tuzov said at the 2nd Congress of Young Scientists, MBIR will be used to continue in-pile and post-irradiation material studies and validate production technologies for radioactive isotopes and modified materials. The reactor will also generate heat and power.

According to Yuri Olenin, MBIR will also contribute to advanced research into the closed nuclear fuel cycle technology. It will also help to validate solutions for the fourth

generation of nuclear facilities and conduct game-changing fundamental and applied research. **“Rosatom’s research reactor MBIR and a Russian mega science project — PIK reactor at Kurchatov Institute — are complementary and enable the full range of neutron studies in terms of both neutron energy and possible research objects,”** Yuri Olenin noted.

MBIR will be at the heart of a new international research center (MBIR IRC) that will function as a competence center for fast-neutron reactors. **“The most powerful and technologically advanced research reactor will stimulate breakthrough discoveries and be an important component of our country’s technology leadership. With MBIR IRC as a cooperation platform for research, we offer everyone an opportunity to shape the international ‘neutron landscape’ and develop national programs for the future nuclear technology,”** says Vasily Konstantinov, Director for International Research and Development Projects at Rosatom and CEO of MBIR IRC Consortium Leader.

He announced at the 2nd Congress of Young Scientists that representatives of 13 international organizations started working on a program of international experimental studies. The studies will begin in the next decade.

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Russian Approach to Lithium

Faced with a decrease in car deliveries and even the exodus of car manufacturers on the back of sanctions, Russia has embarked on further development of its domestic automobile industry. The focus is placed on electric vehicles as they have fewer parts and are easier to produce. Their key component is a battery made from nickel, cobalt, manganese, copper, aluminum, and, of course, lithium — metals that are now called 'battery metals.' Russia is fully self-sufficient in nickel, cobalt, copper, and aluminum; manganese is imported from several sources, and only lithium is yet a major concern. You will learn from this article how Russia deals with it.

Lithium is not mined in Russia, so self-sufficiency in this metal is a problem, dealing with which is high on the agenda.

Global picture

High demand for lithium is a global trend driven by the rapid development of electric vehicles, primarily in China. Supply cannot yet catch up with demand. What is more, the recent pandemic and anti-Russian sanctions have raised concerns about the integrity of the existing supply chains. As a consequence, lithium prices skyrocketed in 2022. In mid-November 2022, the price of lithium hit

an all-time high of USD 84,500 per metric ton. By comparison, the price averaged USD 25,000 in 2018 and fell below USD 6,000 per ton of lithium in 2020. The price of spodumene (a lithium-containing mineral processed into lithium hydroxide and lithium carbonate) rose from USD 598 per ton in 2021 to USD 2,730 in 2022. In mid-September 2022, the price exceeded USD 7,800 per ton.

So, it can be safely said that the prices for lithium products have increased manifold during 2022 compared to the previous two years.

It is difficult to say how much demand has increased as the figures for the output of electric vehicles vary widely. According to the International Energy Agency (IEA), 6.6 million electric vehicles were sold worldwide in 2021, twice as many as the year before. According to Ev-volumes.com, 4.3 million electric and hybrid vehicles were produced in the first half of 2022, an increase of 62% over the same period in 2021. Morgan Stanley announced in late 2022 that the production of electric vehicles in 2022 was up 70%, or about 2 million cars. That means around 2.86 million electric cars were produced in 2021, according to the estimates of the American financial company. We can assume that the variations in the figures are due to the classification of electric vehicles. For example, Morgan Stanley took only electric cars into account while the IEA also included hybrids in its statistics.

Anyway, supply was growing in response to demand. **"The lithium market did not show any meaningful growth in 2019, with about 300,000 tons of the metal produced. Previously, the output had been rising by around 30–50 thousand tons per year. Now the market is growing at 200,000 tons a year,"** Eric Norris, President of Lithium Global Business Unit at the American chemical company Albemarle Corp. told the Financial Times late last December.

As estimated by the Australian Government in a quarterly report released in December 2022, the global output of lithium (in terms of lithium carbonate equivalent) amounted to 691 thousand tons in 2022. The forecast for 2023 is 915,000 tons and 1.087 million tons for 2024. Demand is estimated at 745,000 tons in 2022, rising to 924,000 tons in 2023 and 1.091 million tons in 2024.

LITHIUM MINE PRODUCTION, thousand tonnes

	2015	2016	2017	2018	2019	2020	2021	Growth 2011–2021	Share 2021
Argentina	3.6	5.8	5.7	6.4	6.3	5.9	6	**7.3%**	**5.6%**
Australia	11.9	14	21.3	57	45	40	55.4	**16.8%**	**52.3%**
Chile	9.8	13.6	14.2	17	19.2	21.6	26	**8.1%**	**24.5%**
China	2	2.3	6.8	7.1	10.8	13.3	14	**13%**	**13.2%**
World total	**29.5**	**38.2**	**50.9**	**95.1**	**86.9**	**84**	**106**	**12.4%**	**100%**

Source: includes data from USA Geological Survey, British Geological Survey, UKRI and World Mining Data.

Thus, the Australian Government believes the shortage will not ease in the next two years, and that the price will continue to climb up. According to Benchmark Mineral Intelligence, the shortage of supply in the global lithium market reaches 80,000 tons in 2022, with the production totaling about 635,000 tons. The shortage will persist in 2023, BMI analysts say, but will sharply decrease to 5,000 tons. The decrease will be driven by growing deliveries in 2023 — they are expected to reach 863,000 tons, up 36% year-on-year.

However, according to Stella Li, Executive Vice President of BYD, one of China's electric vehicle manufacturers, the market will turn to surplus in 2023 because new lithium mines will be launched and prices will stabilize. S&P Global Market Intelligence has produced similar estimates. The company forecasts that the supply of lithium-containing products (in terms of lithium carbonate equivalent) will reach 858,000 tons in 2023, or 2,000 tons above demand.

The estimates compared, the market has no consensus on production volumes in 2022 and no single vision of prices, demand and supply in 2023. Significant market growth is the only thing everyone is united over.

In January 2023, the price of lithium fell to little above USD 70,000 per ton. There are two drivers behind the price movement. First, China abolished subsidies on new electric vehicles, and demand declined despite other demand-stimulating measures, such as tax incentives. The second driver is a sharp increase in lithium supplies in the market this year. Bloomberg estimates the increase could be 22% to 42% as compared to the previous year. However, there was no unanimity in January in assessing the lithium market changes either.

Australia is currently the biggest producer of lithium. According to Visualcapitalist.com, its market share is 52%. Chile is the second largest producer, accounting for a quarter of the global supply, followed by China (13%) and Argentina (6%). Four other countries (Brazil, Zimbabwe, Portugal, and the United States) produce 1% of the world's lithium supply each. The rest of the world accounts for as little as 0.1%.

Lithium in Russia

The Russian Government estimates the country's needs at about 3,000 tons — this is how much of various metal compounds was imported in 2021. It should be noted, though, that some of the imports are then exported in the form of other compounds. Russia's internal demand for lithium is 400 to 700 metric tons. Lithium is used in the nuclear power industry, in energy storage systems, and in the production of slag-forming mixtures for ladles and lubricants for mining operations.

There are plans to set up domestic production. **"Accelerated development of lithium ore mining projects at the Zavitinskoye, Polmostundrovskoye,**

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Kovyktinskoye, Yaraktinskoye and Kolmozerskoye deposits in 2023–2030 will help meet most of domestic demand for lithium," says the Russian Metals Industry Development Strategy 2030 adopted last December.

All of the mentioned sites are not easy to mine. For example, Zavitinskoye is an already depleted deposit. Lithium was mined here from 1941 until 1997. The current plan is to extract lithium from the production waste, and Krasnoyarsk Chemical and Metallurgical Plant is obtaining a license for this purpose.

Kovyktinskoye is the largest gas field in Eastern Russia. Lithium is contained in the associated brines, and there has been talk about its extraction for several years. The process accelerated in 2022, and Kovyktinskoye was put into production in late December 2022.

Rosatom also plans to extract lithium — but from ores, not brines. This is a common practice adopted, for example, at Australian pegmatite deposits containing mostly spodumene.

In Russia, a pegmatite deposit, Kolmozerskoye, is located in the Murmansk Region. It is believed to be the most promising deposit, and Rosatom plans to develop it in partnership with the Russian mining major Nornickel. **"Nornickel's products have long played an important role in manufacturing energy storage systems. By expanding our range of metals with lithium, an essential and much sought-after raw material, we intend to strengthen our position as a key supplier for the battery segment,"** Nornickel's press release about an agreement with Rosatom signed in April 2022 quotes its President Vladimir Potanin.

No mining license for Kolmozerskoye has been issued yet. According to the official data as at July 1, 2022, P1 category resources (inferred resources with the greatest probability) at Kolmozerskoye amount to 13.5 million tons of ore containing 152,600 tons of lithium oxide, 1,215 tons of tantalum pentoxide, and 1,485 tons of niobium pentoxide.

On February 8, 2023, in accordance with the decision of the auction commission, the subsoil use rights for the Kolmozerskoye deposit were transferred to Polar Lithium LLC, a joint venture of Atomredmetzoloto and Norilsk Nickel. As expected by Rosatom and Nornickel, the output of lithium hydroxides and/or carbonates at Kolmozerskoye may amount up to 45,000 tons per year in terms of lithium carbonate equivalent.

Thus, within a few years, Russia may have a large mining project that will fully — and even abundantly — meet its current domestic demand for lithium.

According to Rockwood Lithium, one of the world's key lithium producers, a 25 kWh car battery needs 44 pounds (almost 20 kg)

of lithium carbonate. It can be roughly calculated that a 4 GWh battery plant will require about 3,200 tons of lithium carbonate. This means that the annual capacity of the Kolmozerskoye deposit should be sufficient to supply four such plants, and there will be more lithium left for sales to other consumers.

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Kolmozerskoye deposit: facts and figures

Source: Solid Mineral Resources of the Russian Arctic (collective work published by Fedorovsky Russian Research Institute of Mineral Resources)

The Kolmozerskoye deposit has 70 pegmatite veins, 11 of which are of commercial value. Pegmatite bodies are covered by a thin (a few meters) layer of moraine sediments from above. The ore bodies have a plate-like shape; large veins are 570 to 1,680 m long and 10 to 50 m thick. The veins are grouped into parallel vein zones, the largest of which comprise two commercial blocks, Big Potchevarak and Small Potchevarak. Li2O content varies from 0.8 to 1.3%, averaging 1.14%. The deposit is expected to be mined as an open pit. A flotation and gravity separation method has been developed for Kolmozerskoye lithium ores.

Evident Progress

Egyptian and Russian officials and top managers make regular visits to the construction site of Egypt's first nuclear power plant. During the last such visit, members of the delegation praised the progress in El Dabaa construction.

The delegation included Amged El-Wakeel, Chairman of Egypt's Nuclear Power Plants Authority (NPPA), Alexander Korchagin, Senior Vice-President for NPP Construction Projects at ASE (part of Rosatom), NPPA top managers, and representatives of ASE and Russian R&D institutes.

The delegation visited each of the docks designed to receive equipment, and other key locations on the construction site. Its members were told about the performance in 2022 and plans for the current year.

Amged El-Wakeel praised the scale of the achievements made and stressed the importance of reaching the goals set for 2023. In his turn, Alexander Korchagin said, **"The teams are working cohesively and dynamically across all and every project area; the work is going at a good pace. There is a lot to do in 2023, and we are preparing for it responsibly."**

Amged El-Wakeel earlier said that the first shipment of equipment for El Dabaa was

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expected to arrive in the first quarter of 2023. According to him, a core catcher will be the first to be delivered after it passes appropriate tests in Russia. It took about 14 months to manufacture the core catcher — its production began in late July 2021, Amged El-Wakeel said.

The NPPA Chairman explained that the core catcher, a know-how of Russian nuclear engineers, was a distinctive feature of innovative Generation III+ reactors, to which El Dabaa NPP reactors belong. This is the first large-size device to be installed in the reactor building under the bottom of the reactor pressure vessel. It improves safety of the reactor unit in any emergency, preventing the escape of radioactive materials and potential damage to the reactor containment. The core catchers are installed at other reactors constructed by Rosatom abroad, particularly at the Tianwan NPP in China and the Kudankulam NPP in India.

Amged El-Wakeel also said that the construction license for El Dabaa Unit 3 was expected to be issued in mid-2023. He added that the Egyptian nuclear project would pass many milestones during the year.

Adding nuclear to the national energy mix is a global trend, experts say. At present, 32 countries operate nuclear power plants with many others consider building their first nuclear stations.

According to Noura Hassan, a nuclear physicist and professor of the Russian-Egyptian University, the world badly needs new generating capacity to replace old polluting power plants. Demand for clean and sustainable energy, especially nuclear energy, is high, she says. The professor cited a recent study by Oxford University: it demonstrates the world will need to build 235 new nuclear reactors over the next eight years to achieve carbon neutrality by 2050.

According to Noura Hassan, nuclear power is of worldwide importance for two main reasons: it is a clean energy source that produces no carbon dioxide emissions, and also a sustainable long-term solution. NL

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