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Greenlighting Nuclear Benefits Economy

Excluding nuclear from national energy mix is unreasonable because nuclear energy is reliable and contributes to sustainable development. These are the main points made by Rosatom top managers at two key September nuclear events.

On September 21–25, Vienna hosted the 64th annual session of the IAEA General Conference. This year, the session was organized both offline and online. Rafael Mariano Grossi, the IAEA Director General, noted in his opening speech that 442 nuclear power reactors operating in 31 countries supplied over 10% of the world's total electricity and around a third of all low-carbon electricity, and reiterated his point that nuclear power was part of the climate crisis solution. **"I am keen to ensure that the Agency's voice is heard on the great benefits of nuclear power,"** he said.

Rafael Grossi and Rosatom Director General Alexey Likhachev had a meeting on the sidelines of the event.

Rafael Grossi's tweet:

"Happy to see IAEA & Russia further strengthening cooperation towards common goal: more clean energy to fight climate change. Very good meeting with Rosatom Global's Alexey Likhachev today at IAEA GC — Russia is an important partner. Thanks Russia & Rosatom for renewed support."

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Rosatom's Director General Alexey Likhachev stressed in his speech that the global nuclear energy industry had stood the test of the coronavirus pandemic and the consecutive crisis, **"Faced with a developing crisis, nuclear power has yet again demonstrated its stability, environmental sustainability, safety and cost-effectiveness."** In Russia, nuclear companies kept working as usual despite tough times. New construction continued both inside and outside the country; the world's only floating nuclear power plant was put into commercial operation in May, Rosatom Director General said.

"I am confident that if we stay committed to the principles of partnership, professionalism, and trust, if we prevent politicization of the nuclear industry, then we will handle all the current and future challenges. The key prerequisite for this work is uniting efforts of all the interested parties in various formats of mutually beneficial cooperation, with the IAEA playing the central role," Alexey Likhachev concluded.

Useful contribution

An online symposium of the World Nuclear Association was held in early September. Rosatom's Chief Financial Officer Ilya Rebrov and Chief Sustainability Officer Polina Lion took part in the conference panel sessions together with top managers of other global nuclear majors, including Electronuclear, SPIC, CEZ, Uzatom, Kazatomprom, Cameco, CNNC and others, representatives of international organizations, and members of national governments. Kirill Komarov, Rosatom's Deputy Director General for Corporate Development and International Business, gave a detailed video interview during the forum.

Answering the moderator's question, Kirill Komarov noted that, in terms of industrial development, it was more beneficial for a nation to focus on nuclear than on anything else, **"Importing solar panels from Asia doesn't create high skilled jobs, nor does it generate additional tax revenues or spur innovation."**

Polina Lion gave a detailed account of the nuclear contribution into the development of national economies, **"Our customers are interested not only in establishing a safe and secure source of electricity with reasonable costs. They all anticipate some non-financial benefits — such as new jobs, a boost for high education, and local infrastructure development."**

Construction of a nuclear power plant offers a combination of financial, technological, social, economic and environmental benefits for a host country. Depending on the needs of a particular economy, each new build project may have a specific focus and accents. **"For our project in Hungary we were asked to ensure at least 40% of local content, for our Akkuyu project in Turkey there is a requirement of proportion of local employees. We provide personnel education and training for all our customers. Today, we support almost 2,000 foreign students from 58**

countries, who study in Russia on nuclear specialties," Polina Lion explained.

Kirill Komarov supported the point that nuclear was beneficial for national economies for its reliable technology, predictable energy costs and zero emissions. He cited an example from the recent past, and, for clarity, compared the situation with a well-known fairy tale. He said, **"It looks like those arguing for an apparently cheaper '100% renewables' alternative missed the fable of the Three Little Pigs when they were little. The recent blackouts in California illustrate perfectly that what they are advocating is simply building the house of straw. Most of us remember what happens to that construction when a Big Bad Wolf blows. In our case when wind doesn't blow enough. Well, nuclear energy is the house of bricks. It might take longer to build, and it might look as it's not as much fun and hype, but what nuclear offers is the most cost-efficient way to ensure the security of supply in a low-carbon grid."**

The EIA data shows that nuclear power plants are the most efficient among other sources of energy. In 2019, the average capacity utilization factor of nuclear power plants was 93.5% while the capacity factor of gas-fired power stations was only 56.8%. Other types of generating stations have even a lower capacity factor.

Nuclear demonstrated its sustainability and reliability in the hard times of the pandemic. **"Nuclear power guarantees a stable supply of electricity, with highest safety and sanitary standards, together with securing many thousands of jobs,"** Polina Lion stressed in her speech.

These are not just allegations but statistics-backed facts. For example, nuclear power plants in the USA, which has the world's largest reactor fleet, demonstrated the highest capacity utilization factor as compared to other utility scale generators, according to the EIA.

However, today, the perception of nuclear energy is rather absurd. Until recently, no one has spoken about efficiency of nuclear plants when discussing the future of national energy industries. What is more, some national governments declare their commitment to protecting the environment and reducing carbon dioxide emissions while prematurely shutting down nuclear power plants, which prevent emissions of greenhouse gases. They ignore that a 4 GW nuclear power plant replacing a coal-fired power plant of the same capacity prevents CO2 emissions and burning of oxygen produced by 10–12 million hectares of forest. This is almost a territory of Hungary (9.3 million ha) or Greece (13.2 million ha) if they were

Capacity utilization in the USA during the pandemic (by energy source), %

Month of 2020	Nuclear	Coal	Gas combined cycle	Hydro	Wind	Solar photovoltaics
March	87.7	30.9	52.1	37.5	37.8	21.9
April	83.9	25.5	47.3	36.2	38.7	28.2
May	89.1	28.4	48.2	49.7	35.4	32.3

fully covered by forest. **"Now new renewable capacity additions, solar or wind, don't reduce overall carbon intensity. They simply replace one source of low carbon energy (old nuclear reactors) with other low carbon sources,"** Rosatom First Deputy Director General observed.

Some countries, especially in Europe, show a clear prejudice in favor of renewable sources of power in the energy mix over nuclear energy, with a clearly and consistently hostile policy towards the latter. Kirill Komarov could not hide his indignation at it, saying, **"In many countries, nuclear energy is simply being discriminated against. Even if there are no anti-nuclear laws or plans for nuclear 'phase-out', still, as an investor in nuclear, you are facing a risk that over-subsidized solar would flood the market with virtually free electricity."**

What is worse, shutting down nuclear power plants might lead to construction of carbon-intensive infrastructural facilities and put CO2 emission reduction targets at risk. **"So, our message to the governments should be the following: don't bury money in CO2-heavy projects! Invest it in nuclear,"** Kirill Komarov concluded.

Influencing the financial side

Discrimination against nuclear makes it more difficult to obtain funding for nuclear projects. **"You would never be able to break even by simply selling the clean, low-carbon electricity you produce to the market,"** Kirill Komarov said.

According to Polina Lion, the EU Taxonomy Regulation, which classifies energy sources in Europe by sustainability, puts nuclear into the "grey area". The position of the European Commission, which does not want to include nuclear into the list of desirable and recommended source of electric energy, influences opinions of national governments and general public and, what is more important, decisions of investors both inside and outside the European Union. Paradoxically, nuclear meets all the criteria for a technology in the "green area" of the Taxonomy. **"We need to make our best efforts to provide the EU officials and their experts with arguments and practical cases to ensure nuclear energy deserves to be an important part of the future energy mix,"** Polina Lion reminded.

Rosatom has always managed to find a financing mechanism that is acceptable for its international customers planning to build a nuclear

power plant. Until recently, an EPC (engineering, procurement and construction) contract has been the most common financing scheme. For example, it was used in the Kudankulam construction project in India.

Now Rosatom offers its customers other financing schemes, such as BOO (build-own-operate). Rosatom's BOO projects include Akkuyu in Turkey and Hanhikivi in Finland.

Ilya Rebrov admitted that there would be more new build opportunities if Rosatom's offer were supported by project financing or co-financing options. Project financing is a commercially reasonable way of obtaining finance for nuclear new build in the current conditions, he believes. **"Application of the project financing tools is a long journey. Rosatom started with small projects and each year we increase the size of the projects to create expertise so that to further apply the project financing tools to NPP Projects."**

Financial institutions still consider nuclear power plants to be too risky. Ilya Rebrov summarized their arguments in his report:

• Timeline: a long investment phase and quite a long payback period.

• Quality of adequate security (state guarantees; power purchase agreements, contracts for difference etc.) that could, inter alia, help to issue project bonds (green / sustainable bond) on the operational phase of the project.

• Nuclear projects are complex.

• Capital-intensive nature of NPP Projects. Thus, both Financial and Operational Investors require guarantees that the projects shall be implemented on time and without any significant cost overrun.

• Political or regulatory risks as well as nuclear operation safety risks. Both Financial and Operational Investors are not ready to accept them.

• Investors are not able and are not ready to take possession of NPPs as a collateral. NPPs could not be used as the security for the loan.

Rosatom top managers are confident that these risks could be mitigated considerably, but an essential condition for this is political will. **"Large part of political, regulatory and especially power market price risks can be addressed mainly by the involvement and commitment of the hosting state government. That becomes a key success factor for emerging and developing countries,"** Ilya Rebrov said.

Nuclear does not need specific privileges or preferences — equal conditions for all energy generators in the market will be just enough. **"If we want the most feasible and cost-efficient route to net-zero — this simply must change. Energy policy must become truly technology neutral. The playing field must be leveled,"** Kirill Komarov concluded.

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The risk of insufficient finance could be reduced if shared with suppliers. **"The commitment of suppliers to provide financing altogether with their supplies increases their liability for project risks, thus decreasing the residual level of risk for equity investor,"** Ilya Rebrov explained.

In their turn, construction-related risks could be reduced if co-investors join the project when all the licenses are obtained and huge work of building supply chains and planning construction processes is already done.

Icebreakers Arriving

This year has been eventful for Rosatom's nuclear fleet operator Atomflot as the first Project 22220 nuclear icebreaker Arktika finished trials and was put into operation, while a contract was signed to begin construction of the first Project 10510 Leader icebreaker. The fleet renewal is driven by the plans to increase freight traffic on the Northern Sea Route.

Arktika, the first Project 22220 nuclear icebreaker, was officially put into operation on October 21.

Before the commissioning, Arktika had passed the final phase, or ice phase, of sea trials. Started on September 22, the ice phase served to check the vessel's performance in ice-covered waters. In order to make the trials as close to reality as possible, the icebreaker left Saint Petersburg for Murmansk, her port of registry, heading through the North Pole, where she safely got on October 3.

Earlier, from June 23 until September 16, the crew tested Arktika's steam turbine plant, electric propulsion and shaft line systems, deck machinery, service systems, automatics, maneuverability and speed performance. Navigation and communications systems and a helicopter deck underwent testing too. The crew and the testing team had a chance to evaluate the icebreaker's performance even in stormy conditions in the last days of sea trials.

Arktika was hit by a heavy storm, with the wind speed reaching 30 to 32 meters per second and waves as high as 4 meters, which corresponds to force 11 on the Beaufort scale. Waiting out the storm, the icebreaker, like many other vessels in the Gulf of Finland, was going slowly upwind because it made the motions almost insensible. **"It was a violent storm, but the icebreaker made her way through it,"** Chief Officer Vasily Gubkin said in an interview to the Strana Rosatom newspaper.

Since increasingly more commercial ships are escorted on the Northern Sea Route, Arktika's services will be in high demand.

It is planned to build four more Project 22220 icebreakers. According to the project schedule, the Baltic Shipyard will commission two of them, Sibir and Ural, in 2021 and 2022, respectively. Contracts for construction of the other two vessels, Yakutia and Chukotka, were signed last August. These two icebreakers will be put in operation in 2024 and 2026.

Project 22220 icebreakers have two RITM-200 reactors, each delivering 30 MW of shaft power. RITM-200 was developed at Rosatom's Experimental Design Bureau for Mechanical Engineering Afrikantov.

Arktika specifications

Length: 173.3 m

Width: 34 m

Height: 15.2 m

Draft: 10.5 m / 8.65 m

Displacement: 33,540 t

Design service life: 40 years

Crew: 53 people

Capacity: 60 MW

Top design speed: 22 knots

Maximum ice thickness: 2.9 m

Rossiya: New Giant

Arktika is the world's most powerful icebreaker for now, but in the months to come, Zvezda Shipyard in Russia's Far East will lay the keel for the first Leader Project icebreaker, an even more powerful vessel. It will be equipped with two RITM-400 reactors capable of generating 120 MW of shaft power. The new icebreaker will be able to travel through 4-meter thick ice, making a 50-meter wide passage for escorted ships. The plan is to build three icebreakers of the same design. The new vessel will be named Rossiya (Russia) to commemorate the world's fourth nuclear icebreaker that operated in the Arctic in 1985–2013.

The main task of the new Rossiya will be to escort ship convoys and ensure year-round navigation in the Eastern part of the Russian Arctic. It means that, apart from safely escorting ships in ice-covered waters, the icebreaker has to ensure a commercially acceptable traveling speed of about 12–14 knots through an ice cover that is 2 meters thick on the average.

Rosatom and Zvezda signed a contract for construction of the icebreaker this April. Rossiya will be made of large pre-assembled units. Certain sections will be assembled into larger units at the factory and then delivered to the stable to be assembled. The shipyard expects this technology to reduce the overall construction time. According to the project design, the hull and topside of the icebreaker consist of 19 units. The maximum weight of a unit is 1,200 metric tons. This is the lifting capacity of the Goliath crane installed in the dry dock, in which Rossiya will be assembled.

The dry dock is a complex hydraulic structure. It is a rectangular pit that is 485 meters long, 114 meters wide and 14 meters deep. The dry dock is divided into two sections — in each of them, two vessels can be built at a time. Cranes are installed at its side. This is where Rossiya's hull will be built and large-size equipment — two turbine plants (there will be four of them) and reactors — will be installed in the hull. Part of the topside will also be assembled in the dry dock.

After Rossiya is floated out, the remaining turbine plants will be installed, nuclear fuel loaded, and the topside completed.

The icebreaker is planned to be commissioned in 2027. NL

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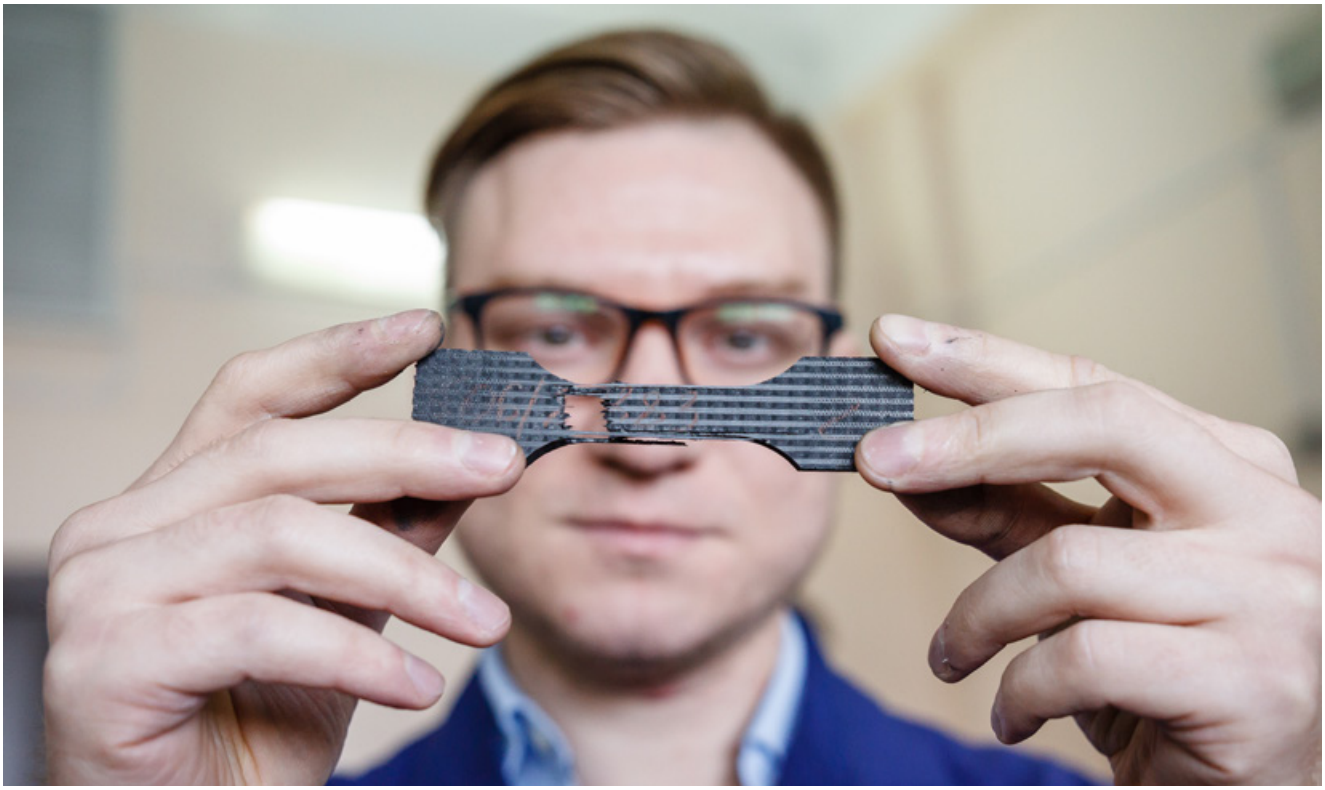


Set in Graphite

On October 1, 2020, the Institute for Graphite-Based Construction Materials celebrates its 60th anniversary. It manufactures advanced materials that meet heat resistance and durability requirements of the nuclear, aerospace, medical and other high-tech industries.

The history of the Institute for Graphite-Based Construction Materials (NIIGraphite) dates back to October 1, 1960. It was established as a center for comprehensive research on carbon-based materials and development of carbon-based products. Its tasks included launching such products into mass production and coordinating activities of research and development laboratories and production plants across the country. NIIGraphite began with the development of carbon ceramic structural materials. Other materials developed at the institute ranged from fine-grain and recrystallized graphites to carbon fluoropolymer composites. NIIGraphite researchers also developed materials for graphite stacks of RBMK reactors, studied their performance and monitored the condition of stacking in uranium graphite reactors to increase their service life.

In the 1970s, NIIGraphite joined in a national R&D program for aerospace materials and took part in the development of carbon-carbon composites, which were used to make friction discs for Buran space shuttle and An-124, Tu-160, Tu-204 and Tu-214 aircraft brakes. Carbon dischargers for the Russian spaceplane Buran were also developed at the institute. They were needed to make it possible to control the spaceplane from Earth. NIIGraphite also set up production of carbon fiber woven and non-woven fabrics. In the same period, the institute developed technology for manufacturing long-lived

radiochemical prepregs based on carbon fiber and fabrics. The prepregs were used to make carbon/silicon carbide composites for the production of heat-exposed components of aircraft engines.

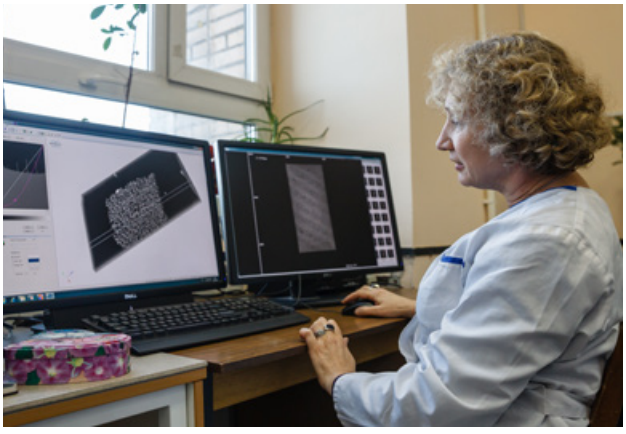
In the next few decades, the institute dealt with the development of ultra-high-strength composites — along with other materials.

Since 2013, NIIGraphite has been part of the Russian state nuclear corporation Rosatom, developing and manufacturing materials and products for the aerospace, medical and, of course, nuclear industries.

For example, NIIGraphite develops structural materials for the core of molten salt reactors in association with the Ural Federal University. Some of these materials are now at the prototyping and initial testing stage.

Isostatic graphite for high-temperature gas-cooled reactors (HTGR) is developed in partnership with Chelyabinsk-based Doncarb Graphite. Thanks to stage-by-stage high-temperature treatment, this material can be used to make light-weight high-strength temperature-resistant complex shaped parts with the highest-quality surface finish.

NIIGraphite has developed silicified graphite



for bearings of the primary coolant pumps installed at Russian-designed nuclear reactors. Silicified graphite is an anti-friction material, or a material reducing friction and wear of moving parts.

Anti-friction graphites are also used in aerospace applications, particularly where temperatures are high. These are plain bearings, face seal friction pairs, steam heads, etc.

In addition, the institute resumed production of regular graphite grades, such as ATG, AG 1500 and Nigran-V, which was suspended after the collapse of the Soviet Union. They are used in aircraft gas turbine engines, fuel systems and other mechanisms. In the future, NIIGraphite plans to set up production of isotropic pyrolytic graphite for aircraft engines.

Another product developed at NIIGraphite is a family of 2D, 3D and 4D carbon fiber reinforced carbon composites for defense applications.

The institute has also developed materials for the casings of radioisotope heater units and thermoelectric generators installed in the Russian Mars 96 spacecraft and Chinese Chang'e 2 and Chang'e 4 lunar probes.

NIIGraphite products are gradually finding their way into medicine. The institute has developed graphite fabric TGN2M used to make atraumatic dressings (dressings that accelerate healing of wounds and burns).

Piezoelectric sensors, on which NIIGraphite researchers are working now, can be used in ultrasound scanners — graphene-based films transmit a much clearer image. Piezoelectric sensors can also be used in positioning and condition monitoring systems of

medical robots.

Carbon-based materials containing BMP2 human protein are needed to treat bone defects — they can fill in defects and improve growth and healing of the bone tissue. They can also be used to produce personalized intervertebral cages for spinal fusion.

Inventions made by NIIGraphite researchers are patented not only in the Russian market, where the institute has 58 current patents and 16 registered know-hows. This year NIIGraphite has filed an international patent application claiming Russian priority for a method of making 3D preforms for multidimensional carbon reinforced composites. The plan for the next year is to file another five patent applications. NL

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Emissions Fifty Years Later

In its Energy Technology Perspectives 2020 report published in September, the International Energy Agency (IEA) lists clean energy technologies that will decarbonize the global economy by the second half of the 21st century. Nuclear is on the list.

The report deals with the problem of reducing carbon emissions. The IEA experts analyze the status quo and consider three forecast scenarios. The first one is the Stated Policies Scenario that reflects the efforts already made or declared by national governments, including those under the Paris Agreement. The second scenario is the Sustainable Development Scenario that expects net-zero emissions to be achieved by 2070. The third option is the Faster Innovation Case. In this case, net-zero emissions will be achieved already by 2050, while electricity generation will grow 2.5 times as compared to the current level, which is **"equivalent to adding the entire US power sector every three years."** The report names two deadlines, 2050 and 2070, by which net-zero emissions should be achieved.

It also considers risks and possibilities related to fast reduction of emissions in key energy-intensive areas, such as transport, industrial production (primarily ferrous metallurgy and production of fertilizers) and households.

Definitions

The IEA defines low-carbon energy technologies as "renewable energy sources (renewables), nuclear power; carbon capture, utilization and storage (CCUS); hydrogen derived from low-carbon energy sources; technologies that improve the efficiency of energy transformation (e. g. switching from incandescent to light-emitting diode [LED] lighting); other non-fossil power and storage options; and cross-cutting technologies that result in minimal emissions of CO2 and pollution." In the context of discussions that are going on in the European Union regarding the 'green' status of nuclear energy, it is important to mention that the IEA has included nuclear into the list of low-carbon technologies, putting it on a par with renewable sources of energy.

Research framework

The IEA experts begin with an assertion that the current situation cannot be regarded as satisfactory. They write, **"Clean energy sources are growing in importance, but they still account for only around one-fifth of energy supply worldwide. In other words, the energy system in its present state is unsustainable."** The experts admit the possibility of lower emissions in 2020 due to the coronavirus pandemic but believe that the decline is temporary and emissions will grow back fast.

Despite continuous calls to cut emissions, they are unlikely to be reduced in the next two decades. And there is more than one reason why.

First, rapid development of the Chinese economy necessitated a no less rapid expansion of generating capacity, primarily coal-fired power plants. **"Since the inception of the 21st century, the share of coal in the global energy supply mix has increased with the economic boom in China,"** the report says.

The second reason is a remaining service life of the existing power plants. Launched in the last two decades, they are intended to operate for 30 to 40 years and, as the authors of the report believe, this will slow down emission cuts due to sluggishness of the existing technology, **"Highly competitive global markets, the long lifetime of existing assets, and rapidly increasing demand in certain areas further complicate efforts to reduce emissions in these challenging sectors."**

Third, technology that could contribute to the reduction of emissions is still at its early development stage. **"Quicker progress towards net-zero emissions will depend on faster innovation in electrification, hydrogen, bioenergy and CCUS,"** the authors of the report are convinced. CCUS stands for 'capturing CO2 emissions in order to use them sustainably or store them'.

Making hydrogen a full-fledged source of low-carbon energy, primarily for industrial applications, demands increasing electrolyzer capacity from the current 0.2 GW to 3,300 GW. If the forecast comes true, the electrolyzers will consume double as much energy as China does now, while emissions will be cut by half. The carbon capture technology will be needed to produce low-carbon synthetic fuel and remove carbon dioxide from the atmosphere. It will be able to neutralize 55% to 80% of emissions.

According to the report, low-carbon technology also includes bioenergy, which comprises, in approximately equal shares, conventional

biomass (wood, charcoal, and other wood processing products) and new sources of bioenergy. The authors of the report think that electricity, hydrogen, synthetic fuel and bioenergy will meet the portion of demand that is now covered by coal, oil and natural gas.

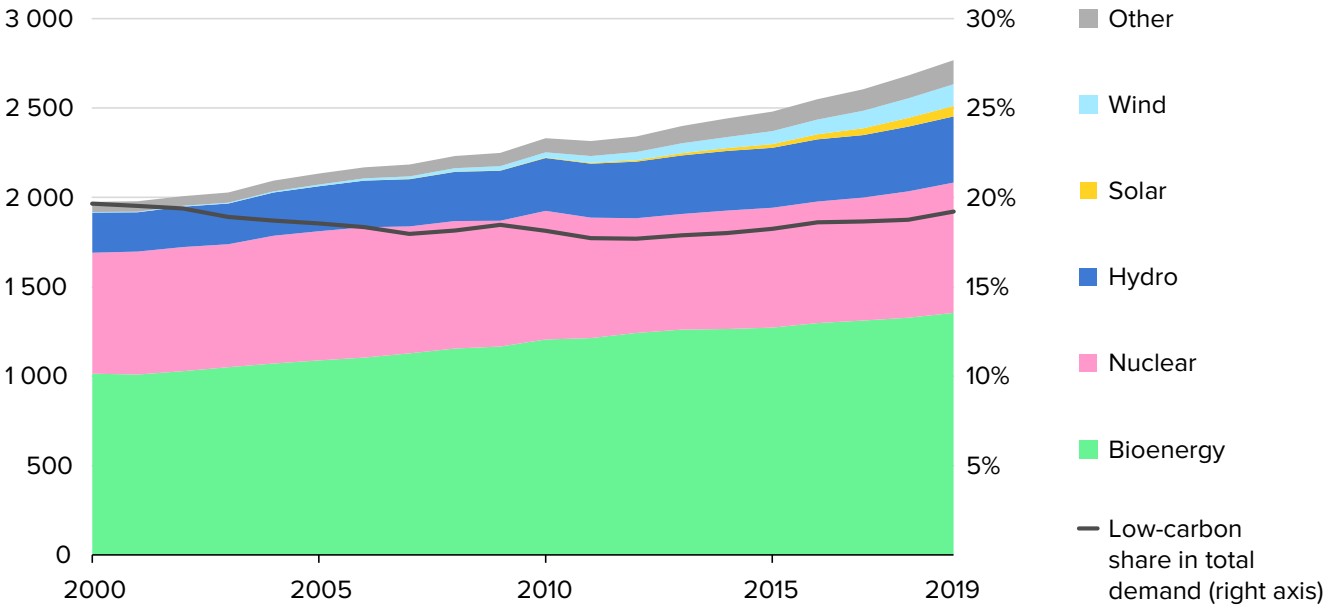
In general, the Sustainable Development Scenario expects demand for electricity to more than double. **"This growth is driven by using electricity to power cars, buses and trucks; to produce recycled metals and provide heat for industry; and to supply the energy needed for heating, cooking and other appliances in buildings."** Production of electricity will triple by 2070, the report says.

However, total consumption of energy will grow much slower due to higher energy efficiency and material savings. **"These help keep demand at roughly current levels through to the early 2050s, when it slowly begins to rise again because most of the potential for efficiency gains from currently available technologies has been exploited. Energy intensity — the amount of energy consumed per dollar of GDP — falls by two-thirds between 2019 and 2070, corresponding to a decline of the energy intensity of 2.2% per year, more than a third higher than the rate of 1.6% per year observed over the period 1990–2019."**

Place of nuclear in carbon-free future

The report admits that it was nuclear technology that contributed to lower emissions and cleaner air in the last century, **"Construction of nuclear reactors surged in the 1960s and 1970s, but slowed down thereafter."** Technological development came in waves — it was nuclear in the 1970–1980s, combined cycle turbines in the 1990s, wind energy in

PRIMARY DEMAND FOR LOW-CARBON ENERGY SOURCES, 2000-19, Mtoe*



*Mtoe — million tonnes of oil equivalent. Other includes geothermal and marine energy.

Bioenergy remains the single largest category of renewables, though solar PV and wind power have increased the fastest in recent years.

the 2000s, and solar panels in the 2010s. However, the authors of the report note regretfully, **"The increased share of renewables in the global energy mix has barely offset the declining share of nuclear power over the period."** As a result, the share of clean energy sources is now less than 20% of the energy mix, or almost the same as in the early 1970s.

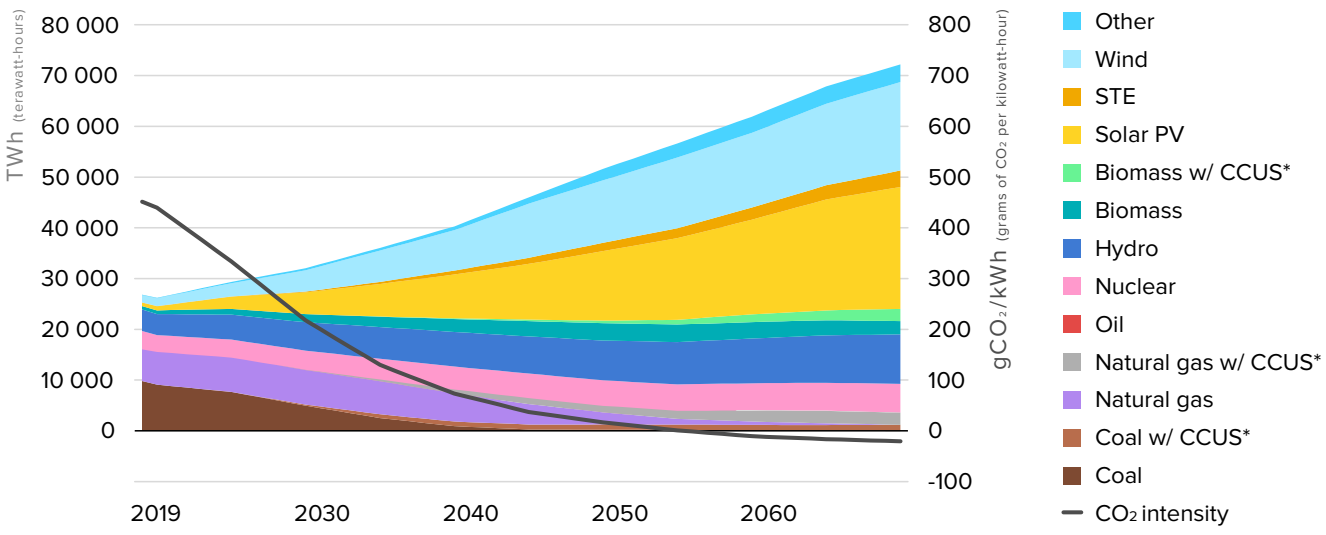
The reasons behind declining interest towards nuclear energy in the late 1980s and early 1990s were lower prices of hydrocarbons and two accidents, in the USA and in the USSR. Interest revived in the late 2000s but died away after the Fukushima disaster.

Nevertheless, the IEA believes that nuclear will be one of the drivers of cleaner power generation because it can be used, for example, to produce hydrogen by electrolysis. Projects in this area were announced by the United Kingdom and the USA.

According to the Sustainable Development Scenario, the share of power generation in the consumption of primary energy resources will grow from the current 20% to almost 50% in 2070. The segment will be driven primarily by solar, wind and nuclear generation. As of 2019, demand for electricity generated by nuclear power plants amounted to 728 million tons of oil equivalent (Mtoe). Under the Stated Policies Scenario, it will reach 1,101 Mtoe by 2070. Almost the same amount (1,140 Mtoe) will be reached already in 2040 under the Sustainable Development Scenario (and grow to as much as 1,472 Mtoe by 2070).

Another section of the report reads, **"Nuclear primary energy use more than doubles between 2019 and 2070, with emerging economies in Asia accounting for around 75% of the growth in capacity."** Under the Sustainable Development Scenario, the share of nuclear energy in the global energy basket will make 8% in 2070 (page 129).

GLOBAL POWER GENERATION BY FUEL/TECHNOLOGY IN THE SUSTAINABLE DEVELOPMENT SCENARIO, 2019-70



*CCUS — carbon capture, utilization and storage. Other includes geothermal power, ocean energy and hydrogen.

Global power generation sector achieves net-zero CO_2 emissions before 2060, largely from renewables which account for over 85% of the generation mix by 2070.

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It will differ by region, though, as the IEA experts say, **"Nuclear meets 13% of total generation in 2070 in China — more than three-times the current share."** According to PRIS, the share of nuclear generation in China's energy basket is 4.9%, which is more than follows from expert estimates.

The task of achieving net-zero emissions in power generation will require a sharp increase in new clean capacity additions, with 15 GW of generating capacity to be commissioned every year. Simultaneously, we will have to add 475 GW of solar capacity (108 GW in 2019) and 190 GW of wind capacity (60 GW in 2019) every year.

According to the IEA estimates, Asia will account for over 80% of nuclear capacity additions globally, from 415 GW in 2019 to more than 780 GW in 2070. It should be noted that capacity additions will be driven mostly by the projects that already exist. They can be supported, though by new projects and small modular reactors, **"Some advanced nuclear technologies, notably small modular reactors (SMRs), support the rising share of variable renewables. Today SMRs are at the prototype development stage: their potential for shorter lead times and lower investment requirements reduce investment risks compared with large-scale nuclear plants."**

Nuclear energy is among the most knowledge-intensive segments in the power generating industry. According to IEA, which has been monitoring R&D expenses in the power industry since the 1970s, nuclear R&D programs were the most heavily invested until 2008. After 2009, investments in renewables, hydrogen technology and energy storage systems surged, but R&D in nuclear continued receiving finance.

Strong research background and achievements make nuclear relatively independent from breakthroughs in other industries. For example, Rosatom has research programs in material studies, new types of nuclear power plants and their components, new fuel, and even computing systems for complex calculations.

The IEA report outlines, in an unbiased manner, opinions of the professional and political community about the opportunities available to us on our way to lower or even zero emissions. The figures given in the report in relation to 2050 and 2070 are more of possible references than firm targets — the time period is too long, and uncertainty is high. This is evident from the figures cited: if demand for electricity doubles and production triples, then what does it say about the current situation and about what will happen in fifty years? The real structure of the energy basket will depend on political tendencies and public values, and on finance available to governments and companies, including the possibility of investing in energy innovations. And, of course, it will depend on disasters of any nature.

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Construction On the Move

Construction of the country's first nuclear power plant is in full swing. The site is buzzing. Russian companies are manufacturing machinery and equipment, which is then delivered to Turkey. Thinking about local talents, Rosatom has again provided support to educational institutions in the host region of the Akkuyu NPP.

Four steam generators for Akkuyu Unit 1 have been delivered to the construction site. These core pieces of the reactor equipment, each weighing 365 metric tons, were unloaded at the Eastern cargo terminal. Their voyage began on August 22 at Atommash (part of Rosatom's engineering division) in the Russian city of Volgodonsk. A large crawler crane Liebherr LR1800 was used to unload them at the point of destination.

The next step is to pass an incoming inspection, which will be conducted by a group of experts. They will assess quality and quantity of the materials supplied, inspect the equipment for defects, check the packaging and quality of corrosion proofing, as well as completeness and correctness of the shipping documents.

Steam generators are Class 1 safety products. They are horizontal cylinder-shaped vessels with two elliptical bottoms. Coolant inlets and outlets are located in the middle of the cylinder. At Akkuyu NPP, chemically

demineralized water will be used as coolant. The upper part of the vessel contains a compartment accumulating steam, while its lower part houses 11,000 stainless steel pipes forming a heat exchange surface. The steam generators will be installed after the erection of columns and supporting structures with embedded parts. The installation precedes the welding of primary coolant pipes.

Core pieces of equipment continue arriving at the Akkuyu construction site. In late September, Atommash finished a reactor pressure vessel for the first power unit of the Turkish nuclear power plant and shipped it to Turkey. This means that Atommash has manufactured and shipped all the most important components of large-size equipment for the reactor of Unit 1.

It took almost three years to manufacture a 12-meter 330-ton reactor pressure vessel. Due to oversized dimensions of the equipment manufactured by Atommash, shipping it to customers is not an easy job. In order to deliver multi-ton pieces of equipment, overhead wires were temporarily removed in the streets of Volgodonsk along the entire way to the pier.

Atomenergomash CEO Andrei Nikipelov commented, **“2020 has been a busy year for us from the very beginning. We planned to ship 3 reactor vessels and 17 steam generators this year, which is a record for the entire time our company has been in this business. I am proud to say that we have reached the goal.”**

The Akkuyu nuclear power plant is growing visibly. Concreting of the basemats has been completed at the nuclear and turbine islands of Unit 2. The basemat concreting process is monitored thoroughly. Quality of the con-

crete mix is assessed first in the stationary laboratory. Then a sample is taken from each concrete mixer truck and analyzed in the mobile laboratory for temperature, cone slump and density. In order to achieve the maximum strength, 2,452 tons of steel rebar is laid in the basemat in reactor building. This is roughly a third as heavy as all steel structures of the Eiffel Tower. A steel framework is used to keep reinforcement bars in the design position. Having an area of 6,864 square meters, the basemat is 2.6 meters thick and lies eight meters deep.

The weight of the entire reactor building is about 470,000 tons. In other words, the foundation will safely carry a load equal to double as much as the world’s largest ocean cruise ship. The basemat of the reactor building has a high earthquake resistance.

Simultaneously with the concreting of the reactor basemat, the work is underway to make a foundation for the turbine island. This building houses key systems and machines generating electric power, such as a turbine generator, a deaerator and feeding pumps, and auxiliary equipment.

The turbine island belongs to the secondary loop, in which heat energy of water steam is

converted into rotational energy of the generator and then into electric energy. Although there are no radioactive media in the secondary loop, safety requirements for the turbine island are as strict as for any other facility of a nuclear power plant.

Nuclear is a knowledge-intensive industry, so talents need to be fostered from early age. Rosatom is willing to make an input in the quality of education in the host region of the nuclear power plant. Akkuyu Nükleer provided financial support to educational institutions in Mersin. Alexei Frolov, Managing Director for GR and International Cooperation at Akkuyu Nükleer, handed over a donation certificate to Yunus Emre Bayraklı, Head of Gülnar District Administration, on the occasion of the new academic year. The money will be given to the Gülnar Department of National Education to be allocated to local schools.

Yunus Emre Bayraklı said, **"We pay special attention to raising future generations and we are glad that Akkuyu Nükleer shares our values. Education is a basis for sustainable development and prosperity of the country. We are thankful to Akkuyu Nükleer for the support the company gives to our district."**

Fatih Burgut, Head of Gülnar Department of National Education, noted that the money received would be used for many different purposes, from classroom repairs to sports

equipment purchases. Akkuyu Nükleer had already made donations before, giving money to a hospital in Silifke, a family health center, and a school in Büyükeceli.

Anastasia Zoteeva, CEO of Akkuyu Nükleer, sent her greetings to schoolchildren and teachers, on the occasion of the new academic year, **"We know that school lays a solid foundation of our future success and achievements. On behalf of Akkuyu Nükleer, I congratulate schools of the Gülnar District, where our nuclear plant is located, on the beginning of the new academic year. The schools have many needs, and we want to support them in augmenting their potential for the sake of future generations. We want local schools to perform better and be more comfortable. I wish you success!"** NL

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Nuclear Power Plants: Safe, Reliable and Promising

Egypt's first nuclear power plant will be a key source of clean energy, while nuclear infrastructure will be the country's development driver. This has been repeatedly stated by both high-rank government officials and top managers of the largest Egyptian companies. Leading international organizations monitor compliance of the project with applicable regulations. The national nuclear infrastructure was assessed by the International Atomic Energy Agency.

The International Atomic Energy Agency (IAEA) provided Egypt with a report of its Integrated Nuclear Infrastructure Review (INIR) mission. Mikhail Chudakov, IAEA Deputy Director General and Head of the Department of Nuclear Energy, handed over a final INIR report to Mohamed Elmolla, Permanent Representative of the Arab Republic of Egypt to the International Organizations in Vienna, on the sidelines of the 64th session of the IAEA General Conference.

The 11-day mission took place in November 2019 at the invitation of the Egyptian authorities. The IAEA experts assessed the country's readiness for nuclear energy and made relevant recommendations.

The INIR team stated that Egypt had established comprehensive national legislation, signed an inter-governmental agreement and made necessary contractual arrangements

for the construction and operation of its first nuclear power plant. Providing suggestions, the team also pointed out actions that could further assist Egypt, such as continuing to develop its legal and regulatory framework and readiness for construction and sustainability.

The team also identified Egypt's practices that would benefit other countries interested in introducing nuclear power, such as its regulatory framework, electrical grid, stakeholder involvement, nuclear security and industrial involvement.

"INIR is a holistic peer review to assist Member States in assessing the status of their national infrastructure for the introduction of nuclear power. The review covers the comprehensive infrastructure required for developing a safe, secure and sustainable nuclear power program," the IAEA website says.

Egyptian authorities and top managers of the largest companies see the country's first nuclear power plant as one of its main sources of clean energy. Amgad Alwakeel, Head of Egypt's Nuclear Power Plants Authority (NPPA) explained in an interview to Masrawy.com that nuclear was a cornerstone of

power generation as it produced no harmful carbon emissions and generated 10% of all clean energy in the world. He cited a study conducted by NPPA, saying that nuclear would be at the heart of the country's future energy mix and, for this reason, needed to be developed.

Amgad Alwakeel stressed that construction of the nuclear power plant and creation of the national nuclear infrastructure would stimulate development of the host region and of the entire country. Increasingly more Egyptian companies get involved into the project. In 2019, three local contractors — Petrojet, Hassan Allam Holding and Arab Contractors — won contracts with ASE Engineering Company acting as a general contractor of El Dabaa project. The Head of NPPA added, **"We promote and support local participation in the project."**

According to Mr. Alwakeel, El Dabaa nuclear power plant is a profitable project. It will generate cheap electricity that will be used by local companies to expand the range and improve quality of local products and services and will be exported to neighboring countries. He noted that El Dabaa should not be viewed as only a power plant but as a project offering strategic advantages.

Sabah Mashali, Chairperson of the Board of the Egyptian Electricity Transmission Company (ETEC), said in an interview to Almalnews.com that El Dabaa NPP would play a key role in Egyptian plans of joining national grids of the neighboring countries. Nuclear will be one of the major sources of clean energy and an important component of the Egyptian energy basket. The nuclear plant will increase capabilities of the single grid. She also added, **"Electricity generated by the nuclear power plant is not expensive**

and can be produced around the clock. Imports of energy from this source are supported in Europe, making nuclear different from others."

Ms. Mashali noted that Egypt could become a regional leader in energy exports. Egypt would be able to export electric power to Europe, Africa and Asia, she said. NL

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Rafael Grossi's tweet:

El Dabaa Nuclear Power Plant will be built in the Matrouh Governorate on the Mediterranean coast. The plant will have four power units with VVER-1200 reactors. According to the contracts signed, Rosatom will be supplying Russian nuclear fuel throughout the life cycle of the plant and providing operation and maintenance support services for the first 10 years of its service life.

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Nuclear Construction at Full Tilt

The Russian nuclear corporation has shipped all of the core machinery and equipment for the Rooppur NPP Unit 1 under construction in Bangladesh. Rosatom Group companies are busy making components for the second reactor unit. Coronavirus has not affected the progress at the nuclear plant construction site.

The Volgodonsk-based production facility of AEM Technologies (part of Rosatom's engineering division) has shipped the last steam generator for the Rooppur NPP, the first one in Bangladesh. The first steam generator was shipped two months ago, together with the reactor pressure vessel. Two more generators were completed in September. That means that AEM Technologies has shipped all the core components for the nuclear island of Rooppur Unit 1.

The last steam generator was delivered from the production site to a special pier where three generators with a total weight of over 1,000 tons were loaded onto a barge. They will be first delivered to Novorossiysk in Russia's south by river and then travel to Bangladesh by sea. The sea route is about 14,000 km long. Steam generators are Class 1 safety products. Each of them is about 14 m long and 4 m wide and weighs 340 tons. It is a horizontal cylinder-shaped vessel with two

elliptical bottoms and inlet and outlet coolant collectors located in the middle section of the shell. The lower section of the vessel is a heat exchanger containing 11,000 stainless steel pipes. One reactor unit has four steam generators.

Russian companies have already started manufacturing equipment for the second unit of Rooppur NPP. The Volgodonsk branch of AEM Technologies has begun welding a lower halve of the reactor pressure vessel. The weight of the component is 160 tons. During the welding, the seams are continuously heated to the temperature of 150–300 °C. After the welding is completed, the lower halve of the RPV will be heated to 250 °C in a gas oven to recover mechanical properties of metal. When the heat treatment is over, the welding seams will be inspected and tested and then metal-clad to form a corrosion-resistant layer.

Simultaneously, the work is underway to manufacture the upper halve of the reactor vessel. At present, it is being machined, which will be followed by the cladding of welding fillets.

The nuclear reactor is a vertical cylinder-shaped vessel with an elliptical bottom. The core and internals are housed inside the vessel. Weighing more than 330 tons, the pressure vessel of VVER-1200 reactors is 12 meters high and 4.5 meters in diameter. From the top, the RPV is covered by a head with the drives of the reactor control and protection system and in-core sensor cable inlets installed on it.

Work is going full tilt at the Rooppur construction site. Last month, installation and concreting were completed at Tier 3 of the internal containment for the reactor of Unit 1. The coronavirus pandemic has had no effect on the construction progress, Bangladeshi Foreign Minister A. K. Abdul Momen told Sputnik. **“The coronavirus could not affect the progress of construction of the Rooppur Nuclear Power Plant. It is a signature project of our Prime Minister, and the Bangladesh Government puts the highest priority on the project,”** the foreign minister said. Since May 2020, Bangladesh has issued all the required visas to Russian technicians and experts working on the project, Momen said, adding that special flights were put on to bring the Russian specialists to Bangladesh. Momen also praised the coordination between all stakeholders in Moscow and Dhaka for their efforts in ensuring that the pace of construction has not slowed.

When the first nuclear power plant is commissioned, Bangladesh will have the necessary nuclear infrastructure. The country is working hard to develop it, and its efforts do not come unnoticed by the international nuclear community. In late September, the International Atomic Energy Agency (IAEA) appointed Shawkat Akbar, Rooppur Project Director and a nuclear physicist, to the Technical Working Group on Nuclear Power Infrastructure. He will be a member of the group from 2020 until 2023.

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In September, Mikhail Chudakov, IAEA Deputy Director General and Head of the Department of Nuclear Energy, sent an appointment letter to the Ministry of Science and Technology of Bangladesh, which approved the appointment. In his letter, Mikhail Chudakov expressed hope that Mr. Akbar would make a valuable contribution to the development of nuclear power infrastructure. **"It is a great honor for me to be a member of the IAEA expert group. Bangladesh is implementing a nuclear plant construction project, so the country needs to be represented in this organization,"** Shawkat Akbar said.

The Rooppur nuclear power plant is constructed to the Russian design. The plant will have two Generation III+ VVER-1200 reactor units having a power capacity of 1,200 MW each.

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