BELLONA

RUSSIAN NUCLEAR POWER

Status as of January 2021

The Bellona Foundation is an international environmental NGO based with headquarters in Norway. Founded in 1986 as a direct action protest group, Bellona has become a recognized technology and solution-oriented organizations with offices in Oslo, Brussels, St. Petersburg and Murmansk and representation in the UK, USA and the Netherlands. Bellona employs more than 60 engineers, ecologists, nuclear physicists, economists, lawyers, political scientists.

Environmental issues are an enormous challenge. They can only be solved if politicians and legislators develop clear policy frameworks and regulations for industry and consumers. Industry plays a role by developing and commercializing environmentally sound technology. Bellona strives to be a bridge builder between industry and policy makers, working closely with the former to help them respond to environmental challenges in their field, and proposing policy measures that promote new technologies with the least impact on the environment.

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2 THE PLACE OF NUCLEAR POWER IN RUSSIA

Russia's nuclear power industry began with a reactor at Obnisk (5 MWe), which came online in 1954. It was the first nuclear power plant (NPP) in the world to produce electricity. The first full size commercial reactors were put into operation around 10 years later, in 1963-64.[1]

Today, Russia runs 38 civilian, power producing nuclear reactors, most of which are located in the European part of Russia, with only a handful located east of the Ural mountain range.

Eleven of the currently operational reactors are light water graphite reactors (LWGR) 19 are light water reactors (LWR), and two are fast-breeder type reactors (FBR).

According to the latest figures from the International Atomic Energy Agency (IAEA), the nuclear reactors operating in Russia as of late 2020 have a total net capacity of 28 578 MWe, and produce 196 TWh of electricity per year.[2] For comparison, Russia's nuclear reactors produced 204 terawatt hours of electricity in 2018 – the then highest level since Soviet times and about 7.7 TWh more than in 2016.[3] In 1989, the Soviet Union produced 212.58 TWh of electricity using nuclear reactors, which included Armenian, Lithuanian, Russian and Ukrainian nuclear power plants.[4]

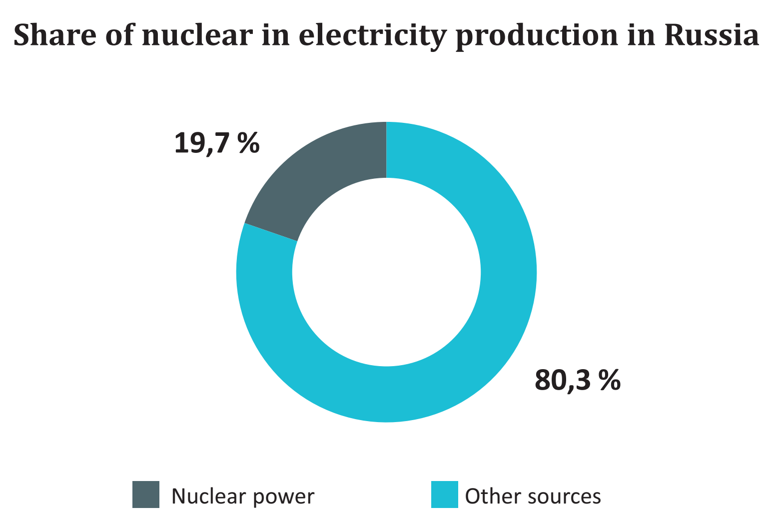

Figure 1: Share of Nuclear in electricity production in Russia

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1 http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx (Retrieved 17.10.2016)

2 IAEA – Power Reactor Information System (PRIS): https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=RU (Retrieved 16.12.2020)

3 World Nuclear News Daily – Mail Newsletter – 15.02.2019

4 World Nuclear News Daily – Mail Newsletter – 10.01.2018

The share of nuclear power in the electricity production in Russia has been increasing over the last several years, and in 2019, 19,7% of all electricity produced in Russia came from nuclear power plants, despite the fact that total production today is lower than it was in e.g. 2018[5]. On the whole, Russia is the fourth largest nuclear power producer in the world, after the USA, France and China.[6]

5 IAEA – Power Reactor Information System (PRIS): https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=RU (Retrieved 16.12.2020)

6 https://pris.iaea.org/PRIS/WorldStatistics/NuclearShareofElectricityGeneration.aspx (Retrieved 21.12.2020)

3 THE NUCLEAR POWER PLANTS OF RUSSIA

The NPPs of Russia are owned and run by the nuclear utility Rosenergoatom. The utility is 100% owned by the state nuclear agency Rosatom, which itself oversees more than 200 enterprises and science institutes and employs 250,000 people. Rosatom is also an international stakeholder. According to the state cooperation, it holds a 16,3% share of the global nuclear fuel market.[7] As of 2018, Rosatom's investment had increased by 20% over the past six years. Its funding from the state budget has meanwhile decreased from 40% to 24%, meaning it had become more self-sufficient.[8]

Figure 2: Map of NPPs in the Russian Federation (IAEA)[9]

A survey conducted by Rosenergoatom has found that the residents of Russian cities with NPPs support the use of nuclear energy. The survey, conducted by ElaKOM in March-April of 2019 across ten regions of the country, covering 10 000 people in 60 cities, says that 66,66% (Volgodonsk) and 98,5% (Polyarnye Zori) have a positive attitude towards nuclear power.[10]

At the same time, the nuclear fleet in Russia is aging, as it is in many countries around the world. We will discuss the current status and prospects of the reactor fleet in the next chapter. Here follows a *table* showing the current and former nuclear power reactors on Russian soil.

[7] http://rosatom.ru/en/about-us/ (Retrieved 16.12.2020)

[8] http://www.world-nuclear-news.org/NP-Rosatom-briefs-Russian-president-on-strategic-goals-28021802.html (Retrieved 31.05.2018)

[9] https://cnpp.iaea.org/countryprofiles/Russia/Russia.htm (Retrieved 21.12.2020)

[10] World Nuclear News Daily – Mail Newsletter – 11.06.2019

TABLE 1: **FORMER AND CURRENT NUCLEAR POWER REACTORS IN RUSSIA**[11]

Name	Type	Status	Location	Reference Unit Power [MW]	Gross Electrical Capacity [MW]	First Grid Connection
AKADEMIK LOMONOSOV-1	PWR	Operational	PEVEK	32	35	2019-12-19
AKADEMIK LOMONOSOV-2	PWR	Operational	PEVEK	32	35	2019-12-19
APS-1 OBNINSK	LWGR	Permanent Shutdown	OBNINSK	5	6	1954-06-27
BALAKOVO-1	PWR	Operational	BALAKOVO	950	1000	1985-12-28
BALAKOVO-2	PWR	Operational	BALAKOVO	950	1000	1987-10-08
BALAKOVO-3	PWR	Operational	BALAKOVO	950	1000	1988-12-25
BALAKOVO-4	PWR	Operational	BALAKOVO	950	1000	1993-04-11
BELOYARSK-1	LWGR	Permanent Shutdown	ZARECHNYY	102	108	1964-04-26
BELOYARSK-2	LWGR	Permanent Shutdown	ZARECHNYY	146	160	1967-12-29
BELOYARSK-3	FBR	Operational	ZARECHNYY	560	600	1980-04-08
BELOYARSK-4	FBR	Operational	ZARECHNYY	820	885	2015-12-10
BILIBINO-1	LWGR	Permanent Shutdown	Bilibino	11	12	1974-01-12
BILIBINO-2	LWGR	Operational	Bilibino	11	12	1974-12-30
BILIBINO-3	LWGR	Operational	Bilibino	11	12	1975-12-22
BILIBINO-4	LWGR	Operational	Bilibino	11	12	1976-12-27
KALININ-1	PWR	Operational	UDOMLYA	950	1000	1984-05-09
KALININ-2	PWR	Operational	UDOMLYA	950	1000	1986-12-03
KALININ-3	PWR	Operational	UDOMLYA	950	1000	2004-12-16
KALININ-4	PWR	Operational	UDOMLYA	950	1000	2011-11-24
KOLA-1	PWR	Operational	POLYARNYYE ZORI	411	440	1973-06-29
KOLA-2	PWR	Operational	POLYARNYYE ZORI	411	440	1974-12-09
KOLA-3	PWR	Operational	POLYARNYYE ZORI	411	440	1981-03-24
KOLA-4	PWR	Operational	POLYARNYYE ZORI	411	440	1984-10-11
KURSK-1	LWGR	Operational	KURCHATOV	925	1000	1976-12-19
KURSK-2	LWGR	Operational	KURCHATOV	925	1000	1979-01-28
KURSK-3	LWGR	Operational	KURCHATOV	925	1000	1983-10-17
KURSK-4	LWGR	Operational	KURCHATOV	925	1000	1985-12-02
LENINGRAD 2-1	PWR	Operational	SOSNOVYY BOR	1101	1188	2018-03-09
LENINGRAD 2-2	PWR	Operational	SOSNOVYY BOR	1066	1150	2020-10-22
LENINGRAD-1	LWGR	Permanent Shutdown	SOSNOVYY BOR	925	1000	1973-12-21
LENINGRAD-2	LWGR	Permanent Shutdown	SOSNOVYY BOR	925	1000	1975-07-11
LENINGRAD-3	LWGR	Operational	SOSNOVYY BOR	925	1000	1979-12-07

[11] Table 1 source: IAEA – Power Reactor Information System (PRIS): https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=RU (Retrieved 16.12.2020)

Name	Type	Status	Location	Reference Unit Power [MW]	Gross Electrical Capacity [MW]	First Grid Connection
LENINGRAD-4	LWGR	Operational	SOSNOVYY BOR	925	1000	1981-02-09
NOVOVORONEZH 2-1	PWR	Operational	NOVOVORONEZH	1100	1180	2016-08-05
NOVOVORONEZH 2-2	PWR	Operational	NOVOVORONEZH	1101	1181	2019-05-01
NOVOVORONEZH-1	PWR	Permanent Shutdown	NOVOVORONEZH	197	210	1964-09-30
NOVOVORONEZH-2	PWR	Permanent Shutdown	NOVOVORONEZH	336	365	1969-12-27
NOVOVORONEZH-3	PWR	Permanent Shutdown	NOVOVORONEZH	385	417	1971-12-27
NOVOVORONEZH-4	PWR	Operational	NOVOVORONEZH	385	417	1972-12-28
NOVOVORONEZH-5	PWR	Operational	NOVOVORONEZH	950	1000	1980-05-31
ROSTOV-1	PWR	Operational	VOLGODONSK	950	1000	2001-03-30
ROSTOV-2	PWR	Operational	VOLGODONSK	950	1000	2010-03-18
ROSTOV-3	PWR	Operational	VOLGODONSK	950	1000	2014-12-27
ROSTOV-4	PWR	Operational	VOLGODONSK	979	1030	2018-02-02
SMOLENSK-1	LWGR	Operational	DESNOGORSK	925	1000	1982-12-09
SMOLENSK-2	LWGR	Operational	DESNOGORSK	925	1000	1985-05-31
SMOLENSK-3	LWGR	Operational	DESNOGORSK	925	1000	1990-01-17

4 BRIDGING THE GAP: LIFETIME EXTENSIONS AND FUTURE NPPS

Following the Chernobyl disaster in 1986, the subsequent collapse of the Soviet Union in 1991, and the collapse of the Russian economy in the early 1990s, few nuclear reactors were built. That period saw only two reactors come into operation: Smolensk-3 (1990) and Balakovo-4 (1993). Since 2000, however, nuclear builds have picked up, and 13 reactors have entered operation. Eleven of these came online between 2010 and 2020. Here are all reactors that came online in the last two decades: Rostov-1 (2001), Kalinin-3 (2004), Rostov-2 (2010), Kalinin-4 (2012), Rostov-3 (2015), Beloyarsk-4 (2015) and Novovoronezh II-1 (2016), Rostov-4 (2018), Leningrad II-1 (2018), Akademik Lomonosov-1 (2019), Akademik Lomonosov-2 (2019), Novovoronezh II-2 (2019) and Leningrad II-2 (2020).

4.1 THE PRACTICE OF LIFETIME EXTENSIONS

The relatively small amount of new capacity added to the fleet of reactors in Russia coincides with few reactors being taken out of operation as well. According to the IAEA, only 9 out of a total of 47 power-production reactors constructed in Russia have been permanently shut down.[12] The oldest of the reactors currently operating is Novovoronezh-4, closely followed by Kola-1, with first grid connections in 1972 and 1973 respectively. As of the start of 2021, the average lifetime of the currently operating reactors is approximately 28,5 years, and the median operating time is currently 36 years. Russia currently has 24 reactors which have been running for more than 30 years, and 11 of these have been running for more than 40 years.

When first put into operation, Russian reactors traditionally received a run time permit of 30 years. But because reactors were slow to roll out in the 1990s, it became clear to the industry that many would quickly reach the end of their permits. In 2000, then, the industry laid the groundwork for drastically extending reactor run times. Today, it’s common to see a VVER-440 or an RMBK reactor receive operational extension permits of 15 years. The newer VVER-1000s receive extensions of 20 years. Lifetime extensions beyond what the reactors were designed for are thus common in Russia.

One example of a lifetime extension is that of the second oldest reactor in Russia: In March 2017, the Kola Nuclear Power Plant took its No 1 reactor off the grid for an upgrade period. Plant officials stated they would modernize all four of the Kola NPP’s reactors, with an eye to increasing their safety, but details of what, exactly; this enhanced safety entails remains unclear.[13] The Kola-1 reactor was put into operation in 1973.[14] Poised to be decommissioned

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[12] IAEA – Power Reactor Information System (PRIS): https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=RU (Retrieved 16.12.2020)

[13] http://www.kolanpp.rosenergoatom.ru/about/press-center/news/ff8a7c004043014ebde6fdc46330c020 (Retrieved 17.04.2017)

[14] https://www.vesti.ru/videos/show/vid/754993/cid/1/# (Retrieved 31.05.2018)

around 2033 the second oldest reactor running in Russia today will then have been running for a total of 60 years, exceeding its designed lifetime with 30 years.[15]

Other reactor types are also receiving extensions. Among them is the unit 3 at the power plant in Beloyarsk, a BN-600 fast reactor, which began operations in 1981. Here, a large-scale program to modernize the systems has been underway since 2009. The program has included the installation of a second reactor emergency protection system, an emergency dampening system using an air heat exchanger and a back-up reactor control panel. In addition, equipment has been replaced, including the unit's steam generators. In 2010, the reactor received approval for a 10 year extension of its lifetime. That period was to expire by the end of 2020. Yet in April 2020, the reactor was approved to operate for another 5 years. According to the director of the plant, it is technically possible to extend the operation of the unit to 2040, for which an investment project will be developed with the goal of applying for an extended license by the middle of the coming decade.[16]

Run time extensions for Russian reactors have provoked protest from environmentalists as the extensions are sometimes granted without proper environmental impact assessments. Such assessments are required by Russian legislation, making the run time extensions something of a legal gray area.[17]

It is Bellona's opinion that lifetime extensions constitute a risky strategy. Making the necessary improvements to old reactor safety is not easy, and some older reactors, like the VVER-440s at the Kola NPP near the Norwegian border, cannot be upgraded to fit today's safety standards. Still, lifetime extensions are a common practice worldwide, and at the same time, a worldwide concern. In 2020, Bellona wrote a report indicating the issues related to lifetime extensions for old nuclear power plants. The main issue is that not all components of a NPP can be replaced during the course of its lifetime – and this concerns in particular the reactor pressure vessel. The vessel deteriorates over time and with use, and Bellona believes that the practice of lifetime extensions leads international society into uncharted territory when it comes to safety risks, of which we currently have insufficient knowledge.[18]

The two main reasons that lifetime extensions are practiced in Russia and other places is because building new reactors is expensive, and that it has been and is hard to put off funds for decommissioning during the original design lifetime of a reactor. Thus, to avoid the expense authorities prolong the lifetime of reactors to increase the time they have to make a profit and put off the necessity of funding decommissioning. Building new reactors is often not a priority before one has to replace the old ones. Although it is possible to understand why extensions seem necessary for operators, Bellona is of the opinion that it is important that authorities prioritize safety and offer the public information and a voice in the matter, using public hearings as an instrument for this purpose.

In addition to runtime extensions, Rosatom is working to improve the efficiency of older nuclear power plants, including by fabricating new types of fuel. This happens for both the

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15 https://www.rosatom.ru/en/press-centre/industry-in-media/unit-1-of-kola-npp-was-reconnected-to-the-grid/ (Retrieved 16.12.2020)

16 https://www.world-nuclear-news.org/Articles/BN-600-licensed-to-operate-until-2025 (Retrieved 22.12.2020)

17 Bellona Position Paper, http://www.bellona.org/position_papers/Life_Extension_Russian_NPPs, 2006

18 https://bellona.org/publication/nuclear-power-plant-lifetime-extension-a-creeping-catastrophe-2

older VVER-440 and the VVER-1000 type reactors, both inside Russia and out, particularly at Kudankulam in India and Paks in Hungary. “Introduction of a new fuel is an option to improve the technical and economic performance of a nuclear power plant without substantial investment," according to fuel producer and Rosatom subsidiary TVEL.[19] At Kudankulam, an increased uranium content in the fuel has led to fuel that only needs to be exchanged every 18 months, as opposed to the former 12-month fuel cycle.[20] This reduces costs. Improved fuel technology is thus also a way of strengthening the argumentation for lifetime extensions in face of the more expensive alternative – that is, taking the reactors out of operation, decommissioning them and replacing the energy generation with other types of energy production, or with newer reactors.

4.2 ROADMAP TO NEW REACTORS: CURRENT NUCLEAR BUILDING PLANS

Since the 90s, the Russian government has presented ambitious plans for nuclear power development via so-called Federal Target Programs. The first of these Federal Target Programs (FTPs) was initiated by a presidential decree from Boris Yeltsin in December 1996. It would take more than three years before this program – called “Nuclear and Radiation Safety in 2000 to 2006” – to finally get approved in February of 2000.[21]

In 2015, Rosatom presented the FTP for nuclear safety for the period from 2016 to 2020. The Program involved eight federal departments and had a budget of 131,8 billion rubles. In 2007, when the first FTP was adopted, there were major risks presented by accumulated radioactive waste and spent nuclear fuel, according to former Rosatom chief Sergey Kirienko. The main goal of the FTP was to decrease the risk of large-scale accidents, to establish the safe condition of radioactive waste and ensure control and stable operation. This included dealing with the nuclear heritage from the Soviet Union, which generated radioactive waste for more than 50 years.[22]

Kirienko also said that the bulk of the program’s funding – 73% – would go toward decommissioning of commercial reactors, as well as taking out of operation several facilities based at the Mayak Production Association, the Siberian Chemical Combine, the Angarsk Electrolysis and Chemical Complex, and Novosibirsk Chemical Concentrates Plant. These facilities have been involved in the state defense program. Around 20% of the funding would go toward handling RAW and SNF, creating infrastructure for their processing and final disposal. Five percent would go to monitoring and nuclear- and radiation safety and around 2% would go towards scientific and technological support.[23]

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19 https://www.world-nuclear-news.org/Articles/TVEL-loads-modified-fuel-into-Paks-unit-3 (Retrieved 28.12.2020)

20 https://www.world-nuclear-news.org/Articles/TVEL-to-introduce-new-fuel-longer-cycle-at-Kudanku (Retrieved 28.12.2020)

21 Bellona Report, http://www.bellona.org/filearchive/fil_larin-report-english-fedprog.pdf, 2009

22 http://www.world-nuclear-news.org/NP-Russia-approves-nuclear-and-radiation-safety-program-17111501.html (Retrieved 18.10.2016)

23 http://www.world-nuclear-news.org/NP-Russia-approves-nuclear-and-radiation-safety-program-17111501.html (Retrieved 18.10.2016)

In other words, Rosatom is not ignoring the prospect of having to decommission older facilities. Still, decommissioning large parts of the current fleet of NPPs does not coincide well with their plans to expand the fleet's generating capacity:

Rosatom's plan for long-term development for the last decade was approved and signed by Russian president Vladimir Putin in July 2009. The program envisioned an increase of NPP installed capacity from 23.1 GWe in 2009 to 43.3 GWe in 2020. To achieve this, a new reactor would have had to go into operational every year from 2011 to 2013, and another two per year between 2013 to 2020.[24] According to the latest figures in 2020, the current capacity of Russia's fleet of nuclear reactors 28,5 GWe, meaning Rosatom has increased the capacity, but not as much as they planned.[25] At the same time, Rosatom has built 11 new reactors (counting the two smaller reactors on board the Akademik Lomonosov floating nuclear power plant) from 2010 to 2021. In essence, Russia has not put enough new capacity online. At the same time, they have taken some older reactors out of operation for decommissioning during the last ten years, resulting in a lower capacity than planned by the end of 2020.

A Russian government decree from 2016 states that Russia will build 11 new nuclear reactors for power production by 2030.[26] At the same time, they plan to decommission more reactors than they build, as we show in the chapter on decommissioning. The one thing that might still mean an increase in the capacity of Russia's nuclear fleet by 2030, is the fact that newer reactors have a larger capacity than older ones, meaning that an increase might still be possible, despite reactors being removed from the grid in parallel with new reactors being added.

The construction of new reactors in Russia is to be financed partially by the state budget, and partially by Rosatom's own development fund. The revenue that goes into this development fund is based on the surpluses arising from the sale of energy from existing nuclear power plants and other commercial activities.[27]

There are exceptions: The nuclear power plant that was planned for construction in Kaliningrad, known as the Baltic NPP, was to be financed partly by private investors, including investors from outside Russia. These private investments were supposed to finance 49 % of the build, with the rest coming from Rosatom. Construction began in 2010.[28] The plant being planned so close to EU-countries made Rosatom deem it likely that investors and electricity companies would be interested in co-funding their effort to build a NPP. In 2016, the project got put on hold, due to lack of interest. Rosatom says that energy demand is rising, and that the region needs an NPP, and that the main market for energy from this project would be the European one. As there are no investors for the project in Kaliningrad, some of the equipment prepared, including reactors, have been put into use in Rosatom's Ostrovets nuclear power plant project in Belarus instead.[29]

A similar freeze has seemed to threaten Rosatom's NPP-project in Turkey, which is based

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[24] WNA, Nuclear Power in Russia, 28/11 2011

[25] IAEA – Power Reactor Information System (PRIS): https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=RU (Retrieved 16.12.2020)

[26] https://world-nuclear-news.org/Articles/Rosatom-postpones-fast-reactor-project-report-say (Retrieved 29.12.2020)

[27] Bellona report, http://www.bellona.org/reports/russian-nuclear-economics, 2011

[28] Bellona report, http://www.bellona.org/reports/russian-nuclear-economics, 2011

[29] https://www.interfax.by/news/belarus/1229816 (Retrieved 18.04.2018)

around the same logic of attracting investors. In Turkey, however, Rosatom has taken it upon itself to complete the project, despite Turkish investors pulling out of the project. Lately, news has surfaced about new investors – meaning Rosatom's stake in the project can be subject to change.[30] More on these and other Rosatom reactor plans abroad can be found in a separate chapter in this document.

Table 2 on the next page shows an overview of NPPs that are currently under construction in Russia. These three reactors will add a total of 3459 MWe to the capacity of the Russian fleet.

TABLE 2: **NUCLEAR REACTORS UNDER CONSTRUCTION IN RUSSIA**[31]

Name	Type	Status	Location	Reference Unit Power [MW]	Gross Electrical Capacity [MW]	First Grid Connection
BALTIC-1	PWR	Under Construction	Neman	1109	1194	
KURSK 2-1	PWR	Under Construction	KURCHATOV	1175	1255	
KURSK 2-2	PWR	Under Construction	KURCHATOV	1175	1255	

In August 2016, a document describing the future of energy production in Russia was made public.[32] This included plans for construction of new NPPs and expansions of old ones with new reactors. Below, we have included the current overview from the IAEA, which refers planned reactor projects that are starting up to 2025, but does not include future prospects like a new NPP at Kola to replace the older VVER-440 reactors there. We refer to *Table* 3 for details on the next 5 years.

TABLE 3: **PLANNED NUCLEAR POWER PLANTS IN RUSSIA**[33]

Reactor unit/ Project name	Owner	Type	Capacity (MW(e))	Construction start year	Expected commercial year
LENINGRAD II-2	ROSATOM	VVER-1200	1200	Planned 2009	2022
LENINGRAD II-3	ROSATOM	VVER-1200	1200	Planned 2011	2023
LENINGRAD II-4	ROSATOM	VVER-1200	1200	Planned 2014	2024
Kursk II-1	ROSATOM	VVER-TOI	1250	Planned 2018	2022
Kursk II-2	ROSATOM	VVER-TOI	1250	Planned 2019	2023
Smolensk II-1	ROSATOM	VVER-TOI	1250	Planned 2022	2027
Smolensk II-1	ROSATOM	VVER-TOI	1250	Planned 2024	2029
Beloyarsk 5	ROSATOM	BN-1200	1250	Planned 2025	2031

30 https://bellona.org/news/nuclear-issues/2019-02-rosatom-reportedly-reaching-new-deal-to-complete-turkish-nuclear-plant (Retrieved 21.12.2020)

31 Table 2 source: IAEA – Power Reactor Information System (Pris): https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=RU (Retrieved 16.12.2020)

32 http://government.ru/media/files/eFBHWjAwsi3waUcgX5Cg0F4RPlbmItHe.pdf (Retrieved 19.10.2016)

33 https://cnpp.iaea.org/countryprofiles/Russia/Russia.htm (Retrieved 21.12.2020)

4.3 RUSSIA'S PURSUIT OF NEW REACTOR DESIGNS

As *Table* 3 shows, Russia is looking to build Fast Neutron reactors, like the BN-1200, as well as the purposed VVER-TOI,[34] water pressurized reactors in the future. The VVER-TOI is planned as a two-unit NPP-design and is slated for serial construction for both domestic and export purposes. It will have a 60-year lifetime, up from the older VVER-type's 30 year life time span. The VVER-TOI concept is supposed to be a universal design blueprint that can be easily parameterized to suit any geographical or security environment.[35]

According to the IAEA, fast neutron power reactors will play an increasingly important role in the Russian Federation in the period between 2020–2025, with much of the fuel being recycled.[36] Although, even after this period, most of the operating units in Russia will be thermal reactors of the VVER and RBMK type.

In essence, the Russian fleet of reactors is the reference for the Russian export of reactors. Specific designs are easier to export if they are shown to already be operating well in Russia. As such, Russia has yet to see any interest in the VVER-TOI-type reactor from abroad, as the first of its kind are still being built at the Kursk-2 NPP. The two reactors currently under construction at Kursk-2 are slated to be finished near the middle of this decade.[37]

Rosatom is building nuclear power plants in many places around the globe. Currently, they are exporting their VVER-1200-design, but the aim is to export the newer VVER-TOI as soon as that design is proven operational. The VVER-TOI design took a step forward toward potential export when it was approved by the European Utility Requirements (EUR) in 2019. European experts from different utilities have gathered to assess the design, and say it complies with their requirements. The EUR requirements cover a range of conditions for operation of NPPs. They include such areas as plant layout, systems, materials, components, safety assessment methodology and availability assessment. Although still requiring regulatory design approval in each country, EUR compliance indicates that the reactor design meets a list of requirements set by 15 member-utilities in the EUR (among them, EDF of France, Iberdrola of Spain, Rosenergoatom of Russia and TVO of Finland) for the next generation of light water reactors. Rosatom has stated that EUR certification for the VVER-TOI design will "contribute to the promotion of Russian nuclear technologies in foreign markets".[38]

In the next chapter, we have a look at the countries that are buying NPPs from Rosatom today.

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[34] TOI refers to "typical optimized, with enhanced information.: (https://www.world-nuclear-news.org/Articles/Russia-s-VVER-VOI-reactor-certified-by-European-ut)

[35] https://en.wikipedia.org/wiki/VVER-TOI

[36] https://cnpp.iaea.org/countryprofiles/Russia/Russia.htm (Retrieved 21.12.2020)

[37] https://www.kommersant.ru/doc/3448572 (Retrieved 29.05.2018)

[38] http://www.world-nuclear-news.org/Articles/Russia-s-VVER-VOI-reactor-certified-by-European-ut (Retrieved 18.06.2019)

5 RUSSIAN NUCLEAR POWER ABROAD:

Within the framework of the state agency Rosatom, the company Atomstroyexport (ASE) is responsible for exporting Russian nuclear technology. Today, the company is involved in the construction of a number reactors, first of the VVER-1000 type and now of the VVER-1200 type, worldwide. Alexey Likhachev, head of Rosatom, stated the following in a meeting with President Vladimir Putin in February of 2018: "Despite fierce competition, we are building more units abroad than all the other countries put together.”[39] In 2020, Rosatom stated that the COVID-19 pandemic has had little effect on their projects abroad.[40]

Over the last decade, Rosatom has committed to exporting nuclear power to other countries in the form of vast loans to cover nuclear power plant construction. The loans are mainly given to projects where Rosatom itself is involved as the primary developer.[41]

Increasing their stake in the international market is one of Rosatom’s four main strategic goals.[42] As of late 2020, Rosatom states on their own webpage that they have a portfolio including 35 reactors in different stages of implementation across 12 countries.[43] The number of reactors in the pipeline varies by source. If we count reactors currently under construction, those that are contracted and those that are ordered, illustrated in the material from the World Nuclear Association, *table*s 6, 7 and 8 in this chapter, we see that Rosatom is active in 15 countries, with a portfolio of 26 reactors. Seemingly, the numbers vary depending on what is defined as part of the portfolio, and thus, knowing which projects to include in any overview can be challenging.

For this document, we have chosen the World Nuclear Association’s database as an English language source. Undoubtedly, their tables may reflect their choice of categorization for different projects – whether they be “contracted” or “ordered”, the actual situation and whether it is likely that the project in question is being completed does vary. To illustrate this, we are providing some details on certain Rosatom projects later in this chapter to explain the context around them.

5.1 THE “PREPACKAGED” REACTOR CONCEPT

Rosatom is currently promoting what it calls “prepackaged” nuclear reactors to its customers abroad in the form of its VVER-1200 reactors. Originally billed as the AES-2006, Rosatom has stated that the reactor is a step up on Russia’s workhorse VVER-1000. The first VVER-1200 was launched domestically at the Novovoronezh-2 NPP and reached

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39 http://www.world-nuclear-news.org/NP-Rosatom-briefs-Russian-president-on-strategic-goals-28021802.html (Retrieved 31.05.2018)

40 https://www.world-nuclear-news.org/Articles/Rosatom-keeps-to-overseas-schedule-despite-pandemi (Retrieved 29.12.2020)

41 http://bellona.org/news/nuclear-issues/2016-10-the-future-of-russian-nuclear-power-plants-rosatom-abroad (Retrieved 17.10.2016)

42 https://rosatom.ru/about/mission/ (Retrieved 28.12.2020)

43 https://rosatom.ru/en/about-us/ (Retrieved 21.12.2020)

full commercial operation in February 2017. The rollout of VVER-1200 type reactors in Russia will make it possible to replace older reactors.

It is difficult to accurately reflect the costs of any given NPP project undertaken by Rosatom, as the company doesn't often publicize the expense of a reactor's individual components. However, projected costs of building a VVER-1200 reactor at the Ostrovets NPP, published by Interfax in 2017,[44] offer some insight on component by component expenses, as reflected in *Table* 4 underneath. This insight does not give the full picture, however, as the costs associated with reactor construction depend upon a magnitude of factors like construction time, plant size, technology improvements, licensing from regulatory bodies, etc.

TABLE 4: **ESTIMATED COSTS OF CERTAIN NPP COMPONENTS WITH A VVER-1200 REACTOR**

Equipment type	Cost in RUB
Reactor core	493,1 million (incl. VAT).
Outer containment	269,1 million (incl. VAT).
In-vessel core barrel (?)	192,2 million (incl. VAT).
Other equipment	496,9 million (incl. VAT).

Even the nuclear industry itself admits that calculating the costs of a NPP-build is hard. As the CEO of Swedish utility Vattenfall stated in September 2019 at World Nuclear Association Symposium in London: "We currently have a situation where the cost of constructing a new reactor ends up being two or three times as much as the initial calculation. That cannot go on."[45]

A recent study published by the MIT in 2020 shows that some of the reasons new builds end up being more expensive than projected is due to what the study calls 'soft' costs. These arise due to changes to the environment in which the construction is happening, creating a need to make last-minute changes in the design based on particular conditions at the construction site or other local circumstances. Changes in safety regulations account for some cost increases but are only one of numerous factors, according to the MIT.[46] The study has been done on new builds in the US, but it is likely that parts of the findings may have parallels in the rest of the worldwide nuclear industry. The VVER-1200 that Russia is currently promoting around the world is meant to be standardized, and thus reducing these soft costs. The challenge is to make a design that needs a minimum of adaptation, and which works in most environments.

The VVER-1200 is a pressurized water reactor with a designed net capacity of 1114 MWe, which is a 20% increase on the capacity of its predecessor. The engineered life expectancy of its main components – the pressure vessel and the steam generators – is 60 years, twice as long as the VVER-1000. The reactor's automated systems are supposed to reduce the number of personnel required to run it by 20% compared to the VVER-1000.

[44] https://www.interfax.by/news/belarus/1229816 (Retrieved 29.06.2018)

[45] https://www.world-nuclear-news.org/Articles/Industry-must-address-costs,-says-Vattenfall-CEO (Retrieved 29.12.2020)

[46] https://www.world-nuclear-news.org/Articles/MIT-study-focuses-on-reasons-behind-new-build-cost (Retrieved 29.12.2020)

The unit also offers numerous passive safety measures and incorporates post-Fukushima safety upgrades such as hydrogen recombiners, passive heat removal and a core melt trap, also called a core catcher. The International Atomic Energy Agency has said the design complies with its post-Fukushima requirements.[47]

However, the launch of the VVER-1200 has not been without problems. After Russia's very first VVER-1200 reactor went into service at the Novovoronezh nuclear plant, it was shut down for two and a half months after it short-circuited. It was revealed that the prototype of the VVER-1200 contained a cooling system flaw. This prompted what Rosatom termed a series of "modernizations," which it undertook at three other VVER-1200s it was building within Russia – one at the Leningrad Nuclear Power Plant, the one in Belarus, and at a second VVER-1200 under construction at Novovoronezh.[48]

What Russia builds internally is key to their export of nuclear reactors. The first VVER-1200 at Novovoronezh is not only a demonstration of the technology that Rosatom is exporting, but is also used as a reference plant when training personnel from other countries. E.g., Turkish personnel who are going to work at and operate the VVER-1200 reactor at Akkuyu have been present at Novovoronezh in 2019 and in 2020 for internships at an operating plant as part of their training.[49]

5.2 RUSSIA IN THE FOREFRONT OF THE INTERNATIONAL NUCLEAR INDUSTRY

Still, there is no shortage of interested parties around the globe. The total value of Rosatom's contracts abroad was 130 billion USD in 2018, and the same in 2019.[50] Rosatom's director, Alexey Likhachev, has said that, over the long term, he expects the worth of Rosatom's contracts abroad to nearly double to 200 billion USD.[51] These are by all marks Rosatom's own projects, as they require no approval from any Russian government agency to build or finance reactors in other countries. It also often signs agreements with foreign governments on its own. Although legislation has been loosened somewhat in recent years, Rosatom still needs approval from the state-structure in Russia for its domestic projects.[52]

At the same time, analyses from Russian environmental group Ecodefense indicate that Rosatom's assessment of their own portfolio might paint an unrealistic picture, and that not all projects indicated are actually being built as planned.[53]

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47 http://www.world-nuclear-news.org/NN-First-VVER-1200-reactor-enters-commercial-operation-02031701.html (Retrieved 12.05.2017)

48 http://bellona.org/news/nuclear-issues/2018-02-investor-pullout-leaves-rosatom-at-sea-with-its-nuclear-project-in-turkey (Retrieved 17.04.2018)

49 WWN Daily – 20th of March 2020

50 http://www.rosatom.ru/en/investors/projects/ (Retrieved 31.05.2018)
https://rosatom.ru/en/investors/projects/ (Retrieved 21.12.2020)

51 https://rg.ru/2016/10/11/medvedev-prizval-sohranit-dostizheniia-v-atomnoj-otrasli-rf.html (Retrieved 12.05.2017)

52 http://www.world-nuclear-news.org/NP-Russian-law-increases-Rosatoms-political-authority-28121701.html (Retrieved 31.05.2018)

53 https://bellona.org/news/nuclear-issues/2019-03-moscow-not-building-as-many-reactors-abroad-as-it-claims-says-new-report (Retrieved 21.12.2020)

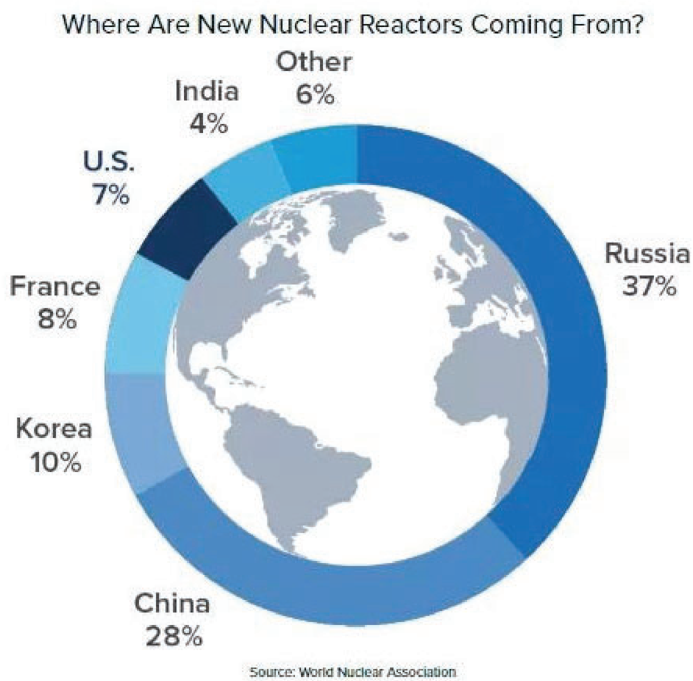

Figure 3: Country of origin for new NPPs worldwide (2018)

While the tables in this chapter indicates a considerable interest in Russian-built NPPs around the world, there are examples of countries that enter into negotiations for an NPP, and then withdraw from negotiations. In November 2016, the government of Vietnam announced it had decided against building NPPs in the country, including the one planned by Rosatom. The country said it no longer viewed nuclear power as competitive compared with other energy sources.[54] Meanwhile, a memorandum of understanding (MOU) was signed between Vietnam and Russia in 2019 on the construction of a center for nuclear science and technology (CNST) in the South-Asian country. Earlier, in 2018, MOUs were also signed on personnel training and on shaping a positive public opinion on the CNST project.[55] Such MOUs are part of the reason why Russia dominates the international nuclear industry. Although we do not go into details about this practice in this report, the general practice is as follows: MOUs are signed between Russia and individual across the world on improving the image of the nuclear industry, cooperation within nuclear research and so on.[56] Rosatom also has a role to play in how many countries develop their legislation for their nuclear industry. Rosenergoatom, one of Rosatom's subsidiaries, signs agreements with several countries on "assistance in producing regulatory and technical documentation for commissioning, operation, prolongation of the service life,

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54 http://avmalgin.livejournal.com/6593471.html (Retrieved 14.11.2016)

55 http://world-nuclear-news.org/Articles/Russia,-Vietnam-progress-with-nuclear-research-cen (Retrieved 18.06.2019)

56 More on the practice of MOUs can be found in an earlier Bellona report: https://bellona.org/publication/25568

and decommissioning of nuclear power plants", potentially paving the way for future prospects.[57]

Overall, Russia is a uniquely important player in the international nuclear industry. In their analysis, Jessica Jewell et. al observe that the international system of nuclear cooperation agreements between 2000 and 2015 were dominated by two countries. Russia and the USA. While US dominance is most prominent in safety and security, Russia's is in NPP construction, reactor and fuel supply, decommissioning and waste. When it comes to the latter technologies, Russia was the supplier in approximately half of all agreements made in this 15-year period. France, USA, China, Korea and Japan together account for another 40% of agreements, meaning that six countries, Russia chief among them, are suppliers in more than 90% of all international nuclear agreements.[58] Figure 3 from 2018, illustrating NPP origin by country around the world as of 2018 also shows clearly that Russia is in a league of its own.

5.3 COUNTRIES BUYING ROSATOM-BUILT NUCLEAR POWER PLANTS

In this chapter, you can find additional information on the different projects of Rosatom outside Russia. The following tables are all courtesy of the World Nuclear Association, updated as of November 2020.[59] Below the tables, you find more detailed context for projects in certain countries, including Bangladesh, Belarus, Bulgaria, Egypt, Finland, Hungary, India, Iran, Turkey and Uzbekistan.[60]

According to the overview in the tables below, 10 Russian built reactors are currently operating outside Russia. If Rosatom pulls through on the projects currently under construction, they almost double that amount by the end of the current decade. And if the contracted projects are all completed, it will mean that almost three times as many reactors with Russian origin will be operating outside Russia.

Currently, Rosatom's main areas for new reactor projects are concentrated in South-East Asia, Eastern Europe and the Middle-East. If we look at the last table, citing prospects, we might see a move towards projects in both Africa and South America in the future, as well as continued expansion within the geographical areas where Rosatom is currently active.

As mentioned above, Rosatom has stated that the COVID-19 pandemic has had little effect on their projects abroad.[61] Several of the projects have had equipment delivered in 2020, as in Turkey and in Bangladesh, as we illustrate in this chapter. At the same time, nuclear projects are vulnerable during a pandemic, as specialists may be unavailable at critical times for project progress. Rosatom has stated that they are worried about

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[57] WWN Daily – Newsletter – 06.04.2018

[58] Jessica Jewell, Marta Vetier, Daniel Garcia-Cabrera, The international technological nuclear cooperation landscape: A new dataset and network analysis, Energy Policy, Volume 128, 2019, Pages 838-852, ISSN 0301-4215,

[59] https://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx (Retrieved 22.12.2020)

[60] https://www.rosatom.ru/en/investors/projects/ (Retrieved 22.12.2020)

[61] https://www.world-nuclear-news.org/Articles/Rosatom-keeps-to-overseas-schedule-despite-pandemi (Retrieved 29.12.2020)

the consequences of the pandemic in relation to the nuclear cities in Russia,[62] and has reported casualties among its staff during the pandemic,[63] but it is unclear what effect this might have had on their operations abroad.

TABLE 5: **RUSSIAN BUILT NPPS CURRENTLY OPERATING OUTSIDE THE RUSSIAN FEDERATION**

Country	Plant	Type	Est. cost	Status, financing
Ukraine	Khmelnitski 2 & Rovno 4	VVER-1000/V-320		operating
Iran	Bushehr 1	VVER-1000/V-446		operating
China	Tianwan 1&2	AES-91		operating
	Tianwan 3&4	AES-91		operating
India	Kudankulam 1&2	AES-92	$3 billion	operating
Belarus	Ostrovets 1	AES-2006 (V-491)		operating
Operating: 10				

TABLE 6: **RUSSIAN NPPS CURRENTLY BEING CONSTRUCTED OUTSIDE THE RUSSIAN FEDERATION**

Country	Plant	Type	Est. cost	Status, financing
Belarus	Ostrovets 2	AES-2006 (V-491)	$10 billion	Loan organised for 90%, construction start 2013
India	Kudankulam 3&4	AES-92	$5.8 billion	Construction start June 2017 and October 2017
Bangladesh	Rooppur 1&2	AES-2006 (V-392M)	$13 billion	Construction start Nov 2017 and July 2018, loan organised for 90%
Turkey	Akkuyu 1&2	VVER-1200 (V-509)	$25 billion for four	Construction start April 2018, BOO
Iran	Bushehr 2	AES-92 (V-466B)		
Construction: 8				

For more information on the reactors under construction, we refer to detailed description of Rosatom's NPP projects in individual countries later in this chapter.

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[62] https://bellona.org/news/nuclear-issues/2020-05-rosatom-fears-for-its-nuclear-cities-amid-coronavirus-pandemic (Retrieved 29.12.2020)

[63] https://www.youtube.com/watch?v=OZCYJCeRBbg (Retrieved 19.12.2020) & https://bellona.org/news/nuclear-issues/2020-05-rosatom-eases-employee-coronavirus-restrictions (Retrieved 19.12.2020)

TABLE 7: **RUSSIAN NPPS CONTRACTED BY OTHER COUNTRIES**

Country	Plant	Type	Est. cost	Status, financing
China	Tianwan 7&8	AES-2006		Contracted
China	Xudabao 3&4	AES-2006		Contracted
Finland	Hanhikivi 1	AES-2006 (V-491)	€6 billion	Contracted, Rosatom 34% equity, also arranging loan for 75% of capital cost, construction start 2018?
Iran	Bushehr 3	AES-92 (V-466B)		Construction contract Nov 2014, NIAEP-ASE, barter for oil or pay cash
Armenia	Metsamor 3	AES-92	$5 billion	Contracted, loan for 50%
Egypt	El Dabaa	4 x AES-2006	$30 billion	Planned, state loan organised for 85%, repaid over 35 years from commissioning.
Contracted: 11				

When it comes to the contracted NPPs, these are at very varying stages of implementation. “Contracted” does not mean that the reactors in question are actually going to be built shortly.

One example is Armenia, where the project to build a third reactor in the country has been postponed due to the fact that upgrades are ongoing for the two already existing units.[64]

Another example is the Hanhikivi NPP in Finland, where construction has been postponed several times. Currently, the project is under review by the Finnish regulator before a construction license can be given by the government.

TABLE 8: **RUSSIAN NPPS ORDERED BY OTHER COUNTRIES**

Country	Plant	Type	Est. cost	Status, financing
India	Kudankulam 5&6	2 x AES-92		Planned, framework agreement June 2017, component contracts July 2017
Hungary	Paks 5&6	2 x AES-2006	€12.5 billion	Planned, loan organised for 80%
Slovakia	Bohunice V3	1 x AES-2006		Planned, possible 51% Rosatom equity
Uzbekistan	Lake Tudakul	2 x AES-2006 (V-392M)	$13 billion	Planned to operate from 2028
Ordered: 7				

[64] https://cnpp.iaea.org/countryprofiles/Armenia/Armenia.htm (Retrieved 28.12.2020)

TABLE 9: **RUSSIAN NPPS PROPOSED FOR CONSTRUCTION, BUT NOT CONFIRMED.**

Country	Plant	Type	Est. cost	Status, financing
India	Kudankulam 7&8	2 x AES-2006		
India	Andra Pradesh	6 x AES-2006		Negotiated in 2015
Bulgaria	Belene/Kozloduy 7	AES-92		Cancelled, but may be revived
Ukraine	Khmelnitski	completion of 2 x V-392B reactors	$4.9 billion	Was due to commence construction 2015, 85% financed by loan, but contract rescinded by Ukraine in 2015
South Africa	Thyspunt	up to 8 x AES-2006		Broad agreement signed, no specifics, Russia offers finance, prefers BOO. On hold.
Nigeria		AES-2006?		Broad agreement signed, no specifics, Russia offers finance, BOO
Argentina	Atucha 5?	AES-2006		Broad agreement signed, no specifics, Russia offers finance, contract expected 2016
Indonesia	Serpong	10 MWe HTR		Concept design by OKBM Afrikantov
Algeria	?	?		Agreement signed, no specifics
Jordan	Al Amra	2 x AES-92	$10 billion	Cancelled in 2018
Vietnam	Ninh Thuan 1	4 x AES-2006		On hold indefinitely
Proposals: up to 30				

5.3.1 Bangladesh

The Rooppur NPP will host two Russian VVER-1200 reactors when it opens in 2024. This will be Bangladesh's first NPP, situated 120 km north of the capital, Dhaka. The Bangladeshi government has been considering building an NPP since the early 60s, but no real progress was made until talks started with Russia in 2009 and a memorandum of understanding (MOU) was signed between the two countries.

In 2011, Russia and Bangladesh originally signed a deal for construction of two VVER-1000 reactors.[65] In 2015, the deal changed, as there were doubts about the older VVER-1000-design. Rosatom offered to construct two VVER-1200 reactors instead, signing a deal worth $12.65 billion. The proposed plant at Rooppur got its initial license for preliminary site works and surveys in June 2016, and got its construction license in October of 2017. Construction began in late November 2017, and the concrete foundation for the first reactor was completed in April 2018. The first reactor will be commissioned in 2023 or 2024, and the second in 2024 or 2025, according to plan. [66] [67] [68]

In November 2020, the VVER-1200 reactor pressure vessel and steam generator for the 1st of the units at Rooppur arrived at the site in Bangladesh, supplied by Rosatom subsidiary Atommash and built at its site in Volgodonsk, Russia. The cargo was

65 http://www.bbc.com/news/world-asia-15552687 (Retrieved 24.05.2018)

66 http://www.world-nuclear-news.org/NN-Construction-under-way-at-Rooppur-1-3011177.html (Retrieved 24.05.2018)

67 http://www.world-nuclear-news.org/NN-Rooppur-1-achieves-first-construction-milestone-05041801.html (Retrieved 24.05.2018)

68 https://www.world-nuclear-news.org/Articles/Atomenergomash-completes-components-for-overseas-p (Retrieved 22.12.2020)

transported 14, 000 km from the port in Novrorossisky to Bangladesh across the Black Sea and through the Suez Canal over the course of 2,5 months.[69]

In March 2018, Bangladesh, Russia and India signed a MOU on cooperation in the implementation of the Rooppur NPP-project. The three countries will cooperate in the field of personnel training and exchanging experience. Under the agreement, Indian companies can be involved in construction and installation works, the supply of materials and equipment of a non-critical category in the interests of the project.[70] There have been speculations as to the role India can actually have in such a project – their first NPP-project abroad, since it is not a member of the Nuclear Suppliers Group – a 48 member grouping that controls the export of materials, equipment and technology that can be used to manufacture nuclear weapons.[71]

In March of 2020, Rosatom signed a new deal with authorities in Bangladesh, amending the existing intergovernmental agreement on the construction of the Rooppur plant. The new deal establishes the right of Bangladesh to engage Rosatom on a long-term basis to assist in the operation, maintenance and repair of the two units Rosatom is building in the country. According to the revised document, Rosatom can also be engaged to supply equipment, expendable materials, spare parts and to provide training to maintenance crews as long as the plant is operating. Rosatom has stated that this will enable them to carry out maintenance, operational support and repair of the Rooppur plant. Whether this will impact the ability and competence of Bangladesh to carry out these operations themselves is yet unclear.[72]

Construction is still ongoing at the Rooppur site. The reactor pressure vessel and a steam generator for the Rooppur unit 1 arrived on site on the 10th of November 2020, and the steam collectors were shipped from Russia in December 2020.[73] Later the same month, the concreting of the internal protective shell of the reactor building at the site of unit 1 was completed, spending 1044 cubic meters of concrete. The dome is now being constructed, and metal works and concreting for this part of the structure is slated to be finished by July 2021.[74]

5.3.2 Belarus

The first unit of the Ostrovets plant in Belarus was scheduled to go online in 2019, and the second unit in July 2020.[75] The two units will deliver a combined total of 2340 MWe net capacity.[76] The construction of the first and second unit started in 2013 and 2014 respectively.[77]

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69 http://www.world-nuclear-news.org/Articles/Rooppur-1-RPV-arrives-at-construction-site (Retrieved 22.12.2020)

70 http://www.world-nuclear-news.org/NN-India-to-assist-in-Rooppur-implementation-0203184.html (Retrieved 24.05.2018)

71 http://indianexpress.com/article/india/india-collaborating-with-russia-for-nuclear-power-plant-in-bangladesh-4853282/ (Retrieved 24.05.2018)

72 https://www.world-nuclear-news.org/Articles/Russia-and-Bangladesh-expand-nuclear-cooperation (Retrieved 22.12.2020)

73 https://www.world-nuclear-news.org/Articles/Steam-equipment-shipped-for-Rooppur-unit-1 (Retrieved 28.12.2020)

74 WNN Daily – 4th of December 2020

75 https://ria.ru/atomtec/20170808/1499941207.html (Retrieved 18.04.2018)

76 http://www.world-nuclear-news.org/RS-IAEA-completes-SEED-mission-to-Belarus-23011701.html

77 http://www.world-nuclear-news.org/NN-First-concrete-for-second-Belarus-unit-0306144.html (Retrieved 04.06.2018)

There have been some incidents during the construction and operation of the Ostrovets plant:

In 2016, according to a whistleblower, a reactor pressure vessel (RPV) weighing 330 tonnes fell from a height of about 4 meters during a crane test in July 2016. The Belarusian government demanded Rosatom exchange the unit for another one, citing safety fears. Although Rosatom's then-director Sergei Kiriyenko said the RPV was undamaged, the company nonetheless took it back, possibly to avoid negative publicity.[78] The Ostrovets NPP received a new RPV in April 2017. This RPV was originally meant to be used at the Baltic NPP in Kaliningrad. Before it was installed, it passed inspections with ASE and the Belarusian Nuclear Power Plant Company, and it was replaced without any additional expense to Belarus, but for delivery.[79] According to Rosatom, this replacement would mean at least a half-year delay for the project.[80] Reportedly, a reactor pressure valve also collided with a cement column in December 2016 at the Ostrovets plant during construction works.[81]

In January of 2017, The International Atomic Energy Agency (IAEA) concluded a five-day Site and External Events Design (SEED) mission to Belarus. In its preliminary findings, the SEED team said the plant's design parameters accounted for site-specific external hazards.[82]

Despite assurances from IAEA, Baltic States like Lithuania and also Poland, have been protesting the project. In August 2017, Poland went public, stating that they will not buy electricity from the Ostrovets NPP.[83] Both Estonia, Latvia and Lithuania will be blockading electricity imports from the Belarusan plant, and they have accused the Belarusian side of skirting safety measures during the plant's construction. This claim has been rejected by Rosatom, which says the plant's design conforms to the highest international standards as confirmed by the International Atomic Energy Agency, a U.N. watchdog.[84] In September of 2020, Estonia, Latvia and Lithuania agreed to cease electricity trading with Belarus when the first unit at the Ostrovets plant is commissioned.[85]

The first reactor at Ostrovets was inaugurated on November 7th in 2020 by President Alexander Lukashenko. A few days later, Belarus shut down production at Ostrovets "to replace some of its equipment" according to the Belarusian Ministry of Energy.[86]

Details from officials are unclear, but unnamed sources have stated that technicians ceased electricity production after several of the plant's voltage transformers, which measure power in electrical circuits, exploded. The incident did not impact the safety of the reactor and no elevated radiation levels have been measured.[87]

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78 http://www.neimagazine.com/news/newsbelarus-returns-rpv-to-russia-from-unit-1-of-the-belarus-npp-5023181

79 http://www.world-nuclear-news.org/NN-Russia-installs-RPV-at-Belarus-plant-03041701.html

80 https://www.interfax.by/news/belarus/1229816 (Retrieved 18.04.2017)

81 https://bellona.org/news/nuclear-issues/2017-05-rosatom-replaces-reactor-core-that-technicians-dropped-at-its-belarusian-plant (Retrieved 22.12.2020)

82 http://www.world-nuclear-news.org/RS-IAEA-completes-SEED-mission-to-Belarus-23011701.html

83 https://ria.ru/atomtec/20170808/1499941207.html (Retrieved (18.04.2018)

84 https://bellona.org/news/nuclear-issues/2020-11-electricity-production-at-belarusian-nuclear-plant-ceases-in-wake-of-mishap (Retrieved 22.12.2020)

85 https://www.world-nuclear-news.org/Articles/Baltic-States-agree-to-block-nuclear-power-from-Be (Retrieved 28.12.2020)

86 WWN Daily – 10th of November 2020

87 https://newsland.com/user/4297673774/content/na-belaes-vzryvy-neskolkikh-transformatorov-napriazheniia/7259140 (Retrieved 10.11.2020)

In December of 2020, a planned visit of EU experts to the Ostrovets plant to review safety measures was cancelled after local officials failed to participate in a preparation meeting before the inspection. Although Belarus has stated that they welcome the inspection at a later time, EU Energy Commissioner Kadri Simson has called the delay "very regrettable, emphasizing the importance of such a review for the nuclear safety of the region.[88]

The second reactor at the Ostrovets plant is planned to come online in 2022.[89]

5.3.3 Bulgaria

Bulgaria has been trying to replace their decommissioned Kozloduy NPP for decades. The replacement long in coming is the Belene NPP. The construction was halted in 1990 in face of difficulties with financing and public protests. A tender was launched in 2005 to continue construction of the plant, and this was won by Atomstroyexport, subsidiary of Rosatom.

The project was yet again cancelled in 2012, after Bulgaria failed to find foreign investors, and allegedly were under pressure from Brussels and Washington to limit energy dependence on Russia. By then, Atomstroyexport had already produced equipment for the plant, including a reactor pressure vessel. These parts were paid for by the Bulgarian government in 2016 after a ruling in the International Court of Arbitration, which awarded.

Atomstroyexport $620 million, and the parts transported to Bulgaria in late 2017.

As of May 2019, Bulgaria started a formal process to find investors for the Belene Project. It has announced a "call for expressions of interest for a strategic investor and/or acquisition of a minority shareholding and/or purchase of electricity". The procedure was scheduled to be complete by 22nd of May 2020,[90] but a delay was announced in March 2020 due to the COVID-19 pandemic. Interested parties are Rosatom, as well as companies from China, Korea, France and the USA.[91]

5.3.4 Egypt

In August 2017, Russia and Egypt completed their talks on agreements to build a NPP at El Dabaa. The four draft agreements – which cover technical support, operation, maintenance, and fuel supply – required approval by the State Council, or the Supreme Administrative Court. The two countries signed an intergovernmental agreement in November 2015 to collaborate in the construction and operation of a nuclear power plant equipped with four 1200 MWe units. The agreement includes provision of a Russian state-backed loan of $25 billion for the $30 billion project. The Russian state loan will cover about 85% of the plant's construction costs, with Egypt to raise the remainder from private investors. The project is to be completed within 12 years and Egypt will start its repayment of the loan at an interest rate of 3% from October 2029.[92]

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88 https://www.bloomberg.com/news/articles/2020-12-16/eu-inspection-of-belarus-nuclear-plant-this-week-canceled (Retrieved 28.12.2020)

89 https://bellona.org/news/nuclear-issues/2020-11-electricity-production-at-belarusian-nuclear-plant-ceases-in-wake-of-mishap (Retrieved 22.12.2020)

90 http://world-nuclear-news.org/Articles/Bulgaria-invites-investors-to-Belene-project (Retrieved 18.06.2019)

91 https://www.reuters.com/article/health-coronavirus-bulgaria-nuclear-idUSL8N2BF0DR (Retrieved 28.12.2020)

92 http://www.world-nuclear-news.org/NN-Egypt-Russia-complete-Dabaa-plant-talks-07081701.html

The final agreement to build the “El-Dabaa” NPP was signed in December of 2017. By that time, the construction time and cost of the project had changed. The NPP was subsequently poised to be finished by 2028 or 2029, and will cost up to $21 billion. It will be built on a slot of land 130 km Northwest of Cairo.[93]

According to Egyptian authorities, the construction license for the first unit of the El Dabaa plant is expected in the second half of 2021.[94]

5.3.5 Finland

The Hanhikivi plant in Finland is a joint venture between European and Russian companies, where Rosatom plays a significant role. The plant was approved by the Finnish parliament back in July 2010.[95]

The Engineering, Procurement, Construction contract, signed on the 21st of December 2013, states that the Russian side will supply a licensed, functional and operational nuclear power unit on a turnkey basis. Hanhikivi-1 will be a single VVER-1200 nuclear power plant. It will be built on the Hanhikivi cape, municipality of Pyhäjoki, in the Finnish region of Northern Ostrobothnia.[96]

The main contractor and owner for the project is Fennovoima, a Finnish nuclear power company established by a consortium of Finnish power and industrial companies. Hanhikivi will be Fennovoima’s first nuclear power plant, and Finland’s third. The Hanhikivi project is owned by Fennovoima, and a 34% stake is held by RAOS Voima Oy, a Rosatom subsidiary.[97]

Russia's Sovcombank has signed a credit agreement contract for financing the construction of the Hanhikivi 1 nuclear power plant in Finland for a maximum amount of EUR500 million ($612 million) and with a 12-year duration. Sovcombank said it has acted as lender to several of Russian state nuclear corporation Rosatom's companies. The Hanhikivi project is owned by Fennovoima, in which a 34% stake is held by RAOS Voima Oy, the Finnish subsidiary Rosatom set up in 2014 for the purpose of buying a share in the company.[98]

In late 2018, it became clear that the completion of the Hanhikivi project would be delayed by four years, until 2028. Back then, plant owner Fennovoima stated that "The goal is to receive the construction license and to start construction of the plant in 2021," and that “The commercial operation of the plant would begin in 2028."[99]

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93 https://life.ru/t/%D0%BD%D0%BE%D0%B2%D0%BE%D1%81%D1%82%D0%B8/1069278/rosatom_podpisal_soghlashieniie_o_stroitielstvie_aes_v_ieghiptie (Retrieved 18.04.2018)

94 https://www.world-nuclear-news.org/Articles/Rosatom-keeps-to-overseas-schedule-despite-pandemi (Retrieved 22.12.2020)

95 https://uk.reuters.com/article/idUKLDE6600ED (Retrieved 25.05.2018)

96 https://www.world-nuclear-news.org/Articles/Hanhikivi-1-design-documents-submitted-to-Finnish (Retrieved 28.12.2020)

97 https://www.world-nuclear-news.org/Articles/Schedule-for-Hanhikivi-1-project-revised (Retrieved 28.12.2020)

98 WWN Daily – Newsletter – 22.01.2018

99 https://www.world-nuclear-news.org/Articles/Schedule-for-Hanhikivi-1-project-revised (Retrieved 28.12.2020)

The design documents for the project were submitted to the Finnish regulator STUK by the Russian side in December of 2020, approximately 10 years after the plant was approved by the Finnish parliament. Rosatom has stated that STUK requires a higher level of detail in the documents required at the licensing stage when compared to most other countries they operate in. The documents include a description of, for example, the conceptual and functional design of the plant, systems and buildings, and a 3D model. It provides the basis for the Preliminary Safety Analysis Report that needs to be accepted by STUK before the Finnish government can provide a construction license for the project.[100]

5.3.6 Hungary

Russia signed a contract with Hungary in 2014 to supply two VVER-1200 units at the Paks-2 NPP. The reactors are financed by a €10.0 billion Russian state loan, which will to cover 80% of the project. In February of 2017, Russia announced it was willing to finance the entire project, but Hungarian officials declined, saying they didn't want to renegotiate the original 2014 contract.[101]

Before the agreement was signed, the Paks NPP consisted of four Russian-supplied VVER-440 pressurized water reactors, which started operation in 1982 and 1987.[102]

The Paks NPP presents an interesting case. At first, the European Commission launched a probe into the Paks expansion over procurement issues and to weigh whether Russia's funding of the project amounted to state aid. In November 2016, the EC closed its procurement procedure, but the investigation of the state aid issue continues. At a joint press conference with Vladimir Putin, Hungarian President Viktor Orban said the EC investigation was the reason the project was not yet underway, and that it would start as soon as it received EU approval.[103]

In making its case to the European Commission for Paks-2, Hungary argued it needed the plant to ensure power for the next two decades while the four reactors at the original Paks-1 plant – which supply half of the country's electricity – are phased out. Hungary stipulated that because the reactors at Paks-1 are Soviet-built Russian models, it was only appropriate that Rosatom build Paks-2. It further said that the VVER-1200 reactor was the only model that could meet its power needs. And it was this argument that the European Commission eventually accepted. EU guidelines state that competitive tenders can be forgone when there are technical reasons to prefer a particular contractor. Hungary is not the first country to make use of that loophole.[104]

In March 2017, the EU granted Hungary a waiver for the Paks-2 construction to go forward. But the waiver came with three conditions. First, profits earned by the plant to be spent on Paks-2 itself, not invested in additional power capacity. Second, the company operating Paks-2 must be legally separate from the company operating Paks-1, and finally, 30 percent of the electricity Paks-2 generates has to be sold on open energy markets.

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[100] https://www.world-nuclear-news.org/Articles/Hanhikivi-1-design-documents-submitted-to-Finnish (Retrieved 28.12.2020)

[101] http://www.world-nuclear-news.org/NN-Putin-Russia-ready-to-fund-entire-Paks-II-project-03021703.html

[102] http://www.world-nuclear-news.org/NN-Putin-Russia-ready-to-fund-entire-Paks-II-project-03021703.html

[103] http://www.world-nuclear-news.org/NN-Putin-Russia-ready-to-fund-entire-Paks-II-project-03021703.html

[104] http://www.politico.eu/article/commission-gives-orban-his-nuclear-deal/

Hungary is gambling on power prices remaining steadily high, but should they drop, the Paks-2 plant will be less profitable than hoped.[105]

During a joint meeting between Russian and Hungarian authorities in May 2019, it became known that Hungary has been able to negotiate a deal that won't require them to start repaying the loan they have taken up with Russia for Paks-2 before the two new units are connected to the grid an begin operations. The loan consists of up to EUR 10 billion and will finance 80% of the project costs.[106]

Concerns have been raised that the river of Danube, who's water is used as a coolant by the Paks NPP, might be subject to serious droughts in the future – thus jeopardizing the nuclear safety at the plant due to potential lack of cooling. Csaba Kőrösi, head of Hungary's Directorate for Environmental Sustainability, has contradicted this, saying that the water levels never will be too low to sufficiently cool the Paks NPP in its current technological state".[107]

The Hungarian Energy and Public Utilities Regulatory Authority (MEKH) approved the plan to construct two VVER-1200 reactors at the existing Paks nuclear power plant site in November of 2020. The Hungarian regulator now has to approve the PAKS II project before construction can start, and it has 12 months to make a decision. It is expected that groundwork for PAKS II can start in early 2021, with a license for pre-construction site preparation. It is also expected that the final construction license for the main building will be ready by September 2021, allowing construction to commence.[108]

5.3.7 India

Rosatom has built two reactors in India (Kudankulam), which were originally supposed to start operation in 2011. In 2014, an additional agreement was signed to build two more reactors at Kudankulam.[109] The first of the four planned units was put into operation in December of 2014. The second of the four VVER-1000 units at Kudankulam reached 100% criticality in January 2017.[110]

The third and fourth units have been under construction since June of 2017.[111] According to Valery Limarenko, president of Rosatom engineering subsidiary ASE Group, Russia and India foresees construction of at least 12 new Russian-designed power units in India by 2020.[112] During the summer of 2017, Russia and India signed agreements enabling construction of the so-called third stage of the Kudankulam-plant, unit 5 and 6.[113]

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105 http://www.politico.eu/article/commission-gives-orban-his-nuclear-deal/

106 http://www.world-nuclear-news.org/Articles/Hungary-makes-environmental-case-for-Paks-expansio (Retrieved 18.06.2019)

107 http://www.world-nuclear-news.org/Articles/Hungary-makes-environmental-case-for-Paks-expansio (Retrieved 18.06.2019)

108 https://www.world-nuclear-news.org/Articles/Energy-regulator-issues-construction-permit-for-Pa (Retrieved 22.12.2020)

109 Bellona Web, http://bellona.org/articles/articles_2011/India_secondthoughts, 2011

110 http://www.world-nuclear-news.org/NN-Kudankulam-2-enters-commercial-operation-0304177.html

111 http://www.world-nuclear-news.org/NN-Construction-officially-begins-on-Kudankulam-3-4-30061701.html (Retrieved 17.04.2018)

112 http://www.world-nuclear-news.org/NN-Construction-officially-begins-on-Kudankulam-3-4-30061701.html (Retrieved 17.04.2018)

113 http://www.world-nuclear-news.org/NN-Russia-India-plan-for-Kudankulam-5-and-6-02061701.html (Retrieved 17.04.2018)

The Comptroller and Auditor General of India (CAG) went public in late 2017, stating that it had discovered several “deficiencies” in the project management of the two first units at Kudankulam, which resulted in delays and economic losses. The initial estimated cost of the two units was INR13,171 crore ($3 billion) in 2001, which gradually rose to INR22,462 crore ($5,1 billion) in 2014, according to CAG – almost doubling the cost of the project for the first two units. There were major delays in the start of commercial operations of Kudankulam 1 and 2 by around seven and eight years, respectively. A report from CAG says these delays were due to the late completion of different activities, "of which many were attributable to Atomstroyexport".[114]

5.3.8 Iran

In 1994, Russia and Iran signed an agreement to build a VVER-1000 reactor at Bushehr. After several delays, the reactor was finally put into operation in 2011, and it was officially transferred from Russian to Iranian control in 2013. It represents the first nuclear power plant in the Middle East. The next year, Russian and Iranian authorities inked another agreement, this one on building a second reactor at the Bushehr site. They further agreed to explore building six more reactors at various locations throughout Iran at an unspecified future date.[115]

A contract for construction of two more units was later signed in 2014. The first foundation stone for Bushehr units 2 and 3 was laid in a ceremony held at the construction site in southern Iran in September 2016.[116] In October 2017, a ceremony was held to mark the start of excavation work for the foundation for the first of the two reactors at Bushehr-2. Iran is reportedly covering all the costs itself.[117]

The two VVER-1000 units will be built with Generation III+ technology, which includes the latest safety features, and they have a combined capacity of 2100 MWe. Bushehr units 2 and 3 are to be completed in 2024 and 2026, respectively.[118]

From 2014 to 2017, Iran’s Bushehr-1 NPP delivered around 6.2TWh of energy to the grid. During the same period, the number of Russian experts at the site was reduced from ca. 300 to ca. 25.[119]

Bushehr has been close to being affected by earthquakes on occasion. In 2003, a 6.6 magnitude quake hit a city close to Bushehr, killing 26 000 people. In December of 2019, another quake hit close to Bushehr, this time with a magnitude of 5.1.[120]

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[114] https://www.world-nuclear-news.org/NN-Auditor-finds-deficiencies-in-Kudankulam-1-and-2-project-2912175.html (Retrieved 28.12.2020)

[115] https://rg.ru/2016/10/11/medvedev-prizval-sohranit-dostizheniia-v-atomnoj-otrasli-rf.html

[116] http://www.world-nuclear-news.org/C-Russia-and-Iran-forge-closer-ties-20011702.html and http://www.world-nuclear-news.org/NN-Iran-starts-building-unit-2-of-Bushehr-15031701.html

[117] http://world-nuclear-news.org/NN-Excavation-work-starts-for-Bushehr-2-31101701.html (Retrieved 18.04.2018)

[118] http://www.world-nuclear-news.org/C-Russia-and-Iran-forge-closer-ties-20011702.html and http://www.world-nuclear-news.org/NN-Iran-starts-building-unit-2-of-Bushehr-15031701.html and https://www.world-nuclear-news.org/Articles/Extending-nuclear-cooperation-to-the-Middle-East (latter retrieved 28.12.2020)

[119] http://www.neimagazine.com/news/newsiran-gradually-reducing-russian-support-at-bushehr-5756299

[120] https://www.theguardian.com/world/2019/dec/27/iran-earthquake-51-magnitude-quake-hits-near-bushehr-nuclear-plant (Retrieved 29.12.2020)

In January 2017, Rosatom announced that two of its other subsidiaries – the Russian Research Institute for Nuclear Power Plant Operation (VNIIAES) and the Rusatom Service – were considering starting a company to offer Russian technical assistance to the Bushehr plant. This entity would provide methodological and technical assistance to Bushehr personnel on nuclear fuel handling, neutron physics calculations, devising a plant maintenance strategy, and helping to commission mobile equipment.

Iran's use of nuclear technology is controversial internationally due to fears that Iranian authorities might use nuclear power production as a base for creating nuclear weapons. The international society has sought to remedy this by entering into the Joint Comprehensive Plan of Action (JCPOA) in 2015, also known as the Iranian nuclear deal. The goal of the deal is to put limits on uranium enrichment in Iran, avoiding weapon-grade enrichment.

In May 2019, US Secretary of State Mike Pompeo announced that the US will regard any assistance to expand Iran's Bushehr NPP beyond the existing reactor will as subject to US sanctions. Iran then stated that it will continue with low-level uranium enrichment in line with its nuclear deal,[121] before announcing that it would reduce compliance with the so called Iranian nuclear deal every 60 days until the sanctions against the country were eased. In January of 2020 however, Iran announced that it will cease abiding by the deal,[122] after the US pulled out of the agreement in 2018 and imposed sanctions on Iran.[123]

In response to queries about whether the current developments around the nuclear deal with Iran might affect nuclear projects in the country Rosatom Director General Alexey Likhachev has said to Russian newspaper RIA Novosti that: "Rosatom has always met and is meeting all its obligations in all of its international projects."[124]

5.3.9 Turkey

The Akkuyu NPP in Turkey, planned on the Mediterranean coastline, has been the subject of several delays and controversies. The four reactors planned are to be the same type of VVER-1200 reactors that are currently operating at the Novovoronezh-2 in Russia.

Turkey pays some $60 billion a year for energy imports.. The bid to develop nuclear energy is thus a bid to become more energy independent. That leaves Turkey dependent on Russia to construct NPPs, but the Turkish government has stated that it does not necessarily only look to Russia, and that other alternatives may also arise.[125]

The first agreement for the Akkuyu project, the first Turkish NPP, was signed with Russia in May 2010 and Turkey commissioned Rosatom in 2013 to build four 1200MWe reactors at the site. The €20bn ($23.4bn) project has repeatedly run into delays, including being briefly halted after Turkey shot down a Russian jet near the Syrian border in November 2015. Relations have since improved and work on the plant has resumed. Rosatom said

[121] WWN Daily – Mail Newsletter – 07.05.2019

[122] https://www.armscontrol.org/act/2020-01/news/iran-abandons-uranium-limits (Retrieved 28.12.2020)

[123] https://www.bbc.com/news/av/world-us-canada-44044350 (Retrieved 28.12.2020)

[124] http://www.world-nuclear-news.org/Articles/Rosatom-committed-to-Iranian-plant-project (Retrieved 18.06.2019)

[125] https://www.gazeta.ru/business/2018/02/06/11639215.shtml (Retrieved 17.04.2018).

in September 2017 that it aimed to start work on the Akkuyu project by the end of March 2018.[126] The construction process officially started in April of 2018.[127]

The current plans as of the end of 2020 is that the 4800MWe, four-reactor power plant will cover about 10% of Turkey's electricity needs, with unit 1 coming online in 2023.[128]

The deadline for start of commercial operation for the first unit at Akkuyu was first set to 2019, but has now been set for 2023 to coincide with the 100-year anniversary of the Turkish Republic.[129] The last three reactors are planned to come online by 2025.[130]

According to RIA Novosti, the plant will be the first NPP that is completed under the model "Build – own – operate". Russia will, in adherence with this model, build and operate the plant on behalf of Turkey.[131] The plant will be owned and operated by Akkuyu Nuclear AS, a joint venture led by Rusatom Energy International.[132]

Still, a number of Turkish companies were to act as investors in the project. Among them were Cengiz Holding and Kolin Insaa. These companies would hold 49% of shares, while Rosatom would hold the majority of 51%.[133] In February of 2018, it became known that three major Turkish companies had withdrawn from the project. A draft agreement had been signed with Rosatom for the transfer of 49% of stakes in June 2017, but the companies said that they failed to agree on commercial terms.[134]

Despite this turbulent financial situation, the plants construction is commencing. Heads of state of Turkey and Russia marked the start of construction in April 2018. At the same time, Rosatom announced that it will be taking on a 100% of the shares in the project, while still looking for additional investors.[135] Alexei Likhachev, head of Rosatom, announced that it was not likely to find such sponsors before 2019. Whether this situation will cause further delays to the project is unclear.[136]

The latest news out of Turkey is that Rosatom is thought to be close to an agreement with the Turkish contractor IC Içtas to become partner in the Akkuyu project.[137]

In November 2020, reports came that Inter RAO, a Moscow based energy holding company, has decided to sell its 0.8% stake in Akkuyu Nuclear JSC, the nuclear power

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126 http://www.neimagazine.com/news/newsakkuyu-construction-to-start-by-2018-5951569 (Retrieved 17.04.2018)

127 http://bellona.org/news/nuclear-issues/2018-04-russia-says-it-can-pay-for-turkeys-first-nuclear-plant-by-itself (Retrieved 17.04.2018)

128 WWN Daily – 11th of November 2020

129 https://www.gazeta.ru/business/2018/02/06/11639215.shtml (Retrieved 17.04.2018)

130 http://bellona.org/news/nuclear-issues/2018-04-putin-attends-ceremonial-kick-off-for-turkeys-troubled-nuclear-plant (Retrieved 17.04.2018)

131 https://ria.ru/atomtec/20170706/1497955390.html (Retrieved 17.04.2018)

132 http://www.world-nuclear-news.org/C-Atomenergomash-General-Electric-JV-signs-Akkuyu-contract-29111701.html (Retrieved 17.04.2018)

133 https://ria.ru/atomtec/20170706/1497955390.html (Retrieved 17.04.2018)

134 World Nuclear News Daily – 06.02.2018

135 http://bellona.org/news/nuclear-issues/2018-04-russia-says-it-can-pay-for-turkeys-first-nuclear-plant-by-itself (Retrieved 17.04.2018)

136 http://bellona.org/news/nuclear-issues/2018-04-putin-attends-ceremonial-kick-off-for-turkeys-troubled-nuclear-plant (Retrieved 17.04.2018)

137 WWN Daily – Newsletter – 12.02.2019

plant project developer Rosatom owns in Turkey.[138] In late December of 2020, it became clear that Russia's Sovcombank PJSC will provide Akkuyu Nuclear JSC – the subsidiary of state nuclear corporation Rosatom – with a loan of up to $300 million for a period of 7 years to finance the construction of the Akkuyu nuclear power plant.[139]

In July 2017, the European Parliament agreed on a resolution that advised Turkey not to build that which would become its first NPP. It also advised Turkey to join international conventions that would require it to perform environmental impact assessments and consult with neighboring countries before building the plant.[140] In 2019, the European parliament again called for Turkey to halt the construction of its NPP, stating the need to consult with neighboring Cyprus, although Turkey has not ratified the Espoo-convention.[141] Cyprus has said it will file official protests over the construction of the Akkuyu NPP. [142]

Turkey plans to build a second nuclear power plant in Sinop, near the Black Sea. A consortium from France and Japan will be responsible for that project.[143]

In late 2017, it became known that the contract to deliver the main equipment of the conventional island for the Akkuyu nuclear power plant in Büyükeceli in Turkey had been awarded to AAEM Turbine technology LLC, the Saint Petersburg, Russia-headquartered joint venture between Atomenergomash JSC (AEM) and General Electric (GE).[144]

Protests have plagued the Akkuyu project since it was first announced. At one point, Greenpeace organized rallies against the NPP in Istanbul and Mersina, which were dispersed by law enforcement using water cannons.[145]

Construction is ongoing at the Akkuyu site. In November of 2020, the reactor pressure vessel for unit 1 of the Akkuyu NPP was delivered from Rosatom subsidiary Atommash to the site in Turkey. The reactor pressure vessel took nearly three years to manufacture, and it was subsequently transported 3000 km over 20 days from Russia to Turkey.[146] A couple of weeks later, the reactor lid for unit 1 was also completed.[147]

5.3.10 Uzbekistan

Uzbekistan has declared its aims to double electricity production by 2030, from 13 to 27 gigawatts. The new energy mix will include nuclear power, gas and wind.[148]

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[138] WNN Daily – 2nd of November 2020

[139] WNN Daily – 18th of December 2020

[140] https://ria.ru/atomtec/20170706/1497955390.html (Retrieved 17.04.2018)

[141] https://www.trtworld.com/turkey/european-parliament-votes-against-turkey-s-upcoming-nuclear-power-plant-24915 (Retrieved 21.06.2019)

[142] WWN Daily – Newsletter – 06.04.2018

[143] http://www.neimagazine.com/news/newsakkuyu-construction-to-start-by-2018-5951569 (Retrieved 17.04.2018)

[144] http://www.world-nuclear-news.org/C-Atomenergomash-General-Electric-JV-signs-Akkuyu-contract-29111701.html (Retrieved 17.04.2018)

[145] https://www.gazeta.ru/business/2018/02/06/11639215.shtml (Retrieved 17.04.2018)

[146] WWN Daily – 11th of November 2020

[147] https://www.world-nuclear-news.org/Articles/Reactor-lid-completed-for-Akkuyu-unit-1 (Retrieved 28.12.2020)

[148] WWN Daily – Mail Newsletter – 20.06.2019

Russia and Uzbekistan signed an intergovernmental agreement on cooperation in the peaceful use of nuclear energy in December 2017.[149] A Nuclear Technologies Information Center, a joint project between UzAtom and Russian state nuclear corporation Rosatom, officially opened in May 2019 in Tashkent. The opening ceremony was attended by Alexey Likhachev, general director of Rosatom. The Center is an important part of Uzbekistan's plans to build its first nuclear power plant, Likhachev has said.[150]

The two countries have agreed on a site for the construction of the first Uzbek NPP, according to Russian Foreign Minister Sergey Lavrov. An intergovernmental agreement was been signed in September 2018 between the two countries for the construction of two VVER-1200 units in the Navoi Region of Uzbekistan.

The aim was to choose a site and grant a site license by September 2020. The first power unit was originally slated for launch by the end of 2028.[151] Despite this, negotiations have drawn out due to technical questions, and a contract has yet to be signed for the construction of two VVER-1200 units. According to Sputnik, the status as of December 2020 is that Uzbek nuclear development plans indicate that construction may start in 2022, if the contract is signed.[152]

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[149] WWN Daily – Mail Newsletter – 20.04.2018

[150] WWN Daily – Mail Newsletter – 16.05.2019

[151] http://www.world-nuclear-news.org/Articles/Russia-and-Uzbekistan-agree-to-start-survey-of-new (Retrieved 18.06.2019)

[152] https://uz.sputniknews.ru/economy/20201221/15646610/Stroitelstvo-AES-v-Uzbekistane-na-kakoj-stadii-nahoditsya-kontrakt.html (Retrieved 28.12.2020)

6 CLIMATE GOALS AND RUSSIAN NUCLEAR POWER

Russian officials are optimistic that nuclear should play a role in combatting climate change. In September of 2020, Russian Minister of Energy, Alexander Novak, stated that "Russia remains a supporter of international efforts to combat climate change, protect the environment and environmental management, ensure universal access to energy and develop clean technologies. We have one of the most diversified energy balances in the world. We have almost all types of energy production. The share of gas is about 46%, nuclear energy – about 19%, coal and hydropower – 18% each." Novak also underlined the role of nuclear in "in the formation of environmentally friendly energy".[153]

Rosatom's deputy director-general for international business, Kirill Komarov, is of the opinion that nuclear power is here to stay. In connection with a huge rise in net profits during the first half year of 2017, he said that the results demonstrate "robust growth and reinforce the reality that nuclear energy remains commercially attractive". He added: "As a reliable source of clean energy, nuclear is contributing significantly to reducing CO_2 emissions and the fight against climate change."[154] Komarov has also stated that "a lot of the time we forget in our discussions and in the scientific community that nuclear energy is part of the green energy balance, just like wind and solar".[155]

These views square with those of many international proponents of nuclear energy. According to those voices, nuclear power could replace fossil fuels in many sectors of the economy, and does not require easy access to raw materials. As such, say its supporters, plants can be built wherever power is needed, regardless of fuel availability.

At the current time, this might not be entirely accurate, due to, among other challenges, grid capacity in rural areas and the share scale of any ordinary NPP project, in both financial and practical terms. But seeing as Rosatom is moving towards building small modular reactors (on which we elaborate under the chapter on research and development in this report) this might become a realistic alternative sometime in the future. It is, however, a much greater challenge for nuclear power, whether in small or big packages, to be deployed in a timely enough fashion to meet current goals for global climate gas reductions by 2050.

Before the landmark 2015 climate summit in Paris, Russia declared it would not hamper the global climate agreement forged at COP-21.[156] That announcement inflated expectations that Russia would ratify the emerging document quickly. Russia ratified the Paris Agreement only in 2019 and has since been a party to the agreement. The parties to the UN Framework Convention on Climate Change have agreed to developing long-term,

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153 https://www.world-nuclear-news.org/Articles/Nuclear-is-environmentally-friendly-energy-says-Ru (Retrieved 28.12.2020)

154 http://www.world-nuclear-news.org/C-Atomenergoprom-sees-89-rise-in-first-half-net-profit-07091701.html (Retrieved 29.05.2018)

155 http://www.world-nuclear-news.org/C-Russia-urges-more-ambitious-nuclear-capacity-target-27061701.aspx (Retrieved 24.05.2018)

156 https://www.theguardian.com/environment/2015/dec/07/russia-pledges-not-to-stand-in-the-way-of-paris-climate-deal (Retrieved 17.10.2016)

low-emission development strategies. All parties are required to put forward nationally determined contributions (NDCs) which illustrate efforts by each country to reduce national emissions and adapt to the impacts of climate change. Russia has not yet to submitted its first NDC. There are, however, also other factors that could motivate Russia to their obligations as party to the Paris Agreement.[157]

Rosatom, for its part, has made various commitments to corporate sustainable development[158] and has pledged to honor the UN Global Compact, under which corporations commit to social and environmental responsibility.[159]

Still, much of Russia's nuclear development could mean expanding, rather than reeling in, the use of fossil fuels. The use of nuclear power at home helps make possible Russia's enormous exports of natural gas, primarily to Europe. Russia's enormously power natural gas giant Gazprom has stated that it makes five times as much exporting gas than it does selling it on the Russian market.[160]

And like gas exports, exporting nuclear power plants abroad can be considered a convenient way to expand economic security. Although Rosatom says it will eventually hand over control of the plants it builds to local authorities, countries will remain beholden to Rosatom while they pay back the enormous state funded loans. These deals also include exclusive fuel sales from Russia for the first 10 operating years of any plant it builds. A case in point is Rosatom's deal with Hungary on the Paks-2 plant to build a VVER-1200 reactor. The €12 billion deal will be 80% financed by a Russian state loan, and Rosatom will operate the plant for 50 years.[161]

In the spring of 2020, Russia's Ministry for Economic Development published a draft strategy for low-carbon development to 2050. The strategy outlines a growth in output from the nuclear sector from 203 TWh in 2017 to 225 TWh in 2030, and 260 TWh in 2050.[162] However, the State Nuclear Agency Rosatom is not only looking to nuclear, although it sees fission as the backbone of the future energy mix.

Rosatom asserts that no more than 40% of a country's energy needs can be covered by renewables, and stipulates that the remainder can be made up by nuclear. The cooperation says it is working on a "green energy balance", which it hopes to one day bring to overseas markets. In line with this logic, Rosatom subsidiary Atomenergomash is producing carbon fiber for use in turbine blades for wind power, with the aim to make Rosatom's portfolio a wind and nuclear power "package". Rosatom plans to commission 970 MWe of wind power capacity by the end of 2022,[163] and is also looking into selling their own wind turbines abroad.[164] Rosatom also does hydropower through

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157 https://www.world-nuclear-news.org/Articles/Russia-drafts-strategy-for-low-carbon-development (Retrieved 22.12.2020)

158 https://www.rosatom.ru/journalist/news/rosatom-utverdil-otraslevuyu-politiku-v-oblasti-ustoychivogo-razvitiya/

159 https://rosatom.ru/journalist/news/rosatom-prisoedinilsya-k-globalnomu-dogovoru-oon/?sphrase_id=1764412

160 WNA, Nuclear Power in Russia, 28/11 2011

161 http://www.politico.eu/article/russias-nuclear-attack-on-europe/

162 https://www.world-nuclear-news.org/Articles/Russia-drafts-strategy-for-low-carbon-development (Retrieved 22.12.2020)

163 http://www.world-nuclear-news.org/C-Russia-urges-more-ambitious-nuclear-capacity-target-27061701.aspx (Retrieved 24.05.2018)

164 http://energo-sibir.ru/news/elektroenergetika/rosatom_khochet_eksportirovat_vetryanye_turbiny/ (Retrieved 25.05.2018)

Atomenergomash, for example in South Africa, where a contract for equipment for a small-scale hydroelectric plant was signed in early 2018.[165] Such deals are to be supplied with equipment by the firm NovaWind, a subsidiary of Rosatom created in 2017.[166]

Although there are plenty mentions of renewables from Rosatom, one thing Rosatom historically has talked less about in public is the potential of energy storage technology. There might be good reason for this. Rosatom's argument is that intermittent renewable energy is unable to provide a reliable baseload for the grid, as there are no guarantees for how much power can be produced at any given time. It all depends on weather conditions, at least if we talk about solar and wind. Therefore, the logic entails that we need nuclear power as the backstop for our power production, as it guarantees predictable amounts of power when the sun does not shine and the wind does not blow.

However, while classic intermittent renewables like solar and wind have variations that depend upon wind and solar exposure, nuclear has its own considerable version of intermittency. A nuclear power plant is, unlike e.g. a gas power plant, unable to turn on and off at will to provide power when necessary or balance the grid – it takes too much time to turn a reactor on and off. Nuclear reactors do have downtime, both planned and unplanned. One thing is planned maintenance, which can leave a single reactor offline for months. Another is unplanned downtime, which happens when reactors have to be shut down due to smaller or more considerable irregularities. Nine years after the Fukushima disaster, for instance, only nine of Japan's 54 reactors have come back online as they work to clear technical and legal hurdles to their operation.[167]

When a nuclear reactor is offline, that means a large, single source of power production in the grid suddenly is unavailable, in contrast to one or a few windmills being offline in a wind park. This is in particular the case when it comes to large reactors, like the VVER-1200 that Rosatom is currently promoting and building abroad. Such a yawning gap in energy is hard to bridge, and this is one reason why reactors often are built in groups of two or more. This vulnerability is however, not increased if all reactors are operating simultaneously at full power, meaning that, to be able to replace each other, they cannot always run on full power at the same time. In sum this means that nuclear reactors do not operate at full capacity when they operate, and that their share scale and intermittency is a considerable challenge in the energy systems of which they are part.

The whole notion of nuclear energy as the backbone of an energy system, providing baseload, as it is often called, is thus not as clear-cut as it seems. Nuclear energy has its challenges, and they are connected to intermittency, which is the argument so often deployed against renewables.

In recent years, Rosatom has also started examining the notion of pairing energy storage solutions with their nuclear reactors. At an event called the "The Baltic environmental cluster – Nuclear Energy & Electromobility," held in late November of 2020, Rosatom subsidiary Atomenergopromsbyt elaborated on using lithium-ion batteries for energy

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[165] http://www.rosatom.ru/en/press-centre/news/rosatom-signs-contract-for-small-scale-hydro-facility-in-the-republic-of-south-africa/ (Retrieved 24.05.2018)

[166] https://m.fin24.com/Economy/nuclear-agenda-in-africa-under-spotlight-as-rosatom-launches-wind-energy-firm-20170921 (Retrieved 30.05.2018)

[167] https://www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx (Retrieved 19.12.2020)

storage in the grid, situated between energy producers (including Rosatom's own NPPs) and the end user in both industry and residences. This is currently being tested in Tulskaya Oblast and Moskovskaya Oblast, and the company has installed 1 MWh of capacity as part of a pilot as of late 2020.[168]

It could be suggested that developing renewable power production and storage could run counter to Rosatom's goal of building more nuclear power plants. Yet, Rosatom seems to view renewables and nuclear not as competitors, but as two energy sources they can bundle and sell as a package. Andrey Rozhdestvin, Director of Rosatom Western Europe, has stated that Rosatom is working to develop energy storage, saying it "is the way to improve the economics of renewables. And that's a mix we'd like to offer to our customers".[169]

In 2020, Rosatom created a new subsidiary, RENERA, which aims to develop energy storage solutions. These efforts have thus gotten a boost. These activities were formerly part of TVEL, Rosatom's fuel subsidiary, but have now been separated out. RENERA will continue to develop lithium-ion energy storage devices for emergency power supply, renewable energy resources and smoothing load demand.[170] RENERA is also developing batteries for use in electric vehicles.[171]

Despite Rosatom's inroads into renewable energy, the company still views nuclear power as its bread and butter. This stands in contrast to other nations that have sizeable nuclear industries but have nevertheless begun to step down their reliance on them. France, which has relied on nuclear for 75 percent of its energy, plans to reduce that to 50 percent by 2035.[172] China, meanwhile, has been investing more in wind farms development than in nuclear power.[173]

In Russia, the only renewable energy source developed on a large scale is hydropower, which accounts for roughly the same amount of the total energy mix as nuclear power. Other sources of renewable energy, like wind and solar, are currently negligible. While simultaneously weighing wind and solar power export, Russia is the most active player on the international market for nuclear technologies, and plans to go further.[174]

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[168] Live stream of the forum Baltic Environmental Cluster – Nuclear Energy – Electromobility on the 26th of November 2020 – Link to organizer's page: http://www.medoka.ru/mezhdunarodnyj-forum-baltijskij-ekologicheskij-klaster-atomnaya-energetika-elektromobili

[169] https://www.euractiv.com/section/energy/news/rosatom-talks-up-wind-solar-power-in-quest-for-diversified-portfolio/ (Retrieved 30.05.2018)

[170] WNN Daily – 8th of October 2020

[171] https://rosatom.ru/journalist/news/rosatom-oborudoval-litiy-ionnymi-batareyami-mashiny-dlya-pervoy-rossiyskoy-gonki-elektrokartov/ (Retrieved 28.12.2020)

[172] https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/france.aspx (Retrieved 19.12.2020)

[173] http://www.eurasiareview.com/26062017-russia-and-nuclear-power/ (Retrieved 29.05.2018)

[174] http://www.eurasiareview.com/26062017-russia-and-nuclear-power/ (Retrieved 29.05.2018)

7 RESEARCH AND DEVELOPMENT

As one of the biggest investors into nuclear technologies, Rosatom is developing several different approaches to nuclear energy. These technologies are thought to be able to solve several of nuclear energy's inherent challenges.

Russian authorities prioritize research and development. In April of 2020, President Vladimir Putin signed a decree on "Development of equipment, technologies and scientific research in the field of atomic energy use in the Russian Federation for the period up to 2024". According to TASS, the cost of the 4-year program would be approximately 750 billion rubles, or 10 billion USD, with 46% of the financed by the Russian federal budget.[175]

7.1 DECENTRALIZING POWER PRODUCTION WITH... NUCLEAR POWER PLANTS?

One of the characteristics of nuclear energy today is that it centralizes power production in one, large facility, requiring a well-developed electrical grid to transport electricity to remote locations. Even grids that are state of the art loose parts of the energy in transition, making it less fruitful to sell energy from NPPs to customers the further they are from the production facilities. Building a nuclear power plant is also a considerable investment, because of the scale of the current reactor types, and it is unlikely that a nuclear power plant can be built wherever power is needed.

Rosatom seeks to solve this in two ways: First, the nuclear mastodon in Russia wants to develop small-scale NPPs (SSNPP) (also known as "small modular reactors" (SMRs)) that can be deployed in remote regions, where there are few other sources of energy and perhaps even no connection to the central electrical grid. In this way, the population of remote regions could be provided with energy. Likewise, industrial enterprises that are organized in power-hungry clusters could have their needs covered by a single power plant. Rosatom is looking at producing SSNPPs with a capacity ranging from 1-300 MWh[176]. Indeed, in late 2020, Rosatom confirmed that their first land-based SMR-project is to be a RITM-200 reactor in Yakutia in the Russian Far East.[177] In anticipation of such energy sources, Jordan has revised its 2000 MWe, two-reactor deal with Rosatom, opting instead for a small modular reactor of less than 300 MWe. [178]

The project in Yakutia will supply electricity to isolated power systems and remote consumers. RITM-reactors are also installed on three new nuclear icebreakers that Rosatom will operate. (The first of these is the *Arktika*, which was launched in late 2020.)

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175 https://www.world-nuclear-news.org/Articles/Rosatom-keeps-to-overseas-schedule-despite-pandemi (Retrieved 22.12.2020)

176 https://ria.ru/atomtec/20170705/1497875662.html (Retrieved 29.05.2018)

177 https://www.world-nuclear-news.org/Articles/Rosatom-plans-first-land-based-SMR-for-Russian-Far (Retrieved 29.12.2020)

178 http://www.jordantimes.com/news/local/jordan-replace-planned-nuclear-plant-smaller-cheaper-facility (Retrieved 30.05.2018)

Rosatom has made pre-design fieldwork for the reactor at the proposed Yakutia site and is awaiting the final report with the results of their studies.[179]

In essence, the decentralization of the nuclear power structure might be a bid to compete directly with renewable sources of energy and to provide what Rosatom sees as a lacking baseline for power production in a future renewable-reliant energy mix. Renewable power sources are valued partly because they can be deployed almost anywhere, supplying energy needs in remote locations, or making consumers independent of centralized power generation. The nuclear industry is hoping to match these characteristics with SMRs.

Rosatom does not stop there, however. The company now offers another more radical portable energy solution: floating nuclear power plants.

7.2 FLOATING NUCLEAR POWER PLANTS

One of Rosatom's more famous projects the last couple of years has been its floating nuclear power plant (FNPP). Called the *Akademik Lomonosov*, the nuclear barge can travel to any coastal region in the world, throw a cable on-shore, and pump energy onto the grid, making it a possible solution to the power needs of many developing nations with a coastline, according to Rosatom.

Rosatom built the floating plant based on its experience with naval nuclear submarines and its nuclear icebreaker fleet. Yet the plant's construction was long and arduous, spanning more than a decade and two shipyards before it was finally launched. It is equipped with two 35 MWe reactors of the KLT-40S type and can burn fuel with an enrichment of up to 20%.

The *Akademik Lomonosov* was originally slated to go into operation in 2010, but was delayed, and finally rescheduled to be operational in 2019. The plant was to be transported to the city of Pevek in the Chukotka region in Russia's Far East. Once there, it would replace the Bilibino NPP,[180] which is to be decommissioned as of 2021.[181]

The FNPP set sail for Murmansk from the Baltic Shipyard in St. Petersburg in April 2018. It arrived in Murmansk on the 17th of May, and was fueled at Atomflot's base near Murmansk before moving onward to Pevek.[182] Rosatom declared it commissioned and fully operational in May of 2020.[183]

As a side note, the deployment of *Akademik Lomonosov* to the Arctic could be seen as part of a bigger move made by Rosatom. Legislation has been put into place to give Rosatom

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[179] WWN Daily – 11th of November 2020

[180] https://en.wikipedia.org/wiki/Akademik_Lomonosov (Retrieved 17.10.2016)

[181] http://bellona.org/news/nuclear-issues/2018-04-russias-floating-nuclear-plant-sets-sail-for-murmansk (Retrieved 03.05.2018)

[182] http://www.world-nuclear-news.org/NN-Floating-plant-arrives-at-Murmansk-for-fueling-2105184.html (Retrieved 04.06.2018)

[183] https://bellona.org/news/nuclear-issues/2020-05-russia-commissions-its-floating-nuclear-plant (Retrieved 29.12.2020)

full authority over the Northern Sea Route, for which Russia has enormous economic ambitions.[184]

In 2011, Rosatom publicized the cost of building the FNPP "*Akademik Lomonosov,*" saying it would amount to 16,2 billion rubles.[185] According to figures revealed in 2016, the cost had increased to 21,5 billion rubles.[186]

Figure 6: Akademik Lomonosov passing the Norwegian coast on its way to Murmansk, May 2018. Photo: Nils Bøhmer

Overall, the project saw massive delays and huge budget overruns, and has so far failed to spark interest in the foreign customers Rosatom had hoped to attract. Still, the *Akademik Lomonosov* is not the last Russian produced floating nuclear plant we are likely to see.

In December 2020, TASS reported that Rosatom is planning an updated version of the *Akademik Lomonosov* to be available for use across the world. The design of the new FNPP was unveiled at a conference in St. Petersburg near the end of the year.

Compared to the 140-meter-long *Akademik Lomonosov*, the optimized plant would be structurally simpler and easier to reproduce on mass scale. The new design would involve two modernized RITM-200 reactors, instead of the current KLT-40. This would increase its output to 100 megawatts – a 30 megawatts increase over what is supplied by the *Akademik Lomonosov*. Rosatom has stated that new design would solve a major

[184] https://bellona.org/news/arctic/2020-09-arctic-cargo-may-fall-short-of-kremlin-goal-reports-say (Retrieved 29.12.2020)

[185] Bellona Report, http://www.bellona.org/filearchive/fil_fnpp-en.pdf, 2011

[186] http://bellona.org/news/nuclear-issues/nuclear-russia/2016-01-russian-floating-nuclear-power-plants-port-to-cost-58-million

flaw in the *Akademik Lomonosov*, which has long worried environmental organizations, including Bellona. Every 12 years, the Lomonosov has to be towed back to Murmansk to offload spent nuclear fuel. The optimized design of the newer floating plants would reportedly feature a removable spent fuel storage module, allowing reactors to remain in place for refueling operations. Transport of new and spent fuel would still be required, but the vessel housing the reactors would stay put. Additionally, crews on the optimized version would also be quartered onshore, unlike the *Akademik Lomonosov*, which features dormitories and recreation facilities for about 70 resident crew members. In all, the scaled-down plant would have a reduced water displacement of 18,700 tons – some 4,000 tons less than the *Akademik Lomonosov*, according to Rosatom.[187]

While it remains unclear precisely which countries Rosatom has approached with offers of FNPPs, the company has long claimed that unspecified governments in North Africa, the Middle East and Southeast Asia are interested in acquiring floating nuclear plants. Rosatom has also reportedly been in talks with Cuba about both land-based and floating reactors.[188] In January, Rosatom CEO Aleksei Likhachev reiterated Rosatom's desire to forge ahead with floating plant construction, saying "we are working through the creation of a flotilla of floating nuclear plants with the government – I hope this plan will be adopted in 2021".[189]

Bellona been skeptical of Rosatom's ambitions for build floating nuclear plants since the *Akademik Lomonosov's* construction began in 2006 and we published a detailed catalogue of our concerns in a report released in 2011.[190]

7.3 NEW POWER REACTOR TECHNOLOGY AND RESEARCH REACTORS

An important goal in Russia's nuclear power development is the so-called fast breeder reactor, which uses plutonium as fuel. The first of these is the new Beloyarsk-4 reactor, which is of the BN-800-type.

Russia plans to develop a new 4th generation of fast breeder reactors. According to earlier plans, this reactor type should be commercially available between 2025-2030. This could, in turn, fulfill Rosatom's goal of operating only fast breeder reactors that will run on MOX fuel by 2050. The concept, according to Rosatom, will lead to a completely closed fuel cycle. The development program was pushed back to an unspecified date, according to a statement by Rosatom in January 2017.[191] In February of 2018, Alexei Likhachev, Head of Rosatom, said that the nuclear enterprise in Russia envisages the first commercial fast

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[187] https://bellona.org/news/nuclear-issues/2020-12-rosatom-redesigning-floating-nuclear-plant-for-foreign-customers-media-reports-say (Retrieved 22.12.2020)

[188] https://bellona.org/news/nuclear-issues/2020-12-rosatom-redesigning-floating-nuclear-plant-for-foreign-customers-media-reports-say (Retrieved 22.12.2020)

[189] https://strana-rosatom.ru/2021/01/15/%D0%B0%D0%BB%D0%B5%D0%BA%D1%81%D0%B5%D0%B9-%D0%BB%D0%B8%D1%85%D0%B0%D1%87%D0%B5%D0%B2-%D0%BC%D1%8B-%D1%85%D0%BE%D1%82%D0%B8%D0%BC-%D0%B2%D0%BE%D0%B9%D1%82%D0%B8-%D0%B2-%D1%82%D0%BE%D0%BF/

[190] https://bellona.org/publication/floating-nuclear-power-plants (Retrieved 22.12.2020)

[191] http://bellona.org/news/nuclear-issues/2017-01-russian-fast-reactor-program-stalls-while-economy-plummets

neutron reactor to be added to the national energy system by in 2020.[192] So far, no new fast neutron reactors have been constructed, and the planned commission of a proposed BN-1200 at Beloyarsk was postponed in 2019 from its original date in 2027 to 2036, due to lack of funding.[193]

Russia is replacing its BOR-60 experimental fast reactor at the Research Institute of Atomic Reactors (NIIAR) at Dmitrovgrad in Ulyanovsk, where the reactor went online in 1969. It will be replaced by an MBIR reactor, which is a 150 MWt sodium-cooled fast reactor with an engineered lifetime of 50 years.

The MBIR (Multi-Purpose Fast Reactor) will be capable of testing lead, lead-bismuth and gas coolants, running on MOX (mixed uranium and plutonium oxide) fuel. NIIAR intends to set up on-site closed fuel cycle facilities for the MBIR, using pyrochemical reprocessing that has been developed on a pilot scale. The company responsible for constructing the research reactor is AEM-Technology. AEM is part of Atomenergomash, itself a subsidiary of Rosatom. The MBIR project is to be open to foreign collaboration, in conjunction with the International Atomic Energy Agency's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO).[194]

7.4 REPROCESSING OF WASTE AND THE CLOSED FUEL CYCLE

Handling and storing radioactive waste (RAW) and spent nuclear fuel (SNF) is undoubtedly one of nuclear energy's biggest issues facing Russia's nuclear industry. The industry in general, and Rosatom in particular, has for a long time discussed the so-called "closed fuel cycle". In essence, this term describes a system where the SNF that is left in the back end of the production chain after power production is reintroduced into the system as new fuel. This requires a process where the usable elements of the SNF, mainly uranium and plutonium, are extracted. That can be accomplished in several ways, from classical reprocessing to introducing certain materials into fast neutron reactors. This can be aided by better technologies for extraction of useful materials, as well as new types of fuel. Although Rosatom mostly speaks about the former, the latter is also in the works.

An example is the new TVS-2M fuel design that replaces the older UTVS fuel assemblies in e.g. a VVER-1000 reactor. The fuel is supposed to boost plant efficiency and operational safety, while reusing the amount of used fuel produced.[195] In early 2018, it became known that Iran had struck a deal with Rosatom's subsidiary JSC TVEL to supply this new type of fuel to their Bushehr-1 NPP as of 2020.[196] The two first VVER units at India's Kudankulam NPP are also preparing to use this type of nuclear fuel from 2021.[197]

Classic reprocessing involves dissolving SNF in an acid bath and chemically separating out uranium and plutonium from other high-level radioactive waste. The Uranium and plutonium

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192 http://www.world-nuclear-news.org/NP-Rosatom-briefs-Russian-president-on-strategic-goals-28021802.html (Retrieved 31.05.2018)

193 https://world-nuclear-news.org/Articles/Rosatom-postpones-fast-reactor-project-report-say (Retrieved 29.12.2020)

194 http://www.world-nuclear-news.org/NN-Russia-starts-to-build-MBIR-vessel-27031702.html

195 WWN Daily – Mail Newsletter – 10.06.2019

196 http://www.world-nuclear-news.org/UF-Irans-Bushehr-I-changes-to-TVS-2M-fuel-25041801.html (Retrieved 29.05.2018)

197 WWN Daily – Mail Newsletter – 10.06.2019

from this process can, in theory, be used to produce new nuclear fuel. The high-level radioactive waste, a byproduct of the reprocessing process, has historically led to challenges for the facilities that conduct these operations. The chemical bath is contaminated by the process as well, increasing the total amount of RAW that has to be handled and stored.

In Russia, reprocessing of SNF from the civilian NPPs is conducted at the RT-1 facility at the Mayak Chemical Combine in the Southern Urals. It is located near Chelyabinsk and its one-million-strong population. The Mayak Chemical Combine was originally built to produce plutonium for the Soviet nuclear weapons program. The production of weapons grade plutonium at Mayak started in 1948, and that contributed to the development of the first Soviet nuclear bomb, which was tested in 1949.[198]

Mayak was also the location of the little known "Kyshtym" nuclear catastrophe in 1957. A cooling system for a tank storing tens of thousands of tons of dissolved nuclear waste exploded. The radioactive cloud that followed contaminated an expansive territory in the eastern Urals. The Kyshtym disaster is second only to the Chernobyl and Fukushima disasters in scale, rated at 6 on the seven-level INES scale. There have also been several other less severe incidents at Mayak since the 1940s.[199]

The RT-1 reprocessing facility at Mayak started operation in 1977 and is today the only facility for reprocessing of civilian SNF in Russia. The facility can only process SNF from VVER-440 reactors and the reactors at the Bilibino NPP, as well as fuel from research reactors and maritime reactors. The annual throughput of SNF at RT-1 is 400 tons.[200]

Since the only facility for reprocessing in Russia is still unable to treat SNF from RBMK type reactors and only started processing waste from VVER-1000 reactors in 2016,[201] the bulk (between 80% and 90%) of the SNF from Russian NPPs is in temporary storage on the sites of the NPPs that produced it, according to earlier Bellona research. SNF stored near the NPPs is kept in spent fuel pools. Some is stored at the central storage facility for VVER-1000 fuel at the Zheleznogorsk Mining and Chemical Combine in central Siberia.[202]

Uranium reprocessed from VVER-440-produced spent fuel is used to make new fuel for RBMK reactors. Fuel from RMBKs is, in turn, not reprocessed at all. That's because reprocessing RBMK has, until recently, not been considered economical due to its low quality and enrichment. Over the past few years, however, Russia has made technological advances that could make it profitable. New methods are being tested, and if successful, they'll be put to use at Zheleznogorsk, where SNF from RMBK reactors is stored.

In the 1970s it was thought that reprocessed plutonium would be used in fast breeder reactors, but that technology was still far off. Fast breeder technology's recent arrival has been long in the coming. Several countries have large quantities of plutonium that they have shored up in hopes it would prove useful as nuclear technology advanced. In some places, specially modified pressurized water reactors can run on MOX fuel. One of those is the BN-600 reactor at Beloyarsk, which was originally intended as a fast breeder running on plutonium fuel.[203]

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198 Bellona Rapport, http://www.bellona.org/filearchive/fil_Bellona_2004_RedReport.pdf, 2004

199 https://en.wikipedia.org/wiki/Mayak

200 Bellona Report, http://www.bellona.org/filearchive/fil_Bellona_2004_RedReport.pdf

201 http://www.world-nuclear-news.org/UF-Russia-proposes-new-closed-fuel-cycle-2309177.html (Retrieved 29.05.2018)

202 Bellona report, http://www.bellona.org/reports/russian-nuclear-economics, 2011

203 https://en.wikipedia.org/wiki/Fast-neutron_reactor (Retrieved 18.05.2017)

In addition to its own waste, Russia is handling and reprocessing waste from other countries. There are several reasons for this. For one, Russia has an economic interest in handling and reprocessing SNF from other countries. For some of the customers, this seems like a necessary step to be able to handle and store the SNF in their own countries. Especially for post-Soviet nations who have Soviet-era nuclear reactors within their borders, Rosatom is the only player on the market that can readily handle reprocessing fuel from older Soviet type reactors.

To give an example, Ukraine has had a contract with Russia that lets it deliver its spent nuclear fuel to Rosatom for reprocessing. Ukraine has five NPPs of Soviet design, four of which are still operational, with a total of 15 running reactors. Annually, the costs for the reprocessing-agreement has been reported to be about $200 million. As long as the deal was on, Ukraine did not have to worry about storing all of its own, non-reprocessed SNF, but the contract says that at a set time, Russia will return the vitrified radioactive waste arising from reprocessing to Ukraine for storage. The set time for this return was originally from 2018 and onwards. In essence, this means that Ukraine should be ready to handle and store these materials, including vitrified high-level RAW, but according to a 2018 Bellona report, Ukraine has been far from ready. Recent news indicate that Ukraine's nuclear agency Energoatom will have a new complex ready to store domestic SNF sometime early 2021, but construction of a complex for storing the vitrified waste from Russian reprocessing has yet to start.[204]

Ukraine is not alone in having to deal with its SNF by reprocessing it. As only three nations in the world, Russia, France and the UK, are currently possessing facilities for reprocessing of SNF from commercial reactors, countries all around the world might be facing this challenge in the near future.

Rosatom says it already has the first instance of the so-called closed fuel cycle up and running, although it also admits that current models are far from optimal.[205] A couple of years back, Rosatom estimated that the current system – in which uranium recovered from nuclear reprocessing, (RepU) and plutonium are only used once – can at best use about 21% of spent light water reactor fuel. The remaining 79% – most of it uranium-238 – has to be stored. The new nuclear fuel cycle they are working to realize could use a further 77% of the total SNF from light water reactors. That will leave a smaller portion of the used fuel in need of disposal as waste.[206] However, it is unclear how they are to deal with the issues currently associated with reprocessing, where the radioactivity level of the RAW and SNF is indeed lowered, but the total amount of waste increases.

Rosatom's project for enabling the closed fuel cycle is called 'Proryv', or Breakthrough. According to Rosatom director-general Alexey Likhachev, it will require fast neutron reactors like the BN-800 or BN-1200. Likhachev said in late September of 2017 that Russia is leading in this field, and that the MBIR – multipurpose sodium-cooled fast

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[204] Bellona – The Ukrainian Nuclear Industry: Expert Review, 2017 (http://bellona.org/publication/the-nuclear-industry-in-ukraine-an-overview)

[205] http://www.world-nuclear-news.org/UF-Russia-proposes-new-closed-fuel-cycle-2309177.html (Retrieved 29.05.2018)

[206] http://www.world-nuclear-news.org/UF-Russia-proposes-new-clogsed-fuel-cycle-2309177.html (Retrieved 29.05.2018)

neutron research reactor that is under construction in Dmitrovgrad will be a step in the right direction for the Proryv project.[207]

Russia will construct a nuclear fuel fabrication facility for its lead-cooled fast-neutron Brest-OD-300 reactor, situated at the Siberian Chemical Combine. The project comprises a fuel production/refabrication module for production of dense uranium plutonium (nitride) fuel for fast reactors; a nuclear power plant with a BREST reactor; and a used fuel retreatment module. A nuclear power plant with BREST-OD-300 is to be part of a pilot energy complex, or ODEK, under construction at SCC's site. The whole project is slated for completion in 2026.[208] [209]

At the World Nuclear Association's Symposium in London in 2017, Lyudmila Zalimskaya, general director of JSC Tenex, described three scenarios for the closed nuclear fuel cycles development that Rosatom is currently working on. Tenex, the nuclear fuel cycle product supplier subsidiary of Rosatom. We list them below, courtesy of World Nuclear News:[210]

The first scenario involves recycling of RepU and plutonium in the existing nuclear power fleet, with RepU used to fuel RBMK reactors and plutonium in the BN-800 fast reactor.

The second scenario is a so-called REMIX nuclear fuel cycle. REMIX fuel is produced directly from a non-separated mix of recycled uranium and plutonium from the reprocessing of used fuel, and can be used in light-water reactors. The used REMIX fuel can be reprocessed and recycled repeatedly.

The third scenario is a two-component nuclear power system involving light water reactors and fast reactors. In this scenario, used fuel from light water reactors is reprocessed with the RepU recycled in the same reactors and the plutonium recycled in MOX fuel in fast reactors. Plutonium separated from used fast reactor fuel is suitable for use in MOX fuel that can then be used in the light water reactors.

Zalimskaya added that Russia is ready to supply "a full set of services" from fuel supply to used fuel reprocessing to countries without such technologies. She added that the amount of spent nuclear fuel will continue to increase, reaching around 1 million tonnes worldwide by 2050. The uranium and plutonium that could be extracted from that used fuel would be sufficient to provide fuel for at least 140 light water reactors of 1 GWe capacity for 60 years, she said. "It makes sense to consider how to turn today's burden into a valuable resource."[211]

In short, Rosatom’s bid to sell nuclear plants throughout the world might secure lucrative fuel reprocessing contracts for the reactors it builds. Their outspoken goal is to achieve so-called equivalent exchange with nature, returning to it only as much radioactivity as they take from it.[212]

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[207] http://www.world-nuclear-news.org/NP-Rosatom-outlines-future-of-nuclear-in-IAEA-address-21091702.html (Retrieved 31.05.2018)

[208] http://www.world-nuclear-news.org/NN-Russia-to-build-fast-reactor-fuel-plant-in-2018-29121701.html (Retrieved 29.05.2018)

[209] https://world-nuclear-news.org/Articles/Russia-awards-contract-to-build-BREST-reactor (Retrieved 28.12.2020)

[210] http://www.world-nuclear-news.org/UF-Russia-proposes-new-closed-fuel-cycle-2309177.html (Retrieved 29.05.2018)

[211] http://www.world-nuclear-news.org/UF-Russia-proposes-new-closed-fuel-cycle-2309177.html (Retrieved 29.05.2018)

[212] http://www.world-nuclear-news.org/NP-Rosatom-briefs-Russian-president-on-strategic-goals-28021802.html (Retrieved 31.05.2018)

7.5 NUCLEAR SCIENCE AND TECHNOLOGY CENTERS ABROAD

Rosatom is not only doing research into nuclear energy. As part of their portfolio abroad, they are offering to construct so-called Nuclear Science and Technology Centers in other countries.

These centers consist of several elements that are to be considered as separate products that one can order from Rosatom. The core structure often includes a nuclear medicine center and a multipurpose treatment center. According to RIA Novosti, the purpose of such centers is to facilitate a process where countries that buy other services from Rosatom can begin to work on developing their own nuclear technologies and knowledge. Such centers can be used for several different research purposes, within medicine, geology, agriculture and so on. Again, according to RIA Novosti, Rosatom is currently building such centers in Bolivia, and have ongoing talks or plans for such projects in Vietnam, Zambia, Belarus, South Africa, Nigeria, Ghana and Rwanda.[213]

[213] https://ria.ru/atomtec/20170705/1497875662.html (Retrieved 29.05.2018) and https://rosatom.ru/en/press-centre/news/russia-and-rwanda-agreed-to-construct-the-first-centre-of-nuclear-science-and-technologies-in-rwanda/ (Retrieved 19.12.2020)

8 DECOMMISSIONING OF NPPS

Several reactors have been taken out of operation in Russia and are waiting to be decommissioned. Rosatom's roadmap from 2015 shows decommissioning plans toward 2030 as shown below. Recent statements from Rosatom indicate plans to decommission 18 reactors, many of them of the RBMK-type, before 2030.[214]

2017	Novovoronezh 1-3
2018	Novovoronezh 1-4
2019	Leningrad 1-1, Bilibino
2020	None planned
2021	Leningrad 1-2
2022	Kursk 1-1
2023	None planned
2024	Kursk 1-2
2025	Leningrad 1-3, Beloyarsk 3
2026	Leningrad 1-4
2027	None planned
2028	Smolensk 1-1
2029	Kursk 1-3
2030	Smolensk 1-2, Kola 1-1, Kola 1-2

Figure 8: Rosatom's decommissioning plans 2015-2030

[214] https://www.world-nuclear-news.org/Articles/Russia-establishes-RBMK-decommissioning-technology (Retrieved 29.12.2020)

8.1 HOW DECOMMISSIONING PROJECTS ARE SUPPOSED TO WORK IN RUSSIA

According to Russian law, decommissioning programs are to be developed no later than 3 years before the end of the lifetime of a unit. A special commission must develop proposals for the project, based on examinations of the unit.

Federal regulations state that permanently shut down reactors are considered to be in operation without generation until the moment of complete removal of nuclear fuel, which is completed, according to Rosatom, within four years from shutdown.[215]

The costs for decommissioning projects are to be paid by a fund created especially for this purpose. The fund's income comes from different sources; among them are the federal and regional budgets, revenue from public and private sources, and payments from the operating organization.

This last notion is the most interesting, as it is comparable to the principle of "the polluter pays", and more so, in Russia, than in other comparable country, according to a report by Friends of the Earth Norway:[216] In other countries, the payments from the operating organization are collected by adding a sum on top of the price of electricity generated by an NPP. In Russia, the operator pays a percentage of revenue (not more than 3,2%). The revenue from sales of electricity from a NPP shall, according to Russian law, lead to a steady stream of funding to a decommissioning fund from the first day of operation of any given NPP.

These rules were made law only in 1995, and as such, many of the reactors in Russia have had little time to accumulate a sufficient financial resources for decommissioning. Today, the Russian decommissioning fund does not have enough money to finance the decommissioning of all power plants currently operating on lifetime extensions. One reason for the lack of available funds is that much of the money in the fund is being spent on reactors that are already closed, including those that were closed before the law establishing the decommissioning fund was signed into force. Extending the lifetime of a reactor thus gives it more time to accumulate the funds needed to take it out of operation. Building new NPPs also increases revenues added to the fund, which might make it easier to pay for decommissioning at reactors that are coming to retirement age. Still, it is a challenge for the fund to "catch up" to the increasing number of decommissioning projects that still loom.

A lack of transparency and information, including a lack of insight into actual decommissioning plans, makes it hard to assess how much such projects actually cost in Russia.[217] Summarizing, the question of how to finance decommissioning efforts is one that requires a review by both Russian authorities and other states that currently use nuclear power. As an industry, the nuclear sector has yet to find a comprehensive solution to the financial component of decommissioning.

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[215] WWN Daily – 10th of November 2020

[216] Naturvernforbundet/Friends of the Earth Norway, Report: How to pay? Financing decommissioning of nuclear power plants, 2017 https://naturvernforbundet.no/__cpcategoryid__::2847::/eksempler-til-etterfolgelse-article36861-3400.html

[217] Naturvernforbundet/Friends of the Earth Norway, Report: How to pay? Financing decommissioning of nuclear power plants, 2017 https://naturvernforbundet.no/__cpcategoryid__::2847::/eksempler-til-etterfolgelse-article36861-3400.html

8.2 DECOMMISSIONING PROJECTS AND THE FUTURE:

Two reactors at Beloyarsk NPP were taken out of operation in 1981 and 1989. Their fuel was at least partly removed, and the reactors themselves were sealed for long-term safety purposes, but the final decommissioning process has not been completed.[218] Rosteknadzor has provided the Beloyarsk NPP with a license to keep the two reactors running in shutdown mode, as the fuel removal process has to be completed before preparations for final decommissioning can take place.[219]

The decommissioning process for two reactors at Novovoronezh NPP that were put into operation in 1988 and 1990 respectively was started in 2011. This will represent the first full scale decommissioning of an NPP in Russia. Rosatom has said the project will yield valuable experience for future decommissioning work.[220]

Of particular interest is perhaps the upcoming decommissioning of a number of RBMK-units, the same type of reactor that exploded in Chernobyl in 1986. Currently, there are 10 such reactors operational in Russia. Most of them will be decommissioned before 2030, according to Rosatom. In the summer of 2020, Rosatom established a RBMK decommissioning technology center near the Leningrad NPP in Sosnovy Bor, close to Saint Petersburg, with a branch near the Beloyarsk NPP.[221] The RBMK reactors have proved very difficult to deal with, due to the radioactive graphite they contain. At Beloyarsk, reactors of the AMB-100 and AMB-200 type, technically the forefathers of the RBMK-type reactors, were shut down in 1981 and in 1990. They still have not been dealt with, and Rosatom hopes to develop an approach that makes it possible to reckon with RBMK-type reactors and other graphite-based builds.[222]

In November of 2017, Natalia Safronova, head of decommissioning with Rosenergoatom told delegates at the International AtomEco-Forum in Moscow that moving from “deferred” to “immediate” dismantling approach for Russia’s nuclear would bring a 20% cost saving. The logic is that immediate dismantling enables the maximum use of residual life of the equipment and structures of the shutdown units, reduces maintenance costs, makes use of existing radioactive waste management facilities and employs the skills of personnel. A feasibility study for such a transition for the 1st and 2nd units of the Novovoronezh plant was to be conducted by the end of 2017.[223] This might mean that Rosatom will decide to speed up decommissioning processes for NPPs to save funds.

If we compare the available information on NPPs being built, those that are planned, and those that are slated for decommissioning before 2030, it appears that Rosatom is planning to replace reactors that are running on extended lifetime permits. Leningrad NPP and Kursk NPP have reactors under construction, which might replace the old ones.

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218 http://www.rosatom.ru/wps/wcm/connect/rosenergoatom/belnpp_en/about/history/

219 WWN Daily – Mail Newsletter – 22.02.2019

220 http://bellona.org/articles/articles_2011/novovornezh_decommission

221 https://www.world-nuclear-news.org/Articles/Russia-establishes-RBMK-decommissioning-technology (Retrieved 29.12.2020)

222 https://www.world-nuclear-news.org/Articles/Russia-establishes-RBMK-decommissioning-technology (Retrieved 29.12.2020)

223 World Nuclear News Daily – Mail Newsletter – 22.11.2017

In addition, Rosatom is planning to build new reactors at Smolensk NPP to replace the old reactors near the end of this decade. Still, only old reactors at Kursk NPP, Bilibino NPP, Leningrad NPP and Novovoronezh NPP are slated for decommissioning in the near future. This indicates that we will see both modern and elderly NPPs running in Russia for at least the next decade.

9 CONCLUDING REMARKS

This report shows how Russia is the most active player in the international nuclear industry. Russia is actively developing nuclear technologies for power production and is building nuclear reactors at home to showcase them for sales abroad.

Rosatom, Russia's state nuclear cooperation, is building reactors in a variety of countries around the world, primarily in Eastern Europe, Asia and the Middle East. At the same time, Rosatom is pursuing partnerships with countries in other parts of the world, including in Africa and in South America. These partnerships include not only potential nuclear power reactor projects, but also nuclear research reactors, and aid in promoting nuclear power and adapting legislation that makes future nuclear builds possible.

Rosatom has two approaches to selling nuclear reactor-builds abroad. Either buyers are able to finance the builds through considerable loans from Russia, or the builds can be completed using the concept of Buy-Own-Operate, which means Rosatom owns the plant, and is responsible for its operation.

Inside Russia, Rosatom has ambitious goals to increase the total power production capacity of the nuclear fleet. It has so far had issues reaching its goals, due to a combination of too few new-builds and older reactors being taken out of operation. Reactors inside Russia are actively being granted permission to run longer than they originally were designed for. These lifetime extensions are more economical than building new nuclear power plants to replace the old ones. In addition to the expense of new build, funds to take older reactors out of operation and properly decommission them are not available – and increased run-times extend the period during which such funds may be accumulated, based on the income from power production. Bellona is skeptical to runtime extensions across the world, and deem we have too little knowledge of the potential consequences.

In addition to a traditional land-based reactors, Rosatom is developing smaller modular reactors, (SMRs), for use both on land, and at sea. The latter is exemplified by the recent commissioning of the first floating nuclear power plant in 2020. Called the *Akademik Lomonosov*, the floating plant has two reactors based on the design Rosatom uses aboard nuclear icebreakers. Although the *Akademik Lomonosov* overshot deadlines by a decade, Russia is looking to work on new designs for similar floating power plants going forward, with the goal of selling their power production capacity across the world.

Rosatom is further developing what it calls a closed nuclear fuel cycle, which is meant to solve one of the nuclear industries biggest issues – what to do with spent nuclear fuel and radioactive waste. So far, no countries in the world have a final, proven solution for storing spent nuclear fuel and radioactive waste long term. Rosatom's approach is to build new reactor designs that would reduce the amount of waste from nuclear power production.

As part of their activities, Rosatom is developing technologies not directly related to nuclear power production. They are also actively pursuing wind power to pair with their nuclear reactors, and potentially sell this as a package to customers. Rosatom is also undertaking research on energy storage technologies, like batteries, for use both in the electrical grid, and for use in electrical vehicles.