BELLONA

RUSSIAN NUCLEAR POWER 2018

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The Bellona Foundation is an international environmental NGO based 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, Kiev, St. Petersburg and Murmansk. Altogether, some 60 engineers, ecologists, nuclear physicists, economists, lawyers, political scientists and journalists work at Bellona.

Environmental change is an enormous challenge. It 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.

Authors:
Oskar Njaa
Nils Bøhmer
Charles Digges

Design: Bellona
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Contact: nils@bellona.no

Web page: www.bellona.org

TABLE OF CONTENTS

1. THE PLACE OF NUCLEAR POWER IN RUSSIA

Russia's 35 nuclear power units at 10 different nuclear power plants (NPPs) generated 202.8 terawatt hours of electricity in 2017, the highest level since Soviet times, about 6.5 TWh more than in 2016 and over 3 TWh more than the federal target for 2017.[1]
This places the country as the third largest nuclear power producer in the world, after the USA and France.[2] On average, 18% of electricity production in Russia over the last several years has come from nuclear power.[3] For comparison, in 1989, the Soviet Union produced 212.58 TWh of electricity, which included Armenian, Lithuanian, Russian and Ukrainian nuclear power plants.[4]

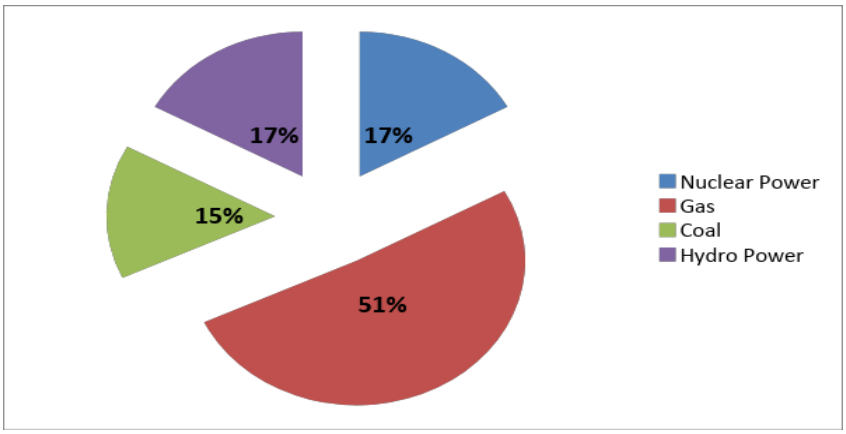

Figure 1 - Power usage in Russia by energy source

Figure 2 – Map of Russian NPPs in and close to Russia[5]

[1] World Nuclear News Daily – Mail Newsletter – 10.01.2018

[2] http://www.world-nuclear.org/ (Retrieved 17.10.2016)

[3] Rosenergatom, 2016 (http://www.rosenergoatom.ru) (Retrieved 17.10.2016)

[4] World Nuclear News Daily – Mail Newsletter – 10.01.2018

[5] https://www.iaea.org/INPRO/10th_Dialogue_Forum/Day3/Session4/02.Khaperskaya_Russia.pdf

2. THE NUCLEAR POWER PLANTS OF 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.[6]

Today, Russia runs 10 civilian NPPs,[7] eight of which are located in the European part of Russia. Two are located east of the Ural mountain range.

Eleven of the currently operational reactors are graphite-moderated reactors of the RBMK model, which is the same type that exploded in Chernobyl in 1986. Of the remaining reactors, 19 are light-water reactors of the VVER-model. Most of the reactors in Russia were put into operation in the late 1970s and the early 1980s. The average run time of those reactors are now just over 31 years, with the longest running in operation for 46 years. (See Table 1 underneath)

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 which employs 250,000 people. Rosatom is also an international stakeholder. It currently occupies around 36% of the world market for uranium enrichment and it produces 17% of all nuclear fuel worldwide.[8] As of 2018, Rosatom's investment has increased by 20% over the past six years. Its funding from the state budget has decreased from 40% to 24%, meaning it is more able to stand on its own feet.[9]

According to the latest figures, 35 reactors are currently in operation at NPPs in Russia, with a total capacity of 27,127 GW. This includes the newest addition, Novovorenezh-6, which was put into operation on October 27, 2016. The biggest producing plants in 2017 were Kalinin, Balakovo and Leningrad.[10]

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

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

[8] http://rosatom.ru/en/about-us/ (Retrieved 17.10.2016)

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

[10] World Nuclear News Daily – Mail Newsletter – 10.01.2018

Table 1 - Nuclear power in Russia per May 2018[11]

NPP	Type	Reactors	Start of operation	Capacity (MWe)	Run time permit
Balakovo NPP	VVER-1000	Balakov-1	28.12.1985	988	2045
		Balakov-2	08.10.1987	988	2033
		Balakov-3	25.12.1988	988	2034
		Balakov-4	04.11.1993	988	2023
Beloyarsk 1 NPP	BN-600	Belyoarsk-3	08.04.1980	560	2025
	BN-800	Beloyarsk-4	17.08.2016	789	2046
Bilibino NPP	EGP-6	Bilibino-1	12.01.1974	12	2018
		Bilibino-2	30.12.1974	12	2018
		Bilibino-3	22.12.1975	12	2021
		Bilibino-4	27.12.1976	12	2021
Kalinin NPP	VVER-1000	Kalinin-1	09.05.1984	1000	2025
		Kalinin-2	03.12.1986	1000	2032
		Kalinin-3	16.12.2004	1000	2034
		Kalinin-4	26.09.2012	1000	2042
Kola NPP	VVER-440	Kola-1	29.06.1973	432	2033
		Kola-2	08.12.1974	411	2034
		Kola-3	24.03.1981	411	2026
		Kola-4	11.10.1984	411	2039
Kursk NPP	RBMK-1000	Kursk-1	19.12.1976	971	2022
		Kursk-2	28.01.1979	971	2024
		Kursk-3	17.10.1983	925	2029
		Kursk-4	02.12.1985	925	2030
Leningrad NPP	RBMK-1000	Leningrad-1	21.12.1973	925	2019
		Leningrad-2	11.07.1975	971	2021
		Leningrad-3	07.12.1979	925	2025
		Leningrad-4	09.02.1981	925	2026
Novovorenezh NPP*	VVER-440	~~Novovorenezh-3~~	~~27.12.1971~~	~~385~~	~~2016~~
	VVER-440	Novovorenezh-4	28.12.1972	385	2032
	VVER-1000	Novovorenezh-5	31.05.1980	950	2035
	VVER-1200	Novovorenezh-6	27.10.2016	1114	2046
Rostov	VVER-1000	Rostov-1	30.03.2001	990	2030
		Rostov-2	18.03.2010	990	2040
		Rostov-3	17.09.2015	1011	2045
Smolensk NPP	RBMK-1000	Smolensk-1	09.12.1982	925	2028
		Smolensk-2	31.05.1985	925	2040
		Smolensk-3	17.01.1990	925	2045

[11] http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx

3. BRIDGING THE GAP: LIFETIME EXTENSIONS AND FUTURE NPPS

Since the Chernobyl disaster of 1986, the collapse of the Soviet Union in 1991, and the following collapse of the Russian economy, few reactors have been built and put into operation. During the 1990s, two reactors were put into operation; Smolensk-3 (1990) and Balakovo-4 (1993). Since the year 2000, 6 reactors have been put into operation; Rostov-1 (2001), Kalinin-3 (2004), Rostov-2 (2010), Kalinin-4 (2012), Rostov-3 (2016) and Novovoronezh-6 (2016).

The small amount of new capacity added to the fleet of reactors in Russia has led to few reactors being taken out of operation as well. Lifetime extensions beyond what the reactors were designed for are thus quite common in Russia.

When first put into operation, Russian reactors receive 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.

Run time extensions for Russian reactors have provoked protest from environmentalists because the extensions are granted without environmental impact assessments. Such assessments are required by Russian legislation, making the run time extensions something of a legal gray area.[12]

A telling example: In March 2017, the Kola Nuclear Power Plant took its No 3 reactor off the grid for a 50-day upgrade period. Plant officials say they will eventually modernize all four of the Kola NPP's reactors, with an eye to increasing their security, but details of what, exactly, this enhanced security will entail remains sketchy.[13] Modernizations on the oldest of reactors and the last in line for upgrade started in May of 2018. This reactor was put into operation in 1973.[14] Poised to be decommissioned around 2030, the oldest reactor running in Russia today will then have been running for a total of 60 years, exceeding its designed lifetime with 30 years.

Bellona is of the opinion that lifetime extensions constitutes a risky strategy. Making the necessary improvements to old reactor designs 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 is a widespread practice worldwide.

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[12] Bellona Position Paper, http://www.bellona.org/position_papers/Life_Extension_Russian_NPPs, 2006

[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)

The two main reasons that life time extensions is practiced in Russia is the fact that building new reactors is quite expensive, and that it is often hard to put off funds for decommissioning during the original design lifetime of a reactor. Thus, to avoid a deficit, operators prolong the lifetime of reactors to increase the time they have to make a profit and put off funds for decommissioning. Building new reactors is not a priority before one has to replace the old ones. More on this in chapter 12.1. Bellona understands why extensions seem necessary for operators, but is also of the opinion that it is important that operators offer the public information and a say in the matter, using public hearing as an instrument for this purpose.

3.1. 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 (FTP) 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. [15]

In 2015, Rosatom presented the latest Federal Target Program (FTP) for nuclear safety for the period from 2016 to 2020. The Program involves eight federal departments and has a budget of 131,8 billion rubles. In 2007, when the first FTP was adopted, there were major risks presented by accumulated waste and used 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 includes dealing with the nuclear heritage from the Soviet Union, which generated radioactive waste for more than 50 years.[16]

Kirienko also said that the bulk of the program's funding – 73% - would go toward decommissioning of commercial reactors, as well as taking facilities at Mayak Production Association, Siberian Chemical Combine, Angarsk Electrolysis and Chemical Complex, as well as Novosibirsk Chemical Concentrates Plant, out of operation. 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.[17]

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:

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

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

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

The latest version of Rosatom's plan for long-term development was approved and signed by Russian president Vladimir Putin in July 2009. The program envisions 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. [18]

Rosenergoatom plans to increase nuclear power generation by the following figures, according to Nuclear Engineering International:

Rosatom's draft annual report sets a power target for 2018 at 205.9TWh, and for 2019 at 213.8TWh.[19]

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. [20]

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, but has since been put on hold over a lack of investor interest.[21] The same freeze seemed to threaten Rosatom's NPP-project in Turkey, which is based around the same logic of attracting investors. In Turkey, however, Rosatom has taken it upon itself to complete the project, despite Turkish investors recently pulling out of the project.

Table 2 on the next page shows an overview of NPPs that are currently under construction in Russia.

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

[19] http://www.neimagazine.com/news/newsrussia-plans-to-boost-nuclear-power-generation-5789303 (Retrieved 18.05.2017)

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

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

Table 2 - Nuclear power plants under construction in Russia:

Name	Type	Total reactors (planned)	Existing reactors	Under construction	Construction start	To be completed	Total capacity being built (MWe)
Baltiyskaya	*VVER-1200*	*2*	*0*	*2*	*2010*	*?*	*2 x 1170*
Kursk-2	*VVER-TOI*	2	0	1	*2018/2019*	2023/24	*2 x 1115*
Leningrad-2	*VVER-1200*	4	0	2	*2008*	2019/20	*2 x 1085*
Novovoronezh-2	*VVER-1200*	2	1	1	*2008*	2019	*2 x 1114*
Rostov	*VVER-1000*	4	3	1	*2010*	2018	*1 x 1011*

The so-called Baltyskaya NPP in Kaliningrad also deserves a special note. This project was to be built with help from investors. The plant being planned so close to EU-countries led Rosatom to 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, are being put into use in Rosatom's Ostrovets project in Belarus instead.[22]

In August 2016, a document describing the future of energy production in Russia was made public. [23] This includes plans for construction of new NPPs and expansions of old ones with new reactors. We refer to *Table 3* on the next page for details.

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

[23] http://government.ru/media/files/eFBHWjAwsi3waUcgX5Cg0F4RPlbmItHe.pdf (Retrieved 19.10.2016)

Table 3 - Planned Nuclear power plants in Russia[24]

Name	Location	Purpose	Reactor type	Capacity (MWt)	Start of operation
Kola-2	Polyarnie zori, Murmansk	Replace old reactors	1 x VVER-600	**600**	**By 2030**
Tsentralny	Buj, Kostromsk Oblast	Enhance the energy supply in the region	2 x VVER-TOI	**2 x 1250**	**By 2030**
Smolensk-2	Desnogorsk, Smolensk Oblast	Replace old reactors	1 x VVER-TOI	**1250**	**By 2030**
			2 x VVER-TOI	**1250**	**By 2030**
Nizhegorodskaya	Nizhegorodskaya Oblast	Enhance the energy supply in the region	1 x VVER-TOI	**1255**	**By 2030**
			2 x VVER-TOI	**1255**	**By 2030**
Tatarskaya	Tatarstan	Enhance the energy supply in the region	1 x VVER-TOI	**1250**	**By 2030**
Beloyarsk	Zarechniy, Sverdlovsk Oblast	Enhance the energy supply in the region	5 x BN-1200	**1200**	**By 2030**
Juzhnoural	Chelabyinsk Oblast	Compensate for the energy deficit in the region	1 x BN-1200	**1200**	**By 2030**
Severskaya	Seversk, Tomsk Oblast	Replace old reactors	1 x BREST-300	**300**	**By 2025**

3.2. Russia's pursuit of fast neutron reactors

As *Table 3* shows, Russia is looking to build primarily Fast Neutron reactors, like the BN-1200, as well as the purposed VVER-TOI, 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 life time, 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. [25]

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 e.g. the VVER-TOI-type reactor from abroad, as the first of its kind are still being built at the Kursk-2 NPP.[26]

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

[24] http://government.ru/media/files/eFBHWjAwsi3waUcgX5Cg0F4RPlbmItHe.pdf (Retrieved 19.10.2016)

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

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

as that design is proven operational. In the next chapter, we have a look at the countries that are buying NPPs from Rosatom today.

4. 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 of the VVER-1000 and 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."[27]

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.[28]

Rosatom is currently promoting what it calls "prepackaged" nuclear reactors to its customers abroad in the form of its new VVER-1200 reactor. Originally billed as the AES-2006, Rosatom says the new 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 full commercial operation in February 2017. A second of these units is expected to come online at the plant in 2019. Both will replace two reactors at the older Novovoronezh-1, which will soon be decommissioned.

It is often 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[29], offer some insight on component by component expenses, as reflected in *Table 4* underneath.

Table 4 – Estimated costs of NPP components with a VVER-1200 reactor

Equipment type	Cost in RUB
Reactor core	493,1 million
Outer containment	269,1 million
In-vessel core barrel (?)	192,2 million
Other equipment	496,9 million
Total cost:	1.425 billion (incl. VAT).

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

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

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

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 highly automated systems are supposed to reduce the number of personnel required to run it by 20% compared to the VVER-1000. 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.[30]

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.[31]

Still, there is no shortage of interested parties around the globe. The total value of Rosatom's contracts abroad was 130 billion USD when this report was written in May of 2018.[32] 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. [33] 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.[34]

Although this report focuses mainly on the actual NPP-projects of Rosatom, the nuclear firm also has a role to play in how many countries develop their legislation for their nuclear industry. Rosenergoatom, one of Rosatom's subsidiaries, is to sign agreements with several countries on "assistance in producing regulatory and technical documentation for commissioning, operation, prolongation of the service life, and decommissioning of nuclear power plants". The first of such agreements was signed with Armenia in April 2018. Belarus, Egypt, Iran and Turkey are to follow suit, according to Rosatom itself.[35]

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

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

[32] http://www.rosatom.ru/en/investors/projects/ (Retrieved 31.05.2018)

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

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

[35] WWN Daily – Newsletter – 06.04.2018

47% of Rosatom's total revenue came from projects abroad in 2016. The total portfolio was worth $133 billion in 2018, involving 44 different countries. Russia is the biggest player in the international market for new nuclear reactors.

Figure 3 – Country of origin for new NPPs worldwide

5. Countries buying Rosatom-built NPPs

In this chapter, you can find additional information on the different projects of Rosatom outside Russia.

Table 5 - Nuclear power plants being planned by Rosatom abroad

Name (Country)	Type	Total planned reactors	Existing reactors	Under construction	Start of construction	Planned completion	Total capacity planned (MWe)
Rooppur NPP (Bangladesh)	*VVER-1200*	2	0	2	*2017*	2023/2024	*2400*
Belarusian (Belarus)	*VVER-1200*	2	0	2	*2013*	2020	*2400*
Tianwan (China)	*VVER-1000*	4	2	2	*2012/2013*	2018/2019	*2100*
El Dabaa (Egypt)	*VVER-1200*	*4*	*0*	*0*	*?*	*2028/2029*	*4800*
Hanhikivi (Finland)	*VVER-1200*	1	0	0	*2018*	2024	*1200*
Paks-2 (Hungary)	*VVER-1200*	6	4	0	*2018*	?	*4400*
Kudankulam (India)	*VVER-1000*	6	2	2	*2016*	?	*4000*
Bushehr (Iran)	*VVER-1000*	3	1	2	*2017*	2024/2026	*3000*
Akkuyu (Turkey)	*VVER-1200*	*4*	*0*	*1*	*2018*	*2023*	*4800*
~~Ninh Thuận 1 (Vietnam)*~~	~~*VVER-1200*~~	~~2~~	~~0~~	~~0~~	~~*2020*~~	~~?~~	~~*2400*~~

*The plans were cancelled in November 2016. See below.
Note: An up to date list can at any time be found at http://www.rosatom.ru/en/investors/projects/

5.1. Bangladesh

The Rooppur NPP will host two Russian VVER-1200 reactors when it stands ready 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 signed a deal for construction of two VVER-1000 reactors[36]. In 2015, the deal changed, as many doubted 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, and the second in 2024, according to plan.[37] [38]

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

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

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

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.[39] 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.[40]

5.2. Belarus

The first unit of the Ostrovets plant in Belarus is scheduled to go online in 2019, and the second unit in July 2020.[41] They will deliver a combined total of 2340 MWe net capacity.[42] The construction of the first and second unit started in 2013 and 2014 respectively.[43]

In 2016, there was an incident at the construction site for the Ostrovets NPP in Belarus, where Rosatom is building two VVER-1200 reactors. 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.[44] 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.[45] According to Rosatom, this replacement would mean at least a half-year delay for the project.[46]

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.[47]

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

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

[41] https://ria.ru/atomtec/20170808/1499941207.html (Retrieved 18.04.2018)

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

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

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

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

[46] https://www.interfax.by/news/belarus/1229816 (Retrieved 18.04.2017)

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

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.[48]

5.3. China

ASE has also sold two reactors to China at Lianyungan. Both are now in operation. Chinese and Russian authorities have signed on to build two more reactors in China at Tianwan.[49] Their construction began in 2012 and 2013 respectively. Both are expected to be complete by 2018.[50] The third unit agreed on is expected to enter commercial operation in late 2018.[51] In early 2018, Kirill Komarov, Rosatom's first deputy director-general for corporate development and international business, said the following about the second phase of the Tianwan NPP:

"Construction of the third and fourth power units of the Tianwan nuclear power plant are being implemented in record-breaking time and can be considered examples of excellent international cooperation in the energy field,"[52]

Work began on the third and fourth unit of the Tianwan in December 2012 and September 2013 respectively, and they were originally slated to enter commercial operation by 2016 and 2017.[53]

The 5th and 6th blocks are under construction as well, although by a Chinese contractor, and are expected to enter commercial operation in December 2020 and October 2021 respectively.[54] A seventh and eight block is also being discussed by China and Russia.[55]

In November of 2016, the heads of state of China and Russia agreed to develop their strategic collaboration in peaceful use of nuclear energy. In particular, the cooperation will revolve around construction of new NPPs at new location in China, increased cooperation in constructing floating NPPs and development of fast-neutron reactors.[56]

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[48] https://ria.ru/atomtec/20170808/1499941207.html (Retrieved (18.04.2018)

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

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

[51] http://www.world-nuclear-news.org/NN-Tianwan-3-starts-supplying-electricity-to-grid-0201185.html (Retrieved 17.04.2018)

[52] http://www.world-nuclear-news.org/NN-Tianwan-3-starts-supplying-electricity-to-grid-0201185.html (Retrieved 17.04.2018)

[53] http://www.world-nuclear-news.org/NN-Tianwan-4-containment-dome-in-place-2909157.html (Retrieved 17.04.2018)

[54] http://www.world-nuclear-news.org/NN-Tianwan-3-enters-warranty-period-0803184.html (Retrieved 17.04.2018)

[55] https://ria.ru/atomtec/20170704/1497822915.html (Retrieved 17.04.2018)

[56] https://ria.ru/atomtec/20170704/1497822915.html (Retrieved 17.04.2018)

5.4. 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.[57]

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 is now 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.[58]

According to an Egyptian news outlet, a Russian loan worth $25 billion will cover 85% of the total costs for the project, while the remaining 15% will be provided by Egyptian banks. The total cost of the project, with interest on Russian loans and the cost of contracting a foreign consultant for the project, is $30 billion, according to the outlet.[59]

5.5. 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.[60]

The main contractor 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.

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

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

[58] 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)

[59] https://dailynewsegypt.com/2017/12/18/egypt-rosatom-sign-21-3bn-contract-establish-dabaa-nuclear-reactors-shaker/ (Retrieved 18.04.2018)

[60] https://uk.reuters.com/article/idUKLDE6600ED (Retrieved 25.05.2018)

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.[61]

5.6. 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.[62]

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. [63]

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.[64]

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 insisted 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.[65]

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 have 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. Hungary is gambling on

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[61] WWN Daily – Newsletter – 22.01.2018

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

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

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

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

power prices remaining steadily high, but should they drop, the Paks-2 plant will be less profitable than hoped.[66]

5.7. 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.[67] The first unit of the four that were planned was put into operation in December of 2014. The second of the four VVER-1000 units at Kudankulam reached 100% criticality in January 2017.[68]

The third and fourth units are under construction, starting in June of 2017.[69] 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.[70] 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.[71]

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 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 7 and 8 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".

5.8. 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

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

[67] Bellona Web, http://bellona.org/articles/articles_2011/India_secondthoughts, 2011

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

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

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

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

explore building six more reactors at various locations throughout Iran at an unspecified future date.[72] 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.[73] 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.[74]

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. [75]

Iran's Bushehr-1 NPP has over the last three years delivered around 6.2TWh of energy to the grid. During the same period, the number of Russian experts at the site has been reduced from around 300 to about 25.[76]

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.

5.9. 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.[77]

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

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

[73] 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

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

[75] 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

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

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

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 in September 2017 that it aims to start work on the Akkuyu project by the end of March 2018.[78]

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 and the 100-year anniversary of the Turkish Republic.[79] The last three reactors will come online by 2025.[80]

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.[81] The plant will be owned and operated by Akkuyu Nuclear AS, a joint venture led by Rusatom Energy International.[82]

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%.[83] 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.[84]

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[85]. 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.[86]

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

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

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

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

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

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

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

[84] World Nuclear News Daily – 06.02.2018

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

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

consult with neighboring countries before building the plant.[87] Cyprus has said it will file official protests over the construction of the Akkuyu NPP.[88]

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.[89]

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).[90]

Olive trees and NPPs

In Turkey, law states that no technological object may be constructed closer than 3 kilometers from an olive grove.
According to a source with Gazeta.ru "Any three olive trees are considered a grove, and such groves can be found everywhere".

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.[91]

5.10. Vietnam

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. [92]

5.11. 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.

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

[88] WWN Daily – Newsletter – 06.04.2018

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

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

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

[92] http://avmalgin.livejournal.com/6593471.html (Retrieved 14.11.2016)

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.

Bulgaria is looking to hold a tender in 2018 to sell and privatize the 2000 MWe Belene NPP-project.[93]

[93] http://www.neimagazine.com/news/newsbulgaria-plans-privatisation-and-sale-of-belene-npp-project-5906032 (Retrieved 03.05.2018)

6. ROSATOM'S COOPERATION WITH OTHER COUNTRIES

Rosatom's presence abroad is not centered only around building NPPs in other countries. It also enters into related cooperation with governments around the world, through e.g. Memorandums of Understanding (MOUs) and other written agreements. Historically, such agreements often turn out to be the first step towards concrete projects being proposed, like with Turkey's Akkuyu NPP.[94]

In this chapter, you can find a list of countries that are dealing with Rosatom, but as of yet have no concrete plans for construction of any Russian-built NPPs. The list is divided by continent, covering South America, Africa, Asia, the Middle East and former Soviet countries.

6.1. South America

6.1.1. Argentina

Russia and Argentina signed a MOU on uranium exploration and mining in the South American country in January of 2018. A press release following the ceremonial signing said that "Rosatom is proposing a nuclear power plant of Russian design in Argentina based on the latest and safest technological standards". The MOU is a follow up to two other deals signed earlier between the two countries. In July 2014, an intergovernmental agreement was signed on cooperation in peaceful use of atomic energy, replacing an even earlier one from December 2012. In April 2015, an MOU on "framework for cooperation" was also signed. This one on the prospects of building a 1200 MWe VVER reactor in Argentina.[95]

6.1.2. Bolivia

In September 2017, Bolivia signed a contract with Bolivia for the construction of a nuclear research and technology center in El Alto, Bolivia. The site selected is 4100 meters above sea level, which would make it the highest nuclear facility in the world. The center will comprise a 200 kW water-cooled research reactor, a multi-purpose experimental gamma-installation, a cyclotron and a radiopharmacology complex. Commissioning of the first parts of the center is scheduled for 2019, and the total investment will exceed $300 million.[96]

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

[95] http://www.world-nuclear-news.org/UF-Russia-to-assist-Argentina-in-uranium-mining-2401184.html (Retrieved 03.05.2018)

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

6.1.3. Brazil

In late 2017, a MOU was signed between Rosatom and the Brazilian companies Centrais Elétricas Brasileiras (Eletrobras) and Eletrobras Termonuclear SA (Eletronuclear) to promote cooperation in nuclear power. It includes the possible construction of a new nuclear power plant in Brazil, according to Rosatom.[97]

This MOU can be viewed as a follow up to the intergovernmental agreement on cooperation in the peaceful use of nuclear energy between the two countries, signed in September 1994. Brazil has two nuclear reactors, Angra 1 and 2, which generate 3% of its electricity, and a third under construction. Its first commercial nuclear power reactor began operating in 1982. Four more reactors are proposed to come on line in the 2020s.[98]

6.1.4. Paraguay

Paraguay and Russia signed an agreement on cooperation for peaceful use of nuclear power in September 2017. Rosatom stated that the agreement will "help to start practical implementation of specific cooperation projects" between the two countries. Paraguay has no previous record of nuclear power use, but it has some uranium deposits. The agreement follows a MOU signed in October 2016.[99]

6.2. Africa

6.2.1. The Republic of Congo

Russia and The Republic of Congo signed an MOU on cooperation in the peaceful uses of nuclear energy in February of 2018. The agreement stipulates implementation of a bilateral cooperation between the two states, including the development of nuclear infrastructure in the Republic of Congo and programs aimed at increased awareness of nuclear technologies and their applications, as well as the use of radioisotopes and radiation technologies in manufacturing, agriculture, healthcare, education and training of personnel. Concretely, the two parties have discussed construction of a Center for Nuclear Science and Technology in Congo, with a Russian-designed research reactor. As of today, The Republic of Congo has no nuclear facilities. This is not to be confused with the neighboring Democratic Republic of Congo, which has had two research reactors in operation. TRICO-1 from 1959 to 1970 and TRICO-II from 1972 to 1992.[100]

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[97] http://www.world-nuclear-news.org/NP-Russian-and-Brazilian-firms-to-cooperate-in-nuclear-power-28111701.html (Retrieved 17.04.2018)

[98] http://www.world-nuclear-news.org/NP-Russian-and-Brazilian-firms-to-cooperate-in-nuclear-power-28111701.html (Retrieved 17.04.2018)

[99] http://www.world-nuclear-news.org/NP-Russia-and-Paraguay-forge-closer-nuclear-power-ties-20091701.html (Retrieved 03.05.2018)

[100] http://www.world-nuclear-news.org/NP-Russia-and-Congo-to-cooperate-in-nuclear-power-14021801.html (Retrieved 04.05.2018)

6.2.2. Ethiopia

On 19 June on the sidelines of the Atomexpo-2017 Forum in Moscow, a Memorandum of Understanding (MOU) was signed between Rosatom and the Ministry of Science and Technology of the Federal Democratic Republic of Ethiopia. The MOU aims to develop bilateral cooperation in the peaceful use of nuclear energy in several areas: The use of radioisotopes and radiation technology in industry, medicine, agriculture and other fields; training and education in the field of peaceful use of nuclear energy; assistance in the creation and development of nuclear energy infrastructure; the development of public awareness programs about nuclear technology and applications.[101]

6.2.3. Namibia

In March 2018, the Russian minister for foreign affairs, Sergey Lavrov, visited Namibia and held talks with the country's deputy prime minister. Lavrov stated that the two countries were finalizing a MOU on the peaceful uses of nuclear energy, opening the window of opportunity for cooperation in extraction of uranium, medicine and the potential construction of a NPP. He also mentioned that the plans included a research center based on a Russian research reactor.[102]

Namibia holds around 7% of the world's uranium reserves. These are mined to fuel NPPs all over the globe, and the Namibian government now wants to use nuclear power itself to solve its power supply challenges. In January of 2017, the Namibian government lifted a ten-year moratorium on new exploration licenses on nuclear fuel minerals, paving the way for increased extraction.[103]

6.2.4. Nigeria

Nigeria signed an agreement with Russia for the construction and operation of a nuclear power plant and a nuclear research center, including a multi-purpose research reactor in October of 2017. Details of the proposed projects are scarce, and Nigeria is thus included in this list of countries, that have agreements, but not concrete projects with Russia in the field of nuclear power. Nigeria has reportedly sought support from IAEA to develop plans for up to 4000 MWe of nuclear capacity by 2025.[104]

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[101] http://www.neimagazine.com/news/newsrussia-signs-mou-with-ethiopia-5853595 (retrieved 17.04.2018)

[102] http://www.world-nuclear-news.org/NP-Russia-discusses-African-nuclear-power-prospects-08031801.html (Retrieved 24.05.2018)

[103] http://www.world-nuclear-news.org/NP-Russia-discusses-African-nuclear-power-prospects-08031801.html (Retrieved 24.05.2018)

[104] http://world-nuclear-news.org/NN-Agreements-signed-for-Nigerian-nuclear-project-3110177.aspx (Retrieved 03.05.2018).

Russia signed its first intergovernmental nuclear cooperation agreement with Nigeria 2009. This was followed by agreements on the design, construction, operation and decommissioning of an initial nuclear power plant. Two sites, at Geregu in Kogi State and Itu in Akwa Ibom State, were in 2015 confirmed as preferred sites for the country's first nuclear power plants after evaluation by the NAEC.[105]

6.2.5. Rwanda

Talks between Rwanda and Russia on the peaceful use of nuclear energy are ongoing. In June of 2018, RIA Novosti reported that Sergey Lavrov, the Russian Minister for Foreign Affairs had been in Rwanda, having talks with President Paul Kagame and Minister of Foreign Affairs Louise Mushikiwabo. Lavrov commented that there was a need for further talks to agree on a cooperation for the use of peaceful nuclear energy after the conclusion of the talks.[106]

6.2.6. South Africa

The situation in South Africa (SA) is of a particular nature. In 2014 a deal between Russia and SA was signed for construction of up to 10 Russian reactors on South African soil. The deal for 9.6 gigawatts of nuclear power was made without any official tenders in SA. That led to a court case that lasted for several years, where the Supreme Court of SA finally ruled that the $76 billion deal was unlawful.[107] Rosatom says it is still committed to contend in an open tender for further nuclear projects in SA, and according to Reuters, they are contending with nuclear firms from South Korea, France, the United States and China for the bid.[108] SA courts have also rejected nuclear co-operation agreements with the US in 2009 and South Korea in 2011.[109]

6.2.7. Sudan

When speaking of Sudanese and Russian nuclear cooperation, the talk of the town has been that the two countries have agreed that Russia will produce a small-capacity, floating nuclear power plant (FNPP) for Sudan. The Sudanese government have also stated that they look to build Sudan's first standard, land-based NPP within eight years (by 2026).[110] In May of 2018, Rosatom signed a MOU with Sudan for nuclear personnel training, as well as a deal on fostering positive public opinion towards nuclear energy in Sudan.[111] Increasing public

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[105] http://world-nuclear-news.org/NN-Agreements-signed-for-Nigerian-nuclear-project-3110177.aspx (Retrieved 03.05.2018)

[106] https://ria.ru/atomtec/20180603/1521962660.html (Retrieved 04.06.2018)

[107] https://www.ft.com/content/ce7d0fdc-2a7d-11e7-bc4b-5528796fe35c (Retrieved 24.05.2018)

[108] https://www.reuters.com/article/russia-rosatom-south-africa-necsa-idUSL8N1JG3KQ (Retrieved 24.05.2018)

[109] https://www.ft.com/content/ce7d0fdc-2a7d-11e7-bc4b-5528796fe35c (Retrieved 24.05.2018)

[110] WWN Dailt – Mail Newsletter – 12.03.2018

[111] http://www.world-nuclear-news.org/C-Rosatom-expands-overseas-links-with-new-agreements-16051801.html (Retrieved 31.05.2018)

acceptance of nuclear power is something Rosatom does "systematically" in all countries where it is building NPPs, according to Head of Rosatom, Alexey Likhachev.[112]

6.2.8. Zambia

Rosatom is considering creating a nuclear research and technology center in Zambia, similarly to the one in Nigeria.[113]

6.3. Asia

6.3.1. Cambodia

Russia and Cambodia signed an inter-governmental agreement on cooperation in the peaceful uses of nuclear energy in September of 2017. The deal establishes the legal basis for the bilateral cooperation between the two countries in nuclear education and training, research, and the use of irradiation technologies in manufacturing, medicine, agriculture and environmental protection.

Earlier, in May 2016, the two countries signed a MOU on the establishment of an information center for nuclear energy in Cambodia, and a joint working group on the peaceful use of nuclear energy.[114]

6.3.2. Japan

Japan's nuclear industry has taken a big hit after the Fukushima accident in 2011. Still, the Japanese government signed a MOU on cooperation in peaceful uses of atomic energy with Russia in December 2016. Rosatom has stated that key areas within the cooperation are post-accident recovery at the Fukushima Daiichi plant, RAW-handling and decommissioning. [115]

Japan and Russia signed a more specific memorandum on the exchange of information on reactor physics experiments for minor actinoid transmutation for radioactive waste processing and management in September of 2017. According to Rosatom, the two countries will work together to improve radioactive waste management. This will revolve around a technology for transmutation of minor actinoid contained in radioactive waste - through burning in fast reactors or an accelerator-driven system of the long-lived

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

[113] http://www.world-nuclear-news.org/NP-Russia-discusses-African-nuclear-power-prospects-08031801.html (Retrieved 24.05.2018)

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

[115] http://www.world-nuclear-news.org/WR-Japan-and-Russia-join-forces-on-waste-management-08091701.html (Retrieved 24.05.2018)

radioactive isotopes americium, curium and neptunium recovered during reprocessing of used nuclear fuel. This can lead to a significant reduction in the volume and radiotoxicity of RAW. [116]

6.3.3. Philippines

On the 13th of November 2017, Rosatom signed a Memorandum of Cooperation (MoC) with the Department of Energy of the Philippines to develop national policies for the development of nuclear energy. The cooperation will include feasibility studies on the construction of small modular reactors, either onshore or offshore. The two parties will also conduct an audit and assessment of the technical condition of the mothballed Bataan nuclear power plant, "including the option of its rehabilitation". The first 620 MWe unit of the plant was completed in 1984 but was never fueled or operated. This MoC is a follow up to a MOU that was signed during the AtomExpo Forum in Moscow in June of the same year. That MOU was signed between Rosatom and the Philippine firm A Brown Company Inc.[117]

6.4. Middle East

6.4.1. Jordan

Jordan's Atomic Energy Comission signed a deal with Russia's Rosatom Overseas for a $10 billion nuclear power plant at Amra in the North in 2015. The plant would consist of two reactors, totaling 2000 MWe in output.

However, in May 2018, it became known that Jordan and Russia had replaced this plan with a project to build a Small Modular Reactor (SMR). An agreement was announced, that said the two countries would conduct a joint feasibility study for building a Russian-designed SMR in Jordan. According to the government of Jordan, the reasoning behind the downscaling of the project is that "the large reactors place financial burden on the Kingdom and in light of the current fiscal conditions we believe it is best to focus on smaller reactor". The reactor is poised to also be used for desalination.[118]

6.4.2. Saudi Arabia

Russia has said they plan to cooperate with Saudi-Arabia on small- and medium-sized reactors. A 'program of cooperation' was signed between the two countries in October 2017, as a follow up to an agreement on cooperation in the peaceful uses of nuclear energy from June 2015.

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[116] http://www.world-nuclear-news.org/WR-Japan-and-Russia-join-forces-on-waste-management-08091701.html (Retrieved 24.05.2018)

[117] http://www.world-nuclear-news.org/NP-Russia-and-Philippines-agree-to-nuclear-cooperation-1511174.html (Retrieved 18.04.2018)

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

The purpose of the reactor project is both to generate power and desalination of seawater. It is unclear whether any future plants will be Russian-built, but both countries have stated that they will "appreciate the prospects" of constructing a Russian-designed NPP in Saudi-Arabia.

Saudi-Arabia allegedly has plans to construct 16 nuclear power reactors within the next 25 years, projecting 17 GWe of nuclear capacity by 2040 to cover 15% of power needs at that time. A royal decree issued in 2010 deemed nuclear power essential to meet growing energy needs, both for water desalination and electricity production, while reducing reliance on hydrocarbon resources.[119] The country will also be building 40 GWe of solar capacity to go with their nuclear reactors.[120]

6.5. Former Soviet countries

6.5.1. Uzbekistan

Uzbekistan's president stated in April 2018 that his country plans to sign a deal with Russia within the year of 2018 for construction of a nuclear power plant. The two countries signed an intergovernmental agreement on cooperation in the peaceful use of nuclear energy in December 2017.[121]

6.6. Recent developments

During the Atomexpo conference and exhibition held in Sochi in May of 2018, Russia signed agreements with no less than 12 countries. Some are countries they already have ongoing deals with, either MOUs or concrete projects for building infrastructure. Agreements were signed with Chile, China, Cuba, Finland, Hungary, Iran, Italy, Kazakhstan, Saudi Arabia, Serbia, Spain and Zambia.[122]

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[119] http://www.world-nuclear-news.org/NP-Russia-Saudi-Arabia-strengthen-ties-in-nuclear-energy-06101701.html (Retrieved 04.05.2018)

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

[121] WWN Daily – Mail Newsletter – 20.04.2018

[122] http://www.world-nuclear-news.org/C-Rosatom-expands-overseas-links-with-new-agreements-16051801.html (Retrieved 31.05.2018)

7. CLIMATE GOALS AND RUSSIAN NUCLEAR POWER

Nuclear power is often characterized as a potential solution to the climate challenge. According to its proponents, 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 things, 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 8.1 in this report) this might become a realistic alternative sometime in the future. It is, however, unlikely that nuclear power, whether in small or big packages, can be deployed in time to meet current goals for global emission reduction.

Before the landmark 2015 climate summit in Paris, Russia declared it would not hamper the global climate agreement forged at COP-21.[123] That announcement inflated expectations that Russia would ratify the emerging document quickly. But that hasn't been the case: As of this writing, Russia still hasn't signed on, and the fight against climate change is not the main motivation for Russia's push to increase nuclear power's role in the global energy mix.

The main purpose for building more domestic nuclear power plants has centered Russia's desire to expend fewer fossil fuels– mainly natural gas – on domestic needs to make them available for export, primarily to Europe. The Russian state offshore company *Gazprom* has said that it makes five times more on gas exports than it does on the Russian market. [124]

Additionally, building nuclear power plants abroad is a convenient way to expand Russian political influence. 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.[125]

While the Russian state's commitment to the Paris Agreement has yet to come into full bloom, Rosatom itself is increasingly talking about climate issues and the role nuclear power can play in solving the climate and energy crisis.

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

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

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

[125] http://www.politico.eu/article/russias-nuclear-attack-on-europe/

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."[126] 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".[127] According to Rosatom, no more than 40% of a country's energy needs can be covered by renewables. The rest thus can be covered with nuclear power. 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,[128] and is also looking into selling their own wind turbines abroad.[129] Rosatom also does hydropower through Atomenergomash, for example in South Africa, where a contract for equipment for a small-scale hydroelectric plant was signed in early 2018.[130] Such deals are to be supplied with equipment by the firm NovaWind, a subsidiary of Rosatom created in 2017.[131]

Although there are plenty mentions of renewables from Rosatom, one thing they seldom talk about in public is the potential of energy storage technology. There might be good reason for this. Rosatom's argument is that 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 backbone for our power production. It can produce predictable amounts of power when the sun does not shine and the wind does not blow.

Energy storage is the key to making power production from renewables available at all times. Thus, the development of such technologies might be contradictory to Rosatom's goal of developing more nuclear power. Still, Andrey Rozhdestvin, Director of Rosatom Western Europe, has stated that Rosatom is working hard on energy storage, as it "is the way to

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

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

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

[129] http://energo-sibir.ru/news/elektroenergetika/rosatom_khochet_eksportirovat_vetryanye_turbiny/ (Retrieved 25.05.2018)

[130] 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)

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

improve the economics of renewables. And that's a mix we'd like to offer to our customers".[132]

Even though Rosatom is expanding into renewable power as well as nuclear, Russia is still spending more resources on the latter than the former. This in contrast to other nations who have a sizeable nuclear industry. France is looking to reduce its reliance on nuclear power, and China is investing more in developing wind farms than in nuclear power.[133]

In Russia, the only renewable energy source worth mentioning 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 negligible. While simultaneously starting to look into export of wind and solar, Russia seems to be using its lack of proficiency in renewables to its advantage by being the most active player on the international market for nuclear technologies.[134]

Figure 5: Leningrad-2 NPP. Photo: Rosatom

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

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

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

8. 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.

8.1. Decentralizing power production with… NPPs?

One of the biggest issues with nuclear energy 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.

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") 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. This way, the population of remote regions can be provided with energy, or industrial enterprises that are organized in power—hungry clusters can have their needs covered by a single power plant. Rosatom is looking at producing SSNPPs with a capacity ranging from 1-300 MWh, saying they have designs in the pipeline. Earlier, the enterprise has said it might start its first pilot project for SSNPPs in the late 2020s.[135] At the same time, it is known that Jordan has changed its deal with Russia for a two-reactor, 2000 MWe NPP to a small modular reactor of less than 300 MWe.[136] It is hard to tell how far Rosatom has come in the development of this technology.

In essence, the decentralization of the nuclear power structure might be a bid to compete directly with renewable sources of energy, and providing what Rosatom sees as the lacking baseline for power production in an energy mix where the majority of power comes from renewables. These power sources are valued for their disruptive capacity to be deployed almost anywhere, supplying energy needs in remote locations, or making consumers independent of centralized power generation.

Rosatom does not stop there though. One of their more famous projects the last couple of years has been that of a floating nuclear power plant (FNPP). The first of its kind, the *Akademik Lomonosov* boasts the ability to travel to any coastal region in the world, throwing a cable on-shore, and pumping energy onto the grid, making it a possible solution to the power needs of many developing nations with a coastline, according to Rosatom.

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[135] https://ria.ru/atomtec/20170705/1497875662.html (Retrieved 29.05.2018)

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

Rosatom has constructed this FNPP based on its experience with nuclear reactors in the naval industry, in submarines and icebreakers. The construction started as long ago as 2006, and the FNPP "*Akademik Lomonosov*" is equipped with two 35 MWe reactors of the KLT-40S type. It can use fuel with an enrichment of up to 20%.

The FNPP was originally slated to go into operation in 2010, but has been postponed, and is now scheduled to be operational in 2019. The floating nuclear power plant will be transported to the city of Pevek in the Chukotka region in Russia's Far East. There, it will replace the Bilibino NPP,[137]which is to be decommissioned as of 2021.[138]

The FNPP set sail for Murmansk from the Baltic Shipyard in St. Petersburg in the late days of April 2018. It arrived in Murmansk on the 17th of May, and will be fueled at Atomflot's base near Murmansk before moving on to Pevek.[139]

As a side note, the deployment of Akademik Lomonosov to the Arctic might be seen as part of a bigger move made by Rosatom. Legislation is being slated to give Rosatom the authority of the Northern Sea Route, for which Russia has big economic ambitions. At the current point, it is unclear whether this legislation will go through the legislator in its current form. The Russian parliament, the Duma, has amongst other things criticized the current plans as they believe that funds for the planned projects will not be available over the state budget before 2020.[140]

In 2011, Rosatom publicized the cost of building the FNPP "*Akademik Lomonosov*," saying it would amount to 16,2 billion rubles. [141] Today, that has increased to 21,5 billion rubles.[142] So although the first project of its kind has seen massive delays and breaches of budget, and has not sparked the interest internationally that Rosatom perhaps hoped for, we might not have seen the last FNPP coming out of Russia just yet.

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

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

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

[140] http://bellona.org/news/nuclear-issues/2018-05-rosatom-legislation-to-control-the-arctic-faces-more-pushback (Retrieved 31.05.2018)

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

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

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

8.2. Technologies in the pipeline

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 will, 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.[143] In February of 2018, Alexei Likhachev, Head of Rosatom, said that the nuclear enterprise in Russia envisages the first commercial fast neutron reactor to be added to the national energy system already in 2020.[144]

Russia is replacing its BOR-60 experimental fast reactor at the Research Institute of Atomic Reactors (NIIAR) at Dmitrovgrad in the Ulyanovsk, where the reactor went online in 1969.

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

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

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, and running on MOX (mixed uranium and plutonium oxide) fuel. Research Institute of Atomic Reactors (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).[145]

Much of the Russian research is devoted to the development of the so-called closed fuel cycle, mentioned above. We elaborate on this concept in the next subchapter.

8.3. Closed fuel cycle

Handling and storing radioactive waste (RAW) and spent nuclear fuel (SNF) is undoubtedly one of nuclear energy's biggest issues. The nuclear industry in general, and Rosatom in particular, has for a long time talked about 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 happen 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. 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.[146]

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 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-

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

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

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. [147]

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.[148]

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, and fuel from research reactors and maritime reactors. The annual throughput of SNF at RT-1 is 400 tons. [149]

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[150], 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. 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. [151]

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.[152]

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[147] Bellona Rapport, http://www.bellona.org/filearchive/fil_Bellona_2004_RedReport.pdf, 2004

[148] https://en.wikipedia.org/wiki/Mayak

[149] Bellona Report, http://www.bellona.org/filearchive/fil_Bellona_2004_RedReport.pdf

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

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

[152] 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 turns a profit 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 VVER-440 and recently also RBMK-reactors. VVER-1000 fuel can soon be reprocessed at a facility in Zheleznogorsk, according to Rosatom.[153]

To give an example, Ukraine has 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 is about $200 million. As long as the deal is on, Ukraine does not have to worry about storing its own SNF, but the contract says that at a set time, Russia will return both the reprocessed fuel and the fission products arising from reprocessing to Ukraine for storage. The set time for this return is 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 recent Bellona report; Ukraine is far from ready.[154]

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.[155] It estimates that the current system – in which reprocessed uranium (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 only 2% of the used fuel in need of disposal as waste.[156] 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

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[153] http://www.rosatom.ru/journalist/smi-about-industry/rosatom-gotov-nachat-zelenuyu-pererabotku-otrabotavshego-yadernogo-topliva/ (Retrieved 31.05.2018)

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

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

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

is leading in this field, and that the MBIR – multipurpose sodium-cooled fast neutron research reactor that is under construction in Dmitrovgrad will be a step in the right direction for the Proryv project.[157]

In 2018, Russia plans to start construction of 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.[158]

Russia currently has four main processing facilities operating at the back-end:
The Mayak reprocessing facility is upgrading its infrastructure for high-active waste handling, and as of 2016, it started reprocessing VVER-1000 fuel, in addition to the VVER-440 fuel it has traditionally handled. The Siberian Chemical Plant, in Seversk, is a production facility operating with RepU. The Mining and Chemical Combine, in Zheleznogorsk, is a cluster of used fuel management with centralised interim wet and dry storage facilities, a pilot demonstration centre for reprocessing, to be commissioned in 2019, and a fabrication plant for mixed oxide (MOX) fuel for fast reactors. NO RAO, The National Operator for Radioactive Waste Management, expects to commission an underground research laboratory for the deep geological storage of highly active waste in 2022.[159]

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[160]:

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

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

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

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

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

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."[161]

In short, Rosatom's bid to sell nuclear reactors to the world might present it with the opportunity to make money from the waste these reactors create. Their outspoken goal is to achieve so-called equivalent exchange with nature, returning to it only as much radioactivity as they take from it.[162]

8.4. 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 consists 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 are 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 a center in Bolivia, and have ongoing talks or plans for such projects in Vietnam, Zambia, Belarus, South Africa, Nigeria and Ghana.[163]

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

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

[163] https://ria.ru/atomtec/20170705/1497875662.html (Retrieved 29.05.2018)

9. GOVERNMENT AGENCIES AND THEIR ROLE

The supervision of Russian civilian NPPs is the responsibility of Rostekhnadzor (The Russian Federal Service for Ecological, Industrial and Nuclear Oversight), which answers directly to the Russian government. Rostekhnadzor took over nuclear power plant oversight from the former Gosatomnadzor, which was shuttered in 2004. Nuclear power plant supervision and oversight in Russia has traditionally been weak and hamstrung by limited budgets under both Rostekhnadzor and its predecessor.[164]

When the law "On introducing amendments to the Federal Law 'On the State Atomic Energy Corporation Rosatom'" was approved in November 2010, Rosatom assumed the authority to issue construction and operating licenses for nuclear power plants, including reactors and facilities for storing RAW in Russia. This used to be Rostekhnadzor's mandate.[165] In practical terms, that means that Rosatom is now licensing itself.

RAW and SNF in Russia are handled mainly by two entities as outlined below:

9.1. NO RAO

The national operator for RAW handling is responsible for handling and disposing of nuclear waste in Russia. It designates locations where fuel is to be stored and is responsible for building the infrastructure. NO RAO is also responsible for the security at the facilities they operate, as well as closing down and decommissioning them. Recently, NO RAO began the practice of publishing an annual environmental report.[166]

9.2. RosRAO

The company responsible for the treatment of RAW. Its mandate is as follows: Collection, transport, reprocessing of RAW, as well as temporary storage of low level and intermediate level RAW. In addition, they are responsible for dealing with the radioactive legacy of the Soviet Union, in the form of remnants from, for instance, the nuclear Northern Fleet. This includes submarines, nuclear icebreakers, and related vessels. RosRAO is involved in cleanup operations at Andreyeva Bay, Gremikha and in some locations in the Far East. They are also responsible for the rehabilitation of areas polluted with radioactivity.[167] Recently, RosRAO began publishing an annual environmental report.[168]

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164 http://www.nti.org/db/nisprofs/russia/govt/nucleara.htm

165 http://www.bellona.org/articles/articles_2011/rosatom_soviet_supremacy

166 http://bezrao.ru/n/124

167 http://rosrao.ru/predpriyatie/o-fgup-%C2%ABrosrao%C2%BB.html

168 http://bezrao.ru/n/135

9.3. The process of waste handling – put simply

The allocation of responsibilities within the nuclear sector in Russia is seemingly a bit unclear. But briefly, this is how it works in the case of SNF from NPPs:

The SNF and RAW from the NPPs in Russia is the responsibility of the respective NPPs. The radioactive material is stored temporarily on site, after which RosRAO, who also handles reprocessing, transports it to central storage facilities. The responsibility for further handling and deposit of RAW and SNF then lies with NO RAO. The storage facilities built and operated by NO RAO are described in detail in a separate chapter.

10. SAFE HANDLING AND STORAGE OF RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL

10.1. Categories of radioactive waste in Russia:

Russia has its own system for categorizing radioactive waste. NO RAO uses this categorization when they systemize the waste for storage in different locations, using different methods. [169]

NO RAO differentiates between two types of depositories for storage of waste: Near-surface (up to a 100 meters below ground level), and deep depositories (more than a 100 meters below surface level).

Table 6 - Categories of RAW in Russia[170]

1st class	High-level waste with heat exhaustion **Requires storage in deep geological formation (more than a 100 meters below ground).**
2nd class	High-level, solid waste Sources of ionizing radiation of 1st and 2nd grade. Long lived, intermediate-level waste.
3rd class	Intermediate-level, solid waste Sources of ionizing radiation of 3rd grade. Long lived, low-level waste.
4th class	Solid waste Sources of ionizing radiation of 4th and 5th grade. Very low-level waste.
5th class	Intermediate-level, liquid waste Low-level waste **Requires deep storage.**
6th class	Waste that originates from the search for and treatment of uranium. **Requires surface-near storage with simplified demands on-site where the waste originates.**

[169] www.Norao.ru

[170] Росатом, *Радиоактивные отходы: От образования до изоляции*, 2013 (ISBN 978-5-99-01862-1-7)

10.2. Where does the waste come from? North-West Russia as an example

In 2016, NO RAOs former deputy director, Denis Egorov, said the total amount of RAW that will need to be stored in Northwest Russia by 2030 is about 200 000 m^3. That figure was based on the following three factors:

1. RAW accruing from Rosatom's daily activities [presumably, power production at NPPs] – 35 000 m^3
2. RAW resulting from decommissioning processes: 138 000 m^3, 130 000 m^3 of which will come from the decommissioning the Leningrad-1 NPP. All four units of this NPP will be decommissioned between 2019 and 2025 according to current plans.
3. RAW produced by extracting and storing 1st and 2nd class waste, which will amount to a total of 32 000 m^3 by 2030.[171]

10.3. Radioactive waste and spent nuclear fuel storage

A report from Rostekhnadzor in 1999 revealed that the storage pools around the RBMK reactors were between 80% and 90% full. Since then, the storage situation has not been dealt with. The storage pools at Zheleznogorsk are also nearly full. [172] By the end of 2010, 19,000 tons of spent nuclear fuel was stored in Russia, 13,190 ton of which was stored in storage pools near the different NPPs. Six thousand and fifty tons of SNF from VVER-1000 reactors were stored in Zheleznogorsk. [173]

Currently, a dry storage for spent nuclear fuel is being built in Zheleznogorsk, with a total capacity of 38,000 ton of SNF. This will be sufficient for housing all SNF from the Russian VVER and RBMK reactors for the next 30 years. The first section of this storage was put into operation in 2010, and has a capacity of 5,000 ton of SNF. The cost of constructing this facility is said by Rosatom to be around 10 billion rubles. [174]

In late 2016, Russia's first ever repository was put into operation. The 48,000 cubic meter facility in the Sverdlovsk Region's close nuclear city of Novouralsk lies at shallow depth and operates as a repository for what Rosatom classifies as type 3 and 4 wastes. The new facility will be able to store solid waste in isolation from the outside environment for 300 years, ten times longer than any other current storage schemes in Russia.[175]

The Russian nuclear industry is not the only stakeholder internationally to seek answers to the challenge of storing RAW and SNF. As such, Russia also cooperates with other nations to

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[171] http://www.mvestnik.ru/eco/pid201610259l/

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

[173] ROSATOM, Annual report 2010

[174] ROSATOM, Annual report 2010

[175] http://bellona.org/news/nuclear-issues/2016-12-russias-first-nuclear-waste-repository-starts-operation

exchange experience on this subject. As an example, Russia's Rosatom and the French radioactive waste management agency Andra signed a cooperation agreement concerning the final isolation of RAW in November of 2017. In practice, this will constitute a cooperation between Andra in France and NO RAO in Russia. They have agreed to hold technical reviews and arrange visits for specialist teams to final disposal facilities in Russia and France.[176]

We will examine the current plans for radioactive waste repositories in Russia in the next subchapter.

10.4. Storage areas currently under discussion:

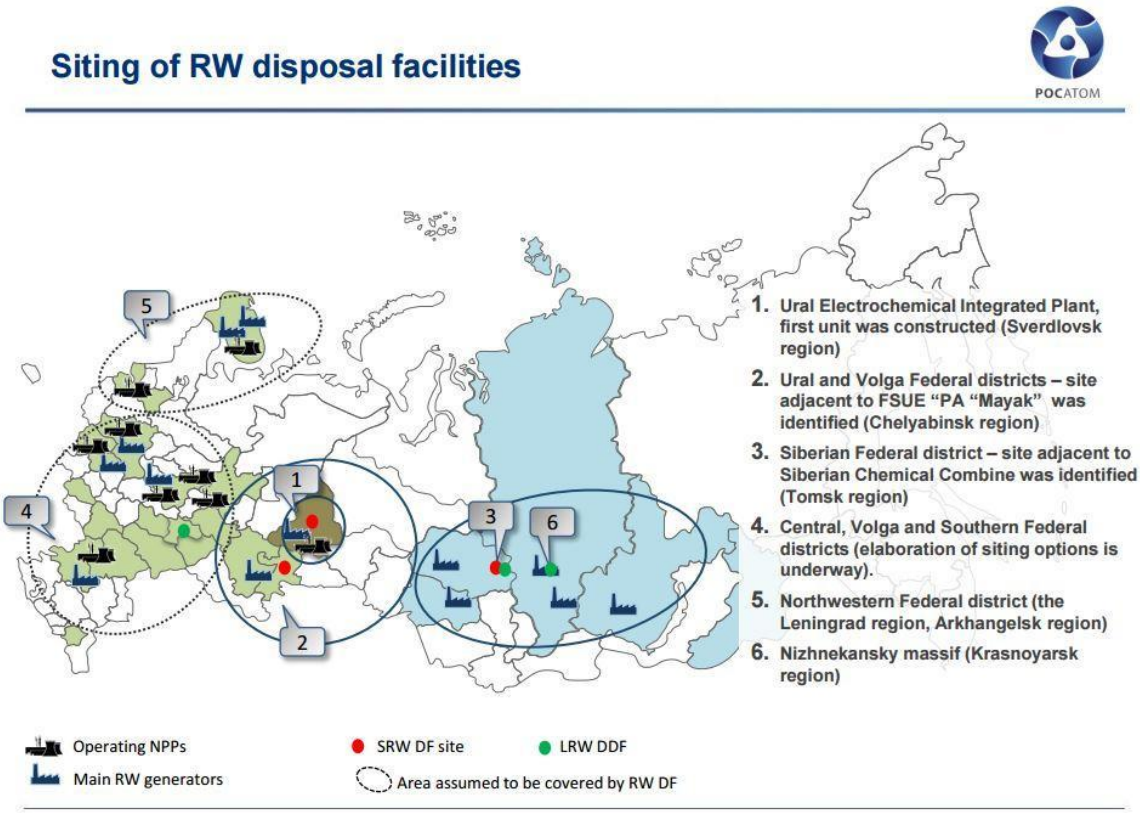

Illustration borrowed from Rosatom presentation[177]

Figure 7 – Possible siting of disposal facilities for radioactive waste in Russia

The numbers indicating the amount of RAW storage below are approximate, and based on the sources indicated in footnotes. They are subject to change as time passes and plans are updated. We describe the different numbered sites on the next page.

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176 http://www.world-nuclear-news.org/WF-Rosatom-and-Andra-expand-cooperation-23111702.html (Retrieved 29.05.2018)

177 https://www.iaea.org/INPRO/10th_Dialogue_Forum/Day3/Session4/02.Khaperskaya_Russia.pdf

1: A repository is operating at the "Ural Electro-Chemicial Combine" in Novouralsk in the Sverdlovsk region. That repository has several near-surface ditches, and is 46,449 m^3. It has space for 48,000 m^3 of 3rd and 4th class RAW. [178] The facility received its first shipment of RAW on November 28, 2016 and the second followed on December 2nd.[179]

2: A repository at the Mayak Chemical Combine is also being considered. If this option is chosen, the prospective repository would be a ground level bunker occupying 13,000 m^2 and housing house 100 000 m^3 of 3rd and 4th class RAW. [180] This site has now been approved, and all required documentation is ready.

3.1: Russia's biggest plans are for what it calls called "Repository 18" and "18A," which it plans to build at the closed nuclear city of Seversk in the Tomsk region. This repository will also consist of tunnels and shafts. Its total space will be 110,000,000 m^2 and it will house up to 500,000,000 m^3 of waste. [181] The beginning of construction is set for 2019, and the facility should be ready by 2021 if current plans hold. [182]

3.2: Another repository is projected in the Tomsk region, also in Seversk. This will a bunker at ground level, occupy 36,000 m^2 of land, and house 200,000 $m^3$of 3rd and 4th class waste. [183]

4: NO RAO is currently weighing options for a repository that would put all of Northwest Russia's RAW in one place. One location under consideration is Sosnovy Bor in the Leningrad region. The site would hold 50,000 m^3 of waste, with a potential to expand to 150,000 m^3. The repository would take shape as a network of tunnels not far below the surface. It would house low-level and intermediate-level RAW separately. [184] There are, however, doubts as to whether the geological environment at Sosnovy Bor is suitable for a repository, so the issue is not decided. Sosnovy Bor is not the only place that is under consideration. The waste handler is said to be considering the Novaya Zemlya Archipelago in the Barents Sea, and the Murmansk region as sites for the potential repository. [185] At the current time, it doesn't appear as if there will be a final decision on a site for North-West Russia in the foreseeable future.

5: NO RAO has selected the Nizhnekansky Rock Massive in the Krasnoyarsk region as the site for a deep geologic repository of the type being built in Finland. If results from an underground laboratory under construction at the site indicate the geology is suitable, the repository will go forward. According to the most recent plans, the repository would consist

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[178] http://bezrao.ru/n/190

[179] https://ria.ru/atomtec/20161206/1482923380.html

[180] http://bezrao.ru/n/190

[181] http://bezrao.ru/n/190

[182] http://bezrao.ru/n/353

[183] http://bezrao.ru/n/190

[184] http://bezrao.ru/n/190

[185] http://bezrao.ru/n/95

of horizontal tunnels accessible via shafts from the surface. Its total space would be 238,680 m^2 and it would hold 45,000 m^3 of 1st class RAW, and another 155 000 m^3 of 2nd class RAW. [186] As of 2016, Russia had earmarked 1 billion rubles to build the underground lab to study the geological conditions and their suitability for long-term nuclear waste storage. [187]

[186] http://bezrao.ru/n/95

[187] http://bezrao.ru/n/311

11. 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 follows:

Figure 8 - Rosatom's decommissioning plans 2015-2030

11.1. 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.

The costs for decommissioning projects are to be paid by a fund gathered 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[188]. In other countries, the payments from the operating organization are collected by adding a sum on top of the price of electricity that is 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 money being put into the 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 amount of finances for a decommissioning project. Today, the Russian decommissioning fund does not have enough money to finance the decommissioning of all power plants that have extended their life time period. 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 giving life to the decommissioning fund was put into force. Extending the lifetime of a reactor thus means it is given more time to accumulate the funds needed to take it out of operation. Building new NPPs will also increase the revenues added to the fund, which might make it easier to pay for decommissioning for reactors that are coming of age.

A lack of transparency and information, including a lack of insight into actual decommissioning plans, makes it hard to know how much such projects actually do cost in Russia.[189] Summarizing, the question of how to finance decommissioning efforts is one that requires a review by Russian authorities. They, along with almost all other nations that are using nuclear power today, have yet to find a comprehensive solution to the financial component of decommissioning.

11.2. Decommissioning projects and the future:

Two reactors at Beloyarsk NPP were taken out of operation in 1981 and 1989. Their fuel was removed, and the reactors themselves were sealed for long-term safety purposes, but the final decommissioning process has not been completed. [190]

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[188] 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

[189] 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

[190] http://www.rosatom.ru/wps/wcm/connect/rosenergoatom/belnpp_en/about/history/

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. [191]

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.[192] 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 does seem that Rosatom is planning to replace reactors that are running on extended lifetime permits. Leningrad NPP, Kursk NPP, Novovoronezh NPP and Rostov NPP have reactors under construction, which might be able to replace the old ones. In addition, Rosatom is planning to build new reactors at Smolensk NPP and, it seems, at Kola NPP, to replace the old reactors. Still, only old reactors at Kursk NPP, Leningrad NPP and Novovoronezh NPP are slated for decommissioning in the near future. This might mean that we will not see only modern NPPs running in Russia before 2030.

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[191] http://bellona.org/articles/articles_2011/novovornezh_decommission

[192] World Nuclear News Daily – Mail Newsletter – 22.11.2017

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