ELEMENTS OF THE STRATEGY FOR NUCLEAR POWER DEVELOPMENT AND SPENT FUEL MANAGEMENT IN RUSSIA[1]

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Russia has the world's fourth largest nuclear generating capacity, 23.6 GWe, provided by 33 commercial reactors at 10 nuclear power plants. Seventeen VVERs, eleven graphite-moderated, water-cooled RBMK-1000 reactors and the BN-600 sodium-cooled fast-neutron breeder prototype reactor produce about 17-18 percent of Russia's electricity generation. Ten 1.2-GWe PWRs, a 0.8-GWe demonstration breeder reactor, and two KLT-40S units (0.032 GWe each on a single floating power plant) are currently under construction.

Analysis of the programs for the development of nuclear power adopted by the Russian government in the recent years shows that in foreseeable future (till 2030-35) the capacity of the nuclear energy production sector will be increased primarily through the construction of new light water reactors (VVERs).

The 2008 Federal Target Program **"Nuclear Power Development Program for the period 2009-2015 and for 2020 perspective"** sets the goal of bringing the total capacity of nuclear power plants to 33 GW by 2015. This will be done by commissioning of 10 new units (9 VVER-1200, 1 BN-800). The total program budget for construction of new nuclear power units for a period from 2009 through 2015 is 1153.7 billion rubles **(**$38.5 billion), of which about 605.7 billion will be allocated from the federal budget. By year 2020 Rosatom plans to construct seven additional light-water reactors and initiate construction of 15 more.

Because the Russia's strategy for nuclear power development does not envisage the use of MOX fuel in the light water reactors, strategic direction of the SNF management is the establishing of a reliable system for long-term controlled storage of SNF. Along with these, programs also include the elements of development and testing of a new technological platform for nuclear power with a closed fuel cycle, the key element of which should be fast-neutron reactors.

Eleven units with VVER-1000 type reactors produce 230 tons of SNF annually. After a 3 to 5-year storing in the cooling ponds adjacent to the reactor sites, the spent fuel is shipped from NPPs to the centralized storage facility at the Mining and Chemical Combine (MCC) in Zheleznogorsk. In total 6170 tons of SNF were discharged from

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VVER-1000 reactors by year 2012, and about of 5000 tons of this fuel is currently stored at the MCC wet storage facility.

Six VVER-440 units produce 87 tons of SNF annually. After storing in the pond at the reactor's site for 3 to 5 years, the WWER-440 SNF is shipped to RT-1 at Production Association "Mayak" in Ozersk for reprocessing.

Eleven RBMK-1000 type reactors annually produce 550 tons of SNF. The SNF is stored under water in at-reactor pools and separate SNF storage facilities. Today, about 13,120 tons of this fuel is stored on NPP sites. The pools at the RBMK nuclear power plants are pretty close to their capacity.

The BN-600 reactor produces 6.2 tons of SNF annually, which, after storing at the reactor's site during three years is sent to RT-1 for reprocessing.

All spent fuel of Bilibino NPP (about of 140 tons) with four EGP-6 reactors (water-graphite heterogeneous channel-type reactor) is stored on-site.

Two facilities under the Federal Atomic Energy Agency Rosatom are involved in activities associated with spent nuclear fuel – the Mayak Production Association (RT-1) reprocessing plant at Ozersk and the Mining-Chemical Combine (MCC) central spent fuel storage pool at Zheleznogorsk. The RT-1 plant's design capacity is 400 metric tons per year, but during past decade the plant has reprocessing annually no more than 100 metric tons of spent fuel of various types. The original design capacity of the MCC storage pool was 13,416 fuel assemblies from VVER-1000 reactors (6,000 metric tons).

The Federal Target Program (FTP) **"Nuclear and Radiation Safety for year 2008 until 2015"**, adopted by the government in 2007, is dedicated mainly to the creation of infrastructure for the management of spent nuclear fuel. Their total budget is 145.3 billion rubles, including 131.2 billion rubles from federal sources. Among of the program's priorities are:

- reconstruction of the "wet" and the construction of a new "dry" storage facilities for spent nuclear fuel with capacity 38 thousand tons at MCC in Zheleznogorsk (Krasnoyarsk region);
- construction of a pilot spent fuel reprocessing plant at MCC (known as Pilot Demonstration Center or ODC);
- creation of a site for high-level waste disposal in Nizhnekansky array (Krasnoyarsk region).

To date the reconstruction of the "wet" storage facility at MCC is completed, and its capacity has been increased from 6,000 to 8,400 tons of VVER-1000 spent nuclear fuel as a result of the installation of higher density storage racks and an increase in the area of the pond.

The construction of dry spent fuel storage facility at the MCC was initiated in the year of 2003, using some of the buildings of the incomplete RT-2 reprocessing plant. Its design capacity is 37,785 metric tons, with 26,510 tons for RBMK-1000 fuel and

11,275 tons for VVER-1000 spent fuel. Construction of the first set of dry storage facility with capacity of 8100 tons for the RBMK spent fuel is completed in the end of 2011, and it is expected that the first shipments of the spent fuel from the Leningrad NPP will be delivered for storage during the first quarter of 2012.

Rosatom views reprocessing as an essential element of its nuclear fuel cycle strategy. Although in the near-term (until 2030-35) nuclear power in Russia will be based primarily on the use of light-water reactors (VVERs), in the longer-term Russia's nuclear industry believes that future nuclear power will be based on fast neutron plutonium-breeder reactors operating on a closed fuel cycle. Following this vision, Rosatom has developed a strategy based on the construction of a new spent fuel reprocessing plant to become operational around 2035 and then the large-scale construction of breeder reactors.

The ODC is designed for development, testing, and demonstration of advanced spent fuel reprocessing technologies for closed fuel cycle, including technologies for reprocessing of SNF of fast reactors. It is considering as prototype of third generation SNF recycling facility. The technology should satisfy such requirements as waste minimization, and to be economically competitive and proliferation resistant. It is assumed that experience accumulated at the ODC will be used in large-scale plant RT-2, which is scheduled to be commissioned by 2030-2035. The ODC reprocessing design capacity is 100 tons of spent fuel per year, but the possibility of increasing the capacity up to 250 tons of spent nuclear fuel a year might be possible. The project cost is estimated at 8.4 billion rubles. It is planned that the ODC will be launched in 2015.

The FTP **"Nuclear Energy Technologies of the new Generation for the period 2010-2015 and until 2020"**, adopted by the Russian government in January 2010. The program is focused on the development of prototypes of competitive and safe commercial fast-neutron-reactor with closed fuel cycle in order to demonstrate the acceptability of their performance for large-scale implementation. The total budget for this FTP is 128 billion rubles (≈$4.2 B) of which 110.4 billion rubles ($3.6 B) will come from the federal budget.

The first phase of this program (2010-2014) is aimed at solving several problems. One is the construction and commissioning of complex for the production of uranium-plutonium oxide fuel for fast reactors. 1.157 billion rubles are allocated for construction of the plant manufacturing MOX fuel for BN-800 fast-neutron reactor at MCC. The plant is expected to produce pellet MOX fuel in the form of fuel assemblies. A capacity of the complex for the production of MOX fuel pellets will be 14 tons per year. Rosatom plans to put this plant in operation before commissioning of BN-800 reactor, which is scheduled for year 2014.

Another objective of this phase is the development of new technical projects of fast reactors with lead (BREST-300), lead-bismuth (SVBR-100) and sodium coolants, as well as multi-purpose fast-neutron research reactor (MBIR). The demo lead-bismuth fast-neutron reactor SVBR-100 is being currently developed by OKB "Gidropress", under scientific supervision of the Institute of Physics and Power Engineering (IPPE) in Obninsk. It is expected that the reactor will be constructed at NIIAR in Dimitrovgrad (Ulyanovsk Region). Total investment in the project is estimated at 16 billion rubles. MBIR is designated for replacement of the existing BOR-60 reactor, resource of which will be expended in 2015.

The second phase of this program (2015-2020) requires the completion of the demonstration models of fast-neutron reactors with lead and lead-bismuth coolants, as well as multi-purpose research reactor on fast neutrons MBIR. Start of the demo lead-bismuth SVBR-100 reactor is planned for 2017, and start of the MBIR reactor for 2019, start of the BREST-300 lead fast neutron reactors by year 2020. Also during this period it is planned to complete construction of the ODC at MCC and to build an industrial complex for production of high-density fuel for fast reactors.

Analysis of the programs for nuclear power development in Russia shows that in foreseeable future (till 2030-35) the capacity of the Russian nuclear energy production sector will be increased primarily through the construction of new light water reactors (VVERs).

Strategic direction of the SNF management is the establishing of a reliable system for long-term controlled storage of SNF. While Rosatom does not envisage the use of MOX fuel in the light water reactors, it views reprocessing as an essential element of its nuclear fuel cycle strategy. With this aim it is pursuing several programs dedicated to developing and testing of a new technological platform for nuclear power that could combine fast-neutron reactors with a closed fuel cycle.

According to Russian nuclear experts, the implementation of the accepted programs could provide a thorough analysis and elaboration of nuclear power development strategy, and will help to choose the right moment for transfer of nuclear power production to the fast-neutron reactors and closed fuel cycle.

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