Russia's Nuclear Energy Plan For the Next Fifty Years

by Marsha Freeman

While the United States wastes precious time, trying to come to a political "consensus" on what kind and how much Federal support should be provided for the revival of nuclear energy development, in Russia, the decision has been made to deploy all of the necessary resources—human, industrial, and financial—to create a fundamental shift in energy policy. Russia is going nuclear.

The annual conference of the American Nuclear Society, held Nov. 12-15 in Washington, provided a contrast between the Russian approach, which has made the national commitment to create the nuclear energy infrastructure for the next 50 years, and the straitjacket of the "free market" in the United States, which is stalling the revival of nuclear power. At that event, Dr. Alexander Chebeskov, from the Institute for Physics and Power Engineering (IPPE), in Obninsk, laid out the systematic multi-decade plan of new nuclear technologies to take Russia into the next century.

Alexander Chebeskov, Viktor Dekusar

This photograph of the construction site of the BN-800 fast-breeder reactor was taken in August 2007. The scheduled date of completion is 2012. The BN-800 is a commercial demonstration plant, whose design will be used for the deployment of half a dozen breeders over the next 20 years.

One of the first questions from his American audience was, who will pay for this program? The Federal program, to build 20 or so new nuclear power plants in the near term "was accepted," he replied, and will be "financed from the Federal budget, using money from the export of oil." No comparable Federal commitment has been made in the United States.

A follow-on question was asked, about the degree of "public acceptance" of nuclear power. The "public attitude is rather good," Dr. Chebeskov replied. Twenty years ago, during the earthquake in Armenia, "people had to burn trees, books, and furniture" when the power plants had to be shut down. "In the [Russian] Far East, we have the same situation," of a severe shortage of power. "People need electricity at home, and this is their first priority." Three or four people out of five are in favor of nuclear power, he reported.

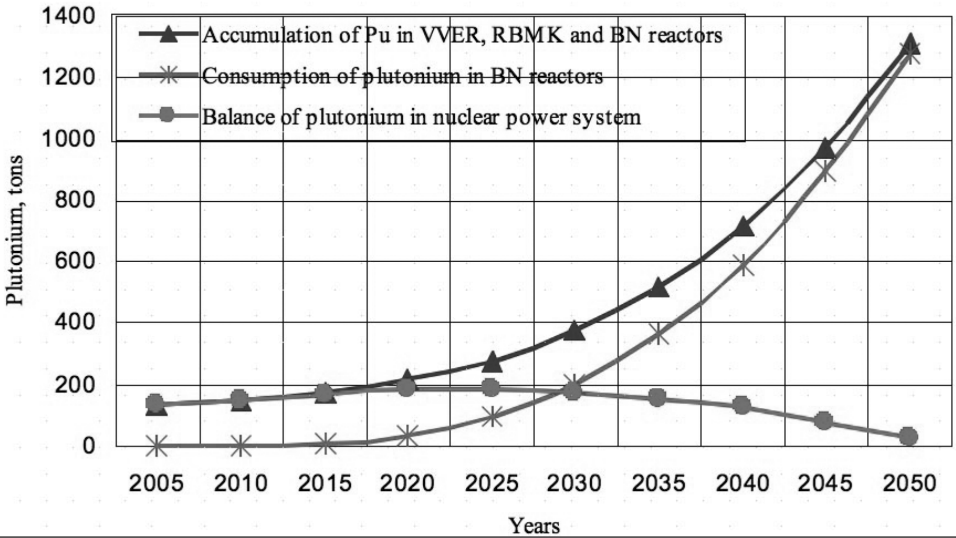
With the decision by the Federal government to pursue this course, the Russian scientific and engineering community is formulating the progression of nuclear technologies needed to meet Russia's energy requirements through the middle of this century. The goal is to make nuclear fission a renewable, virtually limitless resource for the Russian economy, based on the highest energy-dense technologies.

The First Phase

Time is of the essence, Dr. Chebeskov stated. Russia's economic growth has been accelerating since 2000, and there has been a sharp increase in demand for electricity, which has exceeded projections two-fold.

Burning fossil fuels entails many problems, as they are finite, dirty, and becoming more and more expensive, Dr. Chebeskov stated. In Russia, fossil fuel plants are also very old and inefficient, and must be replaced. By 2030, he said, Russia will be short of oil, and export of oil and natural gas abroad is "more attractive." The goal is to look forward at least a half century, and create a "stable kernel"

FIGURE 1
Consumption of Plutonium by Fast-Breeder Reactors



Source: Alexander Chebeskov and Viktor Dekusar, "Valuation of the Scenario for Innovative Russian Nuclear Power Development."

By 2020, Russia plans to introduce the first small series of BN fast-breeder reactors, which will use plutonium in their mix of fuel. By mid-century, the pace of breeder introduction will allow the full use of plutonium stocks from power reactor spent fuel, and the breeders themselves, as plutonium consumption matches production.

of technologies in the energy sector. This will be based on nuclear power.

Russia's nuclear development will occur in two phases: from now to 2030, and from 2030-50. Between 2007 and 2020, Russia plans to increase the share of nuclear energy production for electricity from the current 16% of the total, represented by 23.2 gigawatts of nuclear capacity, to at least 25%, or at least 40 GW. By 2030, 60 GW of nuclear capacity are planned to be on line. The near-term deployment of new reactors will be based mainly on upgraded VVER pressurized water reactor designs.

The two main problems of contemporary nuclear systems, Dr. Chebeskov explained, are that they cannot effectively use plentiful, but not fissile, mined natural uranium. Secondly, today's open cycle, where fuel is used only once, necessitates long-term storage of spent fuel, along with the storage of tailings left over from the uranium enrichment process to make fuel, and of the plutonium that is separated from spent fuel. Both of these "problems" will be solved with new technologies.

To meet the goals for 2030, Russia will add new capacity at the rate of 2-3 GW of new nuclear power per year, in order to replace decommissioned units and add new capacity. Next-generation VVER units will be larger, to increase the rate of growth of capacity. Also, "grid-appropriate" units—meaning smaller-scale reactors—to "meet remote regional demands and to export to developing countries," will be deployed. Last Spring, the keel was laid for the barge that will be the platform for Russia's first 70 MW floating nuclear power plant, for the energy-short city of Severodvinsk, in the Arkhangelsk region, producing both electricity and heat.

The plan is to "match exports" to the number of units and amount of fabricated nuclear fuel deployed domestically. This will require creating a broad technical base, and completing the consolidation of the previously separate branches of the Russian nuclear industry, which is under way. The Russian nuclear agency Rosatom has already secured contracts to construct new nuclear power plants in eastern Europe and India, and is in the process of bidding on units that will be built in new nuclear nations.

At an international nuclear conference in Moscow in November, Russian nuclear official Alexander Glukhov described the construction opportunities abroad that are of interest to Russia, including in Vietnam, Indonesia, and Morocco. "But central and eastern European countries, particularly the Czech Republic, Bulgaria, and Slovakia, are the most interesting markets," in the near term, in addition to Ukraine and Belarus.

This plan for new nuclear power plants must be assured a reliable supply of fuel. Dr. Chebeskov estimated that, assuming a 50-year operating life for existing and new VVER reactors, with a total installed capacity of 100 GW by mid-century, up to 1 million tons of natural uranium would be needed, to extract enough fissile fuel for the reactors. The total natural uranium resources in Russia, he reported, are currently assessed to be from 600,000 to 1 million tons. Clearly, other sources of nuclear fuel will be required.

For the near term, Russia has instituted a new program, called "Uranium for Russia," based on exploration for new deposits within the Russian Federation. Agreements and contracts for the import of resources are also being put into place, notably with resource-rich Kazakstan. In September, Russia and Australia signed a bilateral agreement, under which Russia will buy uranium at the rate of 4,000 tons per year, and at the end of November, Russia and Canada agreed to jointly prospect for uranium on their territories, and establish joint ventures for extraction.

But in the medium to long term, it will be the application of new technologies that will provide the resources to expand the use of nuclear fission energy, providing the bridge to nuclear fusion power.

By 2030, at the end of the first phase, seven fast-breeder reactors, which create new fuel, are planned to be commissioned, reaching 60 GW of capacity. After 2031, fast-breeder reactors will replace conventional VVERs for new capacity, and some of the operating VVERs may be converted to the thorium-uranium fuel cycle, using uranium-233 produced in fast reactors.

Creating New Resources

Dr. Chebeskov proudly reported that work has been under way in Russia for more than 50 years on scientific, design, and technology development for nuclear power plants and the nuclear fuel cycle. In 1954, the 5 MW Obninsk reactor became the first in the world to produce electricity, at the institute where Dr. Chebeskov works.

This heritage is the foundation for the second phase, 2030-50, for nuclear technology development. It is a plan which requires that a "fuel resource must last for an historically meaningful period (hundreds of years)." The objective is to "use innovative technology to switch to a new energy resource—plentiful uranium-238—by the middle of the 21st Century." This will require the "transition to a new technological platform, with the total closure of the fuel cycle, based on fast reactors," he explained. The advanced nuclear research and development program to implement this plan is already substantially under way.

By 2012, Russia will complete construction of the BN-800 commercial demonstration fast reactor, a follow-on to its BN-600 sodium-cooled fast reactor, which has been operating for 27 years. Fast-breeder reactors provide a number of advantages over conventional reactors. The BN-800 will use mixed oxide, or MOX, fuel. MOX fuel is made up of 5-9% plutonium, using a material now considered as "waste," from conventional power plants and nuclear weapons production. In the near term (to 2030), the plan is to construct a small number of commercial fast-breeder reactors, based on the operating experience of the BN series, which will use recycled plutonium as a fuel.

Russian fast reactors not only create a "new" resource by using recycled plutonium, but are also designed to breed at least as much fuel as they use. By placing a blanket of plentiful fertile but not fissile material—such as uranium-238 or thorium-232—in the path of the energetic neutrons produced in the fission process, fissile isotopes, such as plutonium-239, are created, which can then be used as fuel in reactors.

When the BN-800 is completed in 2012, it will demonstrate fast reactor technology on an industrial scale. During the first phase to 2030, a small number of industrial-scale breeders reactors will be deployed. A new design for a sodium-cooled fast reactor, which is more efficient than water-cooled designs, the BN-1800, and designs using other liquid metal coolants, are being developed, and are at varying levels of maturity.

When natural uranium (U-238) is enriched, to concentrate the fissile isotope, U-235, to a few percent, only a small percent of the natural uranium is used. As an example, for the 23.2 GW of current nuclear capacity in Russia, 3,800 tons of natural uranium must be mined or taken out of stocks, per year. After enrichment, a little over 600 tons of fuel are created, with the remaining 3,200 tons left as "enrichment tails," or depleted uranium. In Russia, uranium enrichment tails are accumulating at a rate of about 4,000 tons per year. These tailings can be enriched, as an additional source of reactor fuel.

In terms of reprocessing reactor spent fuel, to extract the more than 95% of the material that can be recycled and re-used, the Russian RT-1 plant has been operating since 1971, reprocessing spent fuel from VVER-440 reactors and the BN-600 fast reactor. In addition to creating a new resource, reprocessing also helps to eliminate the need for large-scale spent fuel storage. Reprocessing 1,000 tons of spent fuel from conventional reactors, such as the VVER, reduces the spent fuel to 100 tons, a ten-fold reduction. The decision has not yet been made to reprocess the spent fuel from the graphite-moderated RBMK reactors, Dr. Chebeskov reported. In order to manage the spent fuel from the 50 GW of VVER reactors expected to be operating in the near term—or more than double current online capacity—it is estimated that a reprocessing plant with a capacity up to 1,000 tons per year is required, and will be built.

In this transition to a full nuclear closed cycle economy, a small series of fast-breeder reactors is planned, with 5 GW capacity each. A fuel-manufacturing facility, that can produce about 100 tons of MOX fuel per year for the breeders, is also required. At an experimental level, the fabrication of MOX fuel for fast reactors has already been demonstrated.

For the long term, Russia plans to develop the technology to efficiently use its reserves of natural uranium itself as a fuel, not just as a feedstock to extract a tiny percentage of fissile U-235. Fast-breeder reactors will be introduced with breeding ratios greater than one, meaning they will produce more fuel than they consume. Both uranium-238 and thorium-232 will be used in the breeder blanket as fertile material, to be irradiated and transmuted into fissile isotopes. Russia is estimated to have about 3% of world thorium resources, or 75,000 tons.

Nuclear power technologies being developed in Russia also include follow-on advanced-generation fast reactors, and the Gas Turbine-Modular Helium Reactor, based on a design by General Atomics, to burn plutonium from nuclear weapons, and to produce hydrogen.

For Russia, the next 50 years will used to build the bridge to a nuclear future. With or without the United States, other countries will soon be following suit.