Anatoly S. Diyakov

The nuclear "renaissance" & preventing the spread of enrichment & reprocessing technologies: a Russian view

Concerns about sharp growth in oil and natural gas prices and shortages of fossil fuel reserves have led many countries, including developing countries, to express interest in nuclear power. An additional factor contributing to the growth of interest in nuclear power is essential improvements in reactor technology. Since the Chernobyl disaster in 1986, for example, the reliability and efficiency of nuclear power plants (NPPs) have grown substantially.

Russia is among the countries that are pursuing very ambitious programs of nuclear power development. Russia has 31 commercial power reactors at 10 sites, with a total generating capacity of about 23 to 24 GWe,[1] which provided about 16 to 17 percent of Russia's electric power in 2008. The operating NPPs include six VVER-440 reactors, nine VVER-1000 reactors, eleven RBMK reactors, four EGP-6 models, and one BN-600 fast breeder reactor. The total energy output of Russia's units was improved during recent years, and the capacity factor of its reactors increased from 56 percent in 1998 to 77.7 percent in 2007.

In 2006, the Russian government outlined a long-term Program for the Development of Russia's Nuclear Sector. The program's main goal is to respond to growing annual energy demand and diminish the share of domestic gas and oil consumption for electricity production. Reductions in domestic gas consumption could give Russia's state corporation Gasprom the opportunity to export more gas to the West and thereby to earn more profit. Some of the new nuclear power units are designed to power Gasprom's commercial enterprises, such as the NPP at Kola Peninsula as well as floating NPPs, which will be used for the development of new gas deposits under the Arctic Circle. In addition, because much of Russia's electrical generating capacity is coming to the end of its life, this program is also aimed at the replacement of existing generating infrastructure, including replacement of Russia's aging nuclear generating capacity. The program calls for nuclear energy to provide 25 percent of Russia's electricity production by 2030 and for the construction of 42 new nuclear reactors.

In April 2007, President Vladimir Putin signed a decree consolidating Russia's civilian nuclear activities within one giant state-owned corporation, Rosatom. It incorporates uranium mining, enrichment, nuclear fuel fabrication, operation of NPPs, manufacture

of large nuclear-related equipment, construction of NPPs at home and abroad, and nuclear-energy R&D institutes and universities. One of its missions is to compete in the global nuclear market with other industry giants such as France's AREVA. Rosatom will also try to attract investments to help expand Russia's domestic nuclear power production capacity.

Rosatom has begun implementing a long-term development plan for the design of advanced nuclear power systems, the construction of advanced light water reactors, and the next generation fast breeder reactors. The overall plan is comprised of specific plans to increase uranium mining, advance fuel development, and expand enrichment services, manufacturing, and construction capabilities both domestically and within international partnerships. On September 20, 2008, the Russian government approved a new program that covers Rosatom Corporation activity through the 2009 – 2015 period. The total cost of the program is 2.084 trillion rubles (approximately U.S. $83 billion), of which 1.264 trillion rubles (approximately $50.5 billion) will be provided by Rosatom and 820 billion rubles (approximately $32.8 billion) from the federal budget.[2]

Seven nuclear units are under construction currently in Russia, four of them projected to begin operation between 2009 and 2012.[3] According to the program approved on September 20, 2008, construction of two new VVER-1200 units is to be initiated each year, starting in 2009. By the end of 2015, 11 new nuclear power units are to be put into operation[4] and construction is to be initiated on an additional 10.[5] Shortages of qualified workers and rising costs of nuclear construction could delay the realization of these plans, however.

Rosatom is also pursuing a very aggressive program of nuclear power construction abroad. Currently it is building two VVER-1000 light water reactors at the Koodankulam NPP in India, and one at the Bushehr NPP in Iran. Rosatom has won a tender on construction of two nuclear power units at the Belene NPP in Bulgaria. On December 5, 2008, Russia signed a contract with India to construct four more units at the Koodankulam NPP. According to Vladislav Karagodin, deputy director of Atomenergoprom, Rosatom expects to construct 12 power plants overseas by 2020. Atomstroyexport, a Rosatom division responsible for construction of civil nuclear facilities abroad, is a leading contender to build four power plants at the first NPP in Turkey, as well as two power plants in Belarus and Armenia. Just recently, Atomstroyexport signed a contract with China Nuclear Energy Industry Corporation (CNEIC) for constructing two fast neutron reactors BN-800 in China. It is expected that construction on the first of them will begin in August 2011. Also, Rosatom is actively negotiating with Algeria, Argentina, Brazil, Chile, Egypt, Libya, Malaysia, Mongolia, Morocco, Namibia, South Africa, and Vietnam on the construction of NPPs.

Beyond 2015, the expansion program is more uncertain, chiefly because Rosatom is expected to find its own funding by that time. However, by converting to a corporation, Rosatom can now retain its profits from selling power, building NPPs abroad, selling nuclear fuel, and selling uranium enrichment, as well as by attracting investments from other Russian corporations, like Gasprom, for building domestic NPPs. Continued government construction subsidies may also be available – if not from the federal government, then perhaps from the regional governments.

Russia's financial system and economy have not been immune to the current global financial and economic crisis, which has reduced its financial reserves. As a result, the crisis has made full realization of Russia's plans for nuclear power development highly uncertain. Rosatom chief Sergei Kiriyenko has admitted that Russia's economic recession will force an amendment of the country's construction schedule for new nuclear reactors because of a drop in domestic electricity consumption.[6] At the same time, Prime Minister Vladimir Putin has declared that Russia's plans on nuclear power should not change, and Russia should put in operation 26 new nuclear power units by 2020.[7] Nevertheless, some Russian experts believe that Rosatom will take economic changes into account and might amend plans for NPP construction.

The global economic crisis will affect the plans of countries that have announced an interest in nuclear energy, adding uncertainty about whether many of them will follow through with their plans. However, much of the growth in nuclear power has been in Asia, and this tendency is unlikely to change with the economic crisis. The plans of China, India, and Russia to develop nuclear power could maintain the global interest in acquiring nuclear energy. And it is reasonable to expect that some countries that were less impacted by the economic crisis, particularly countries in the Persian Gulf region that possess huge financial resources, will follow through on their plans. This could result in nuclear power spreading to an additional dozen countries.

The anticipated growth of nuclear power around the world may lead to the spread of nuclear fuel cycle technologies as well. The expectations associated with a renewed *interest* in nuclear power and the *rate* of nuclear power growth in the world may be exaggerated; at the very least we can expect that the growth would occur not immediately, but over a long period. Nevertheless, there are definite concerns about the implications of nuclear power expansion for the nuclear nonproliferation regime. Driving these concerns is a sense that, beyond interest in nuclear power, developing countries also have an interest in retaining their right under the Nuclear Non-Proliferation Treaty (NPT) to possess nuclear fuel cycle technologies. A potential spread of nuclear fuel cycle technologies, especially technologies for uranium enrichment and for reprocessing spent fuel to separate plutonium, poses a serious concern to the nuclear nonproliferation regime because enrichment and reprocessing capabilities give states the capability to produce fissile materials for weapons.

This is not a new problem. Indeed, as early as 1946, the Acheson-Lillenthal report declared that proliferation risks are inherent to the nuclear fuel cycle. If nations engage in fuel cycle activities it increases the risk of:

- Spread of sensitive technologies from declared facilities, resulting in their illegal transfer to other entities;
- Diversion of nuclear materials from declared fuel cycle facilities;
- Running a military program at undeclared fuel cycle facilities; and
- Breakout – that is, withdrawal from the NPT and the subsequent use of safeguarded nuclear facilities for military purposes.

The reality of these dangers was recently demonstrated by North Korea and the A.Q. Khan network. International Atom-

ic Energy Agency (IAEA) Director General Mohamed ElBaradei has said that the fuel cycle is the "Achilles heel" of the nonproliferation system.[8]

Some countries have already declared their right to acquire enrichment and reprocessing technologies. This right is in fact secured for countries party to the NPT. The NPT does not restrict peaceful development and use of nuclear power; Article IV of the Treaty asserts, "Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes."

However, in ensuring the right to peaceful use of nuclear energy, the NPT also imposes specific obligations upon its member states. In accordance with Article II of the NPT, "Each non-nuclear-weapon State Party to the Treaty undertakes not to receive the transfer from any transferor whatsoever of nuclear weapons or other nuclear explosive devices or of control over such weapons or explosive devices directly, or indirectly. " Article III requires that each Treaty participant state "undertakes to accept safeguards . . . for the exclusive purpose of verification of the fulfillment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons."

The right to develop the nuclear fuel cycle, afforded by the NPT, is considered by some to be a loophole in the nonproliferation regime. This loophole, and recent violations of commonly accepted obligations by certain countries, raises questions about the NPT's capacity to protect international security adequately from threats that may occur.

It would be wrong to blame the authors of the NPT for this loophole. Over the four decades that have passed since the NPT first came into effect, the world has changed dramatically. The NPT to a large extent was initially intended to prevent creation of nuclear weapons by industrially advanced countries such as West Germany, Italy, Sweden, Switzerland, South Korea, Taiwan, and others, while simultaneously providing them the benefit of peaceful nuclear use and security guarantees. When the NPT was being negotiated in the 1960s, hardly anyone could have imagined that, with time, the main actors in proliferation and the dangers arising from it would come to be those countries that had recently become liberated from Europe's colonial dominion (at the time called "developing" or "third-world" countries) and also non-state entities – namely, terrorist organizations.

Considering that objective forces are compelling more and more countries to turn to nuclear energy to satisfy their energy needs, and that they have the right to develop the nuclear fuel cycle, it is necessary to search for solutions that, on the one hand, would prevent proliferation of sensitive nuclear technologies and, on the other hand, would ensure interested countries guaranteed access to *external* sources of nuclear fuel cycle services and products.

In light of the expected broad utilization of nuclear power, the strengthening of the nonproliferation regime should be sought in two ways. One way presupposes that states abandon plans to acquire uranium enrichment and spent nuclear fuel reprocessing technologies if they do not possess them already. However, this proposal has practically no chance to be realized, at least not in the near future. Furthermore, attempts to implement it at present would be counterproductive to strengthening the nonproliferation regime, since it would require amending

the NPT. In other words, the NPT would have to be "reopened," and another discriminatory division among NPT member states – countries permitted to have the nuclear fuel cycle and those not – would have to be created in addition to the nuclear- and non-nuclear-weapons countries division that already exists. Considering the unwillingness on the part of most non-nuclear states to undertake additional restrictions, it is difficult to expect that the negotiations process, involving participation from all 140 NPT member states, would be successful. Many countries believe that restrictions on development of technologies should be universal for all NPT participant states, and should not permit some to develop technologies while prohibiting others. For example, Canada has no enrichment plants at present, although it is considering the possibility of creating an enrichment facility for production of low-enriched uranium for its CANDU reactors. Brazil, which does have an active enrichment program, would be permitted to have it. Efforts to create and enforce this further division would do more to weaken the NPT than it would to strengthen it. As the example of Iran shows, additional division of states into those permitted to have enrichment and reprocessing and those forbidden not only undermines the unity of NPT member countries, but also facilitates development of a black market for nuclear technologies.

The second way to strengthen the regime entails switching to innovative nuclear power technologies that could sustain the nonproliferation regime by means of inherent physical and technological properties. This would require development of new types of power reactors and the fuel cycles for them. To this end, work is presently being conducted through a number of international programs, including the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), Generation IV, and GNEP+ANFC. However, progress has been slow in these programs, and the possibilities for the creation and use of such innovative nuclear technologies lie in the distant future. Therefore, the expansion of nuclear power in the world, even if started by 2020 to 2025, will be based on the use of light water reactors and existing fuel cycle technologies. Taking into account the current trend toward increasing the operational lifetime of nuclear power reactors up to 60 or 70 years, it becomes obvious that there is a need to find such solutions that could work during a period of at least a century.

In the view of Russian experts, efforts to prevent the spread of enrichment and reprocessing technologies as it relates to the broad expansion of nuclear power should be focused on:

- Creating international institutional barriers;
- Providing assurances of nuclear fuel supply and services; and
- Offering various incentives to newcomer countries from advanced countries supplying nuclear technologies and services.

Taken together, these measures, while not creating legal obstacles for development and use of nuclear power by newcomer countries, would induce them voluntarily to renounce acquisition of nuclear fuel cycle technologies.

Institutional barriers. Institutional barriers require newcomer countries to adhere to a number of binding obligations, without which they cannot expect to get assistance from the nuclear technology supplier countries in developing their

plans for nuclear power. Such obligations may include:

- Acceptance and ratification of the Additional Protocol (1997) with the IAEA on application of advanced safeguards;
- Joining the Vienna Convention on Civil Liability for Nuclear Damage; and
- Creating the legislative basis and organizational infrastructure necessary for operation of a NPP.

A document titled "Milestones in the Development of a National Infrastructure for Nuclear Power" was published by the IAEA in 2007. It enumerates the basic infrastructural elements that a state desiring to use civilian nuclear energy should have. The IAEA makes the decision about a country's readiness to develop nuclear energy, taking into account a country's success in implementing these infrastructural elements. To keep newcomer countries from perceiving these requirements as the creation of another discriminatory regime, it will be expedient for nuclear states to extend the provisions of the 1997 Additional Protocol to their own entire civil nuclear infrastructures.

Assurances of nuclear fuel supply and services. Among the various driving forces behind countries' intentions to acquire nuclear fuel cycle technologies, energy security should be considered the most serious. Therefore, any reasonable and reliable measures in preventing the spread of sensitive nuclear fuel cycle technologies should rely on guaranteed supplies of an entire list of products and services for the civil nuclear fuel cycle, and especially should provide credible access to enrichment services. Without providing these guarantees it will be difficult to expect that states (especially those considered "problematic") be willing to forgo indigenous enrichment capabilities.

It must be noted that from the very beginning of nuclear power utilization the uranium and nuclear fuel market has demonstrated high standards of supply reliability. However, the risk of consumers not receiving nuclear fuel cycle services from the market remains, mainly if supplies are curtailed for political reasons. Therefore, it is necessary to create the conditions in which any country that strictly follows its obligations to comply with the nonproliferation regime should be able to obtain reliable guarantees of reasonably priced supply of fuel cycle services.

In the view of IAEA Director General ElBaradei, these assurances could be made possible through the establishment of multilateral fuel cycle centers, where enrichment and reprocessing activity would be carried out under multinational control.[9] The World Nuclear Association (WNA) Working Group has concluded that a potential strategy aimed at avoiding the spread of sensitive technologies should include "a credible assurance of access to enrichment and reprocessing services" through the strengthening of the existing world market and, in the longer term, "through the establishment of multilateral nuclear fuel cycle centers."[10]

During the past several years, a number of proposals for realizing this strategy have been suggested, including:

- International fuel supply guarantees (the initiative of six countries: France, Germany, The Netherlands, Russia, the United States, and the United Kingdom);
- Creation of enriched uranium reserves (a fuel bank) under the auspices of the IAEA (proposed by the Nuclear Threat Initiative in 2006 and subsequently

endorsed by a Russian initiative in 2007); and

- Creation of a mechanism for the multilateral nuclear fuel cycle (proposed by IAEA Director General ElBaradei), which may be realized both by converting existing national nuclear fuel cycle enterprises into enterprises under multinational control (the enrichment plant in Angarsk, for instance) and by creating new regional multinational centers. For example, for countries in the Pacific and South Asian regions such a center could be created in Australia, which possesses considerable natural uranium reserves. Another center could be created for the countries of the Greater Middle East.

In January 2006, President Putin proposed a Global Nuclear Infrastructure Initiative. The key objectives of the Initiative are strengthening the nonproliferation regime and providing ensured nondiscriminatory access to nuclear energy from all interested parties through the establishment of a network of international centers providing nuclear fuel cycle services (including uranium enrichment) that would be placed under IAEA control.[11] Within the framework initiative, Russia, jointly with Kazakhstan, has established the International Uranium Enrichment Center (IUEC). Subsequently, Russia also offered to include the IUEC in the list of Russian facilities that could be placed under IAEA safeguards, per the safeguards agreement between the Russian Federation and the IAEA.[12]

The Angarsk enrichment plant, which has never produced highly enriched uranium, is currently the smallest of Russia's enrichment plants, with a capacity of only 2.5 million separative work units (SWU)/year. Including the new capacity associated with the Russian-Kazakh joint venture and additional proposed expansion, however, it could reach 10 million SWU/year by 2015. Foreign shareholders will have a right to participate in the center's management, including by having access to all information about prices and contract provisions. They will also be able to contract for deliveries of enriched uranium or enrichment services, and receive a share of the profits. They will not, however, have access to enrichment technology.

The IUEC was legally established as a joint-stock company in 2007 on the basis of the Angarsk enrichment plant. The IUEC is open to participation from any NPT member state that meets nuclear nonproliferation requirements and shares a commitment to the center's objectives. Companies in new member countries are joining the IUEC on the basis of separate intergovernmental agreements between the Russian Federation and the country where each company is located. Currently, a Russian company, TENEX, has 90 percent of shares; a Kazakh company, NAC Kazatomprom, has 10 percent. The plan is that, over time, Russia's shares will drop as new members join. The eventual redistribution of shares in the IUEC is expected to be: Russia's TENEX, 51 percent; Kazakhstan's NAC Kazatomprom, 10 percent; and companies in new member countries, 39 percent.

Up to now, only Armenia and Ukraine have expressed interest in joining the IUEC, with each buying 10 percent of shares. (Their process of joining the IUEC through an exchange of notes has been initiated but not yet finished.) Russia invited Tehran to participate in the IUEC as an alternative to an indigenous Iranian enrichment capability, but Iran rejected this offer. Also,

Russia has extended an offer for India to participate in the IUEC, to help the country secure guaranteed fuel supplies in the future.

Offering various incentives. These early proposals are, in different ways, aimed at the supply side; neither of them touches on the profit motive. It has become apparent that it is also necessary to use mechanisms that induce customers, from an economic standpoint, to renounce acquisition of their own nuclear fuel cycle technologies. This can be done by:

- Offering financial aid and aid in creating a nuclear power infrastructure;
- Supplying reactors for use in black-box mode (for example, supplying low-capacity reactors for desalinating seawater [floating power plants]); and
- Offering packaged contracts.

Such contracts would link the supply of power reactors inseparably with supply of fresh fuel and take back of spent fuel for the reactor's operating life. Contracts that would include removing spent fuel, as well as providing other back-end services, would create far stronger incentives to rely on international mechanisms for fuel supply. The attractiveness of such practices for newcomer countries is not only the fact that they could have guaranteed supply of fresh fuel, but also that they are freed from the problems of disposing of spent fuel, which otherwise presents serious obstacles to national nuclear power development programs.

The contract for construction of the Bushehr NPP in Iran by the Russian company Atomstroyeksport serves as an example of a package agreement to promote nuclear power while minimizing proliferation risks. The construction of the Bushehr NPP was initiated by the German company Siemens in 1975, but was stopped after the Islamic revolution and the Iran-Iraq War. Since then, the United States, convinced that Iran is trying to develop a nuclear weapons capability under the cover of a civil nuclear program, has undertaken efforts to convince nuclear suppliers to refrain from providing any nuclear assistance to Iran and has placed an embargo on supplying high-tech sensitive technologies to Iran. However, Russia, arguing both that each NPT member country has a right to develop and use nuclear power for civil purposes and that the Bushehr nuclear power project posed no proliferation risk, decided to help Iran in its completion, despite U.S. pressure not to do so.

In January 1995, the Russian company Zarubezhatomenergostroy signed a contract with the Iranian organization on nuclear power to complete construction of a light water reactor at Bushehr. Russia also agreed to supply Iran with one nuclear power unit VVER-1000 and the nuclear fuel for it, and to train Iranian specialists to service the reactor. But under U.S. pressure, the Russian government has blocked cooperation with Iran on some sensitive nuclear technologies, including assisting in building a centrifuge enrichment plant.

After details of Iran's clandestine nuclear activities were revealed in 2002, Russia conducted difficult negotiations with Iran, resulting, in February 2005, in a new agreement between the countries. Under this agreement, Russia will supply fresh uranium fuel throughout the Bushehr reactor's first 10 years. For its part, Iran will return the resulting spent fuel to Russia for final disposal. Together, these two parts of the agreement minimize Iran's need to enrich its own uranium as well as eliminate Iran's opportunity to reprocess spent fuel and use extracted plutonium in nuclear weapons. Additionally, through

Russia's insistence, the two countries agreed that any transfers to the Bushehr reactor will be placed under IAEA safeguards.

Iran informed the IAEA that the Bushehr reactor was due to begin operation by the end of 2009, but recently it was announced that launching Iran's Bushehr nuclear power plant is scheduled for March 2010. During 2007 to 2008, Russia delivered 82 tons of nuclear fuel (with enrichment between 1.6 and 3.6 percent U-235) to the Bushehr reactor. The fuel was expected to be loaded into the reactor during the second quarter of 2009.

It seems that practical implementation of all these measures will require continuous efforts over a long period of time. But this strategy, if endorsed by all NPT states in a way that takes into account the national legislations as well as the international obligations of advanced nuclear countries but that does not restrict the rights of newcomer countries, could provide newcomers with a real advantage in implementing plans to use nuclear energy in responding to their energy needs.

ENDNOTES

1 One GWe (gigawatt electric) is equal to one billion watts.

2 Program of the Rosatom State Corporation Activity for the Long-Term Period (2009 – 2015), http://www.government.ru/content/governmentactivity/rfgovernmentdecisions/archive/2008/09/20/9565546.htm.

3 Currently under construction are the BN-800 breeder reactor at the Beloyarskaya NPP; five VVER-1000 light water reactors: Rostov-2, Kalinin-4, two units at the Novovoronezhskaya NPP, and one unit at the Leningradskaya-2 NPP; and one floating reactor.

4 These 11 are the reactors that were under construction as of the end of 2008 plus three VVER-1200s at Leningrad and one each at Rostov and Tver.

5 These 10 are fourth VVER-1200s at Leningrad and Rostov, a second at Tver, three units at Nizhegorodskaya, and four at the South Urals site.

6 "Russian Nuclear Program Slowed on Weak Energy Demand," *Uranium Intelligence Weekly*, March 9, 2009.

7 S. Kirienko, "The program of construction of new NPP remains unchanged," April 21, 2009, http://www.nuclear.ru/rus/press/nuclearenergy/2112560.

8 "Multidisciplinary Approaches to the Nuclear Fuel Cycle: An Expert Group Report," submitted to the IAEA Director General; IAEA Document INFCIRC/640, April 28, 2005.

9 Statement by the IAEA Director General Mohamed ElBaradei to the 58th Regular Session of the UN General Assembly, November 3, 2003.

10 WNA Report, "Ensuring Security of Supply in the International Fuel Cycle," May 12, 2006, http://www.world-nuclear.org/reference/pdf/security/pdf.

11 Vladimir Putin, Statement on the Peaceful Use of Nuclear Energy, January 25, 2006, http://www.kremlin.ru/appears/2006/01/25/1624_type63374type63377_100662.shtml.

12 See IAEA Document INFCIRC/327.