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The Nuclear Energy Futures Project

The Russian Nuclear Industry: Status and Prospects

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Addressing International Governance Challenges

Abstract

If ever there was a country for which the catchphrase "nuclear renaissance" truly applied, it would be Russia. In the Soviet Union, nuclear energy served as a symbol of technological progress and scientific achievement in the country's rivalry with the West. However, the march of Soviet nuclear progress was brought to a halt by the nuclear accident involving a Soviet-designed reactor at Chernobyl in 1986. After languishing for two decades, the nuclear industry in Russia has recently been greeted with renewed funding and enthusiasm. This paper explores the goals and challenges of the Russian nuclear power industry, discussing its status and prospects.

Canadian Centre for Treaty Compliance

CIGI's Nuclear Energy Futures Project is being conducted in partnership with the Centre for Treaty Compliance at the Norman Paterson School of International Affairs, Carleton University, Ottawa.

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Letter from the Executive Director

On behalf of The Centre for International Governance Innovation (CIGI), it is my pleasure to introduce the Nuclear Energy Futures Papers Series. CIGI is a Canadian-based non-partisan think tank that addresses international governance challenges and provides informed advice to decision makers on multilateral governance issues. CIGI supports research initiatives by recognized experts and promising academics; forms networks that link world-class minds across disciplines; informs and shapes dialogue among scholars, opinion leaders, key policy makers and the concerned public; and builds capacity by supporting excellence in policy-related scholarship.

CIGI's Nuclear Energy Futures Project is chaired by CIGI Distinguished Fellow Louise Fréchette and directed by CIGI Senior Fellow Trevor Findlay, Director of the Canadian Centre for Treaty Compliance at the Norman Paterson School of International Affairs, Carleton University, Ottawa. The project is researching the scope of the purported nuclear energy revival around the globe over the coming two decades and its implications for nuclear safety, security and nonproliferation. A major report to be published in 2009 will advance recommendations for strengthening global governance in the nuclear field for consideration by Canada and the international community. This series of papers presents research commissioned by the project from experts in nuclear energy or nuclear global governance. The resulting research will be used as intellectual ballast for the project report.

We encourage your analysis and commentary and welcome your thoughts. Please visit us online at www.cigionline.org to learn more about the Nuclear Energy Futures Project and CIGI's other research programs.

John English
Executive Director

Glossary

Atomenergomash – A Rosatom, Atomenrgoprom, and TVEL subsidiary responsible for providing equipment for nuclear power plants.

Atomenergoprom – The Rosatom subsidiary holding company for civil nuclear energy that includes power plant operator, Energoatom, nuclear fuel producer and supplier TVEL, uranium trader Tenex, equipment supplier Atomenergomash and overseas nuclear builder Atomstroyexport.

Atomstroyexport (ASE) – A Rosatom and Atomnergoprom subsidiary responsible for construction of civil nuclear facilities overseas.

Bistry Neutron (BN) − A fast neutron reactor. Russia has built two of these breeder reactors, the BN-350 in Kazakhstan and a BN-600, in Russia, and hopes to complete the BN-800, an 800 megawatt breeder reactor, by 2012.

EGP – A type of reactor constructed in Eastern Siberia in the 1970s that produces both electricity and heat.

Energoatom – A Rosatom and Atomenergoprom subsidiary that operates Russian nuclear power plants (until recently named Rosenergoatom).

IUEC – The International Uranium Enrichment Center, Russia's planned multinational enrichment facility at Angarsk, Siberia. Kazakhstan and Armenia have already enlisted as shareholders and Ukraine and Slovenia may well do so.

KLT-40S – Russia's new floating nuclear power plant.

OMZ – Manufactures the reactor pressure vessels and other key components for Russia's modern reactors. It is the largest heavy industry company in Russia.

RBMK – Russia's graphite moderated reactor. This reactor type was made infamous by the 1986 Chernobyl accident.

Rosatom – Formerly Russia's nuclear ministry (for both nuclear energy and fissile materials in nuclear weapons), recently changed to a state-owned corporation.

Rostechnadzor – Russia's nuclear regulatory agency.

RT-1 – Russia's aging spent fuel reprocessing plant at Mayak (RT-2 has not been completed).

Techsnabexport (TENEX) – A Rosatom and Atomenergoprom subsidiary responsible for international trade in highly enriched uranium and other nuclear fuel elements and isotopes.

TVEL – A Rosatom and Atomenergoprom subsidiary responsible for manufacturing nuclear fuel for Russian and foreign reactors.

UES – Formerly Russia's electric power holding company. By July 2008, most of its generating capacities were privatized with the state only retaining control of the transmission grid, Rosatom and hydroelectric electricity generation.

VBER – New medium-power light water reactors Russia would like to deploy by 2020. These new reactors are based on Russian naval reactors.

VVER – A pressurized water reactor, often used as a light water reactor.

Introduction

If ever there was a country for which the catchphrase "nuclear renaissance" truly applied, it would seem to be Russia. In the Soviet Union, nuclear energy, like the space program and the military, held a place of pride as a symbol of technological progress and scientific achievement in the country's rivalry with the West. Indeed, nuclear energy both reminded Soviet citizens of their impressive nuclear weapons arsenal and served to fulfill one of the slogans that had guided the Soviet Union since its early days – "Communism equals Soviet power plus electrification of the whole country."

According to some experts the nuclear power industry absorbed as much as a quarter of the Soviet Union's gross domestic product from 1946 to 1986 (Kudrick, 2004). Boosted by these resources, the Soviet Union not only boasted the first reactor to supply power to the electrical grid and the first breeder reactor, but also put nuclear power to more unconventional uses such as nuclear ice-breakers, and more prosaic but highly questionable purposes such as providing central heating to entire cities. Year after year, bigger and bigger nuclear plants were built, culminating in 1500 megawatt reactors in Lithuania and plans for 2000 megawatt reactors and similarly sized breeder reactors. Dozens of reactors were also exported to the Soviet Union's Warsaw Pact allies. Indeed, Soviet nuclear plant building was such a vast enterprise that it launched an ambitious if ultimately unsuccessful effort to automate the process of building reactors (Josephson, 2000).

In its haste to build, the Soviet Union brushed aside environmental and public health concerns, cut corners by constructing early plants without containment vessels, and failed to rectify other faulty design elements and safety practices. Its origins in the nuclear weapons effort also helped shape a nuclear security culture with greater secrecy and less transparency than that of other nuclear energy producers. However, the march of Soviet nuclear progress was brought to a screeching halt by the nuclear accident involving a Soviet-designed reactor at Chernobyl in the Ukraine in 1986. Five years later, the Soviet Union collapsed.

However, after languishing for two decades, the nuclear industry in Russia has recently been greeted with renewed funding and enthusiasm. A well-known figure, former Prime Minister Sergei Kiriyenko, has been put atop the Russian nuclear energy enterprise. Kremlin money has been forthcoming, old plans have been dusted off and new ones proposed.

Still, many questions remain. It is far from clear whether Russia will be able to fulfill its ambitious goals to more than double its electrical output from nuclear power, increase exports of nuclear reactors, and play an even larger role in providing fuel and fuel-related services for nuclear plants. Indeed, some analysts view the goals as impossible without cross-subsidization from Russia's lucrative natural gas industry. Likewise, Russia has for decades insisted that it will move to a closed nuclear fuel cycle, but that appears to be an elusive goal. More importantly, while Russia's record in operating nuclear plants appears to have improved considerably, its nuclear establishment often appears to have retained a secretive, closed, centralized pre-Chernobyl mindset aided by the centralization of power in the Kremlin in recent years. That has meant that crucial public health, safety, and environmental issues, such as spent fuel disposal, remain unresolved and could ultimately threaten the public acceptance necessary to achieving the industry's goals.

Author Biography

Mr. Miles Pomper became editor of *Arms Control Today* in March 2003. Prior to joining ACT, Mr. Pomper was a foreign policy reporter for *CQ Weekly,* where he covered the full range of foreign policy issues, including arms control and proliferation concerns. He has also worked at the Legi-Slate News Service and written several book chapters and analytical articles for publications such as the *Foreign Service Journal* and the *Houston Chronicle.*

Mr. Pomper has also served as a Foreign Service officer with the US Information Agency, and the assistant information officer and a spokesperson of the US Embassy in Caracas, Venezuela. Mr. Pomper holds a masters degree in international affairs from Columbia University and masters degree in journalism from Northwestern University.

Background – Soviet/Russian Nuclear Energy Efforts

The Soviet Nuclear Energy Program

Russia's nuclear energy industry goes back more than half a century, emerging directly from its nuclear weapons effort. In 1954, Russia's Institute of Physics and Power Engineering (FEI) began operating the AM-1 ("peaceful atom") reactor based on the same graphite-moderated technology that it had used to produce plutonium for its weapons program. The reactor, located in the then closed city of Obninsk was water-cooled and was designed to produce up to five megawatts of electricity. It was the world's first reactor explicitly designed for this purpose. It served as a research reactor as well as heating the town's centrally distributed water supply until it was shut down in 2002 (Digges, 2002).

In the 1950s Obninsk also developed fast breeder reactors. In 1955, it produced the BR-1 ("bystri" or fast reactor) leading to the first such reactor to generate power, the BR-5. This reactor had a capacity of five MWt and was used for basic research for designing sodium-cooled fast breeder reactors. After a major reconstruction in 1983, it is now the BR-10, with a capacity of 8 MWt, and is used to investigate fuel endurance, to study materials, and to produce isotopes.

Obninsk launched another type of fast breeder reactor in 1959, leading to a commercial-scale prototype fast neutron reactor in Kazakhstan, the BN-350 (fast neutron). It operated from 1972 to 1999, producing 120 megawatts of electricity and heat to desalinate Caspian seawater.

The AM-1 reactor served as a prototype for other graphite channel reactor designs including the Chernobyl-type RBMK reactors. Russia's first commercial-scale nuclear power plants started up in 1963-1964 and the first of today's typical models was commissioned in the early 1970s. By the time of the 1986 Chernobyl accident, Russia had 25 power reactors in operation, almost equally split between the RBMK reactors and light-water reactors similar to those in the West, as well as a few other varieties. These pressurized water reactors, known by their Russian acronym VVER, like their Western counterparts were the outgrowth of the Soviet naval propulsion program.

Chernobyl and the Soviet Collapse

The Russian atomic energy complex then suffered three serious blows – the Chernobyl nuclear accident, the collapse of the Soviet Union, and the financial crises of the 1990s. The first generated public opposition to nuclear energy, the second led to a sharp drop in overseas sales for the Russian nuclear energy industry, and the third drained the complex of needed finance.

Russia inherited 80 percent of the Soviet Union's nuclear complex, which included both civilian and military facilities (USNPAS, 2008). It still is the fourth largest nuclear electricity generator in the world, following the United States, France, and Japan (IPFM, 2007). Nonetheless, between the Chernobyl accident and the mid-1990s, Russia only commissioned one new four-unit plant, in Balakovo, as well as adding a third unit at Smolensk. That brought the total amount of electricity generated from nuclear power to 21 GWe (WNA, 2008b).

By the time of Russia's financial crisis in 1998, the federal government had cut well back on funding for the nuclear energy ministry (then called Minatom). An ambitious program for developing 16 new reactor units was scrapped. Electrical output by the nuclear sector in 1998 was even below that of the previous year (Khripunov, 1999). During this period, Russia's nuclear industry tried several means of winning needed funds.

Most spectacularly, Russia seriously considered opening a repository for international spent fuel. Although several different models were floated, Minatom's concept of an international spent fuel service involved offering two different services: temporary storage, with later return of the spent fuel for the minority of customers who would prefer that or reprocessing without return of plutonium or wastes for most customers (Bunn et. al, 2001: 75). In 2000, Minatom envisioned importing 20,000 tons of spent fuel over 10 years, generating US$21 billion in total revenue, and US$7.2 billion after taxes and expenses. In 2000, the Duma passed legislation permitting such imports, but the Kremlin never exercised the option and by 2006 said that it would not do so.

Without government money, Minatom sought to sell its technology abroad to win needed funds. Most controversially, it sought cooperation with Iran, helping to build a nuclear reactor at Bushehr after the US government pressured other countries not to take on the project. It also provided training for nuclear operators and Iranian mathematicians and physicists, as well as helping Iran extract ore. US intelligence suggested that Russian nuclear scientists were helping Iran produce weapons-usable heavy water and nuclear-grade graphite. Under US pressure, however, Russia did back away from selling Iran uranium enrichment technology.

Another important yet controversial customer was India. Since 2001, Russia has been supplying fuel for India's two US-supplied reactors at Tarapur. Russia has claimed that such assistance is consistent with Nuclear Suppliers Group (NSG) guidelines that allow such transfers when they are deemed essential to safe operation of the facility. The US and nearly all the other NSG governments disagree with Russia on the matter (USNPAS, 2008).

Perhaps the most successful effort was the 1993 US-Russian "Megatons to Megawatts" agreement. The accord calls for Russia to downblend 500 metric tons of Russian weapons-grade highly enriched uranium for use in US reactors over a 20-year period. To date, the program has downblended more than 337 metric tons, the equivalent of 13,000 nuclear warheads, according to USEC and the US Department of Energy. The downblended low enriched uranium (LEU) currently supplies more than 40 percent of the fuel for US power reactors.

Such exports in 2007, for example, brought TENEX nearly US$800 million in revenues. By comparison, in 2004, electricity generation and nuclear plant exports, the nuclear industry's other major revenue sources (aside from limited government funding) provided profits of about US$650 million according to then Minatom chief Alexander Rumyantsev. Total exports in 2004, for example, amounted to US$3.5 billion (Kudrick, 2008; WNA, 2008b).

Domestic nuclear construction was revived in the new millennium with a first unit at Rostov (now known as Volgodonsk-1) starting up in 2001 and a third unit at Kalinin launched in 2004. A sign of the industry's disfavour, in 2004 the ministry of atomic energy (Minatom) was downgraded to a mere agency (Rosatom). Yet, by 2006 the Kremlin had shifted gears again, supporting ambitious plans to add 2-3 GWe per year to the grid until 2030, and in 2007, attempting to turn Rosatom into a state-owned corporation like Russia's natural gas giant Gazprom.

A Nuclear Renaissance?

Russia's revived interest in nuclear power reflects a number of factors. Perhaps most important is the immense role that oil and natural gas exports play in the Russian economy and the effect that rising prices for these commodities have had on the Russian polity. Rising oil wealth has translated into a better standard of living for the Russian people and increasing investment in energy-intensive industries such as mining and construction. The result has been annual increases in energy demand of around five percent a year, including increases in domestic gas consumption (Murina, 2008).

Moreover, domestic prices for the natural gas used in electricity generation are heavily subsidized and production at Gazprom's leading fields is in decline. Gazprom wants to cut back on the percentage of its gas used in domestic electricity generation, since it can make about five times as much exporting this fuel to the West. The Kremlin is hoping that nuclear energy can fill the gap (WNA, 2008b). In addition, much of Russia's electrical generating capacity is antiquated, with more than a quarter (50 GWe) coming to the end of its design life by 2010 (including a substantial proportion of Russian' first- and second-generation nuclear reactors), providing a further inducement to new nuclear plant construction. And Russia's nuclear plants are far from evenly distributed, with most of them concentrated west of the Urals, leaving room for further expansion in the country's Far East.

In 2007, nuclear power supplied 16 percent or 160 billion kilowatt-hours of electricity out of a total of just over 1 trillion kilowatt-hours. In the last few years, nuclear electricity output has risen substantially because of improved performance from existing plants rather than the construction of new ones. From 1998 to 2003, capacity factors (which measure the amount of electricity produced in relation to the maximum output achievable) increased from 56 percent to close to 76 percent (Kuznetsov, 2007).

Russia is seeking to extend the lifetimes and improve the output of its existing reactors by using higher quality fuel and operating them more efficiently. Fuel developments include the use of burnable poisons – gadolinium and erbium – as well as structural changes to the fuel assemblies. These changes have increased the enrichment levels and lifetime of fuel, cutting operating costs (WNA, 2008b).

Climate Change Concerns Not Critical

Unlike many other countries, increasing concern about climate change does not appear to have been an important motivation for Russia's renewed interest in nuclear energy. A 2005 survey by the International Atomic Energy Agency (IAEA) showed that only 26 percent of the Russian public supported the proposition that "we should expand the use of nuclear power to meet the world's growing energy needs, in order to help climate change." Nearly twice as many Russians (51 percent) were actively opposed to this proposition (IAEA, 2005).

In part, this reflects the fact that Russia's electricity sector and heat are largely powered by relatively "green" natural gas. It also stems from the fact that the 1997 Kyoto Protocol to the 1992 United Nations Framework Convention on Climate Change and other arrangements are constructed in a way that they do not substantially affect Russia's choice of fuels. The implementation of the Kyoto accord, made possible by Russia's approval, calls for bringing carbon dioxide emissions back to the level of 1990 by 2012. For Russia, that task is simple given that with the end of the Soviet Union, its economy collapsed soon after that date. By 1998, Russian emissions were almost half of what they were in 1990 and even by 2006, they were 34 percent below the 1990 level.

Despite this, Russia produces greater emissions and emissions per capita than Japan, in part because of its wasteful use of electricity (Russia's northern climate also plays a role). Electricity consumption per capita was higher in Russia than Japan in 2002, despite per capita income in Japan being almost ten times as high (Grachev, 2008). And Russia has been more than willing to accept energy intensive industries such as aluminum-smelting that other countries shun, even if it uses nuclear power to fuel the plants (WNA, 2008b).

Even with it's recent growth, very inefficient industry and power sectors and few policies aimed at curbing emissions, its emissions are still expected to be below 1990 levels in 2020 (IEA, 2008). Russia has also benefited as the host country for 73 joint implementation projects under the Kyoto protocol, under which other countries have received credits for reducing emissions in Russia (Hohne *et al,* 2008).

Follow-on negotiations to the Kyoto protocol set to take place in Copenhagen in 2009 could determine whether climate change considerations play a larger role in Russia's future energy policies. In July 2008, the G8 countries endorsed a goal of cutting global emissions in half by 2050. One Russian expert has estimated that meeting this goal would require Russia to increase its installed capacity and electricity production at nuclear plants seven times over by 2050 (Grachev, 2008). However, it was not clear if the baseline for cuts would be current levels or those of 1990. Environmentalists advocate the 1990 level, but Russia, alone among the G8, would actually find it easier to meet this target rather than cutting current levels.

Russia's Current Nuclear Fleet and Fuel-cycle Facilities

Russian Reactors

Russia currently has 31 reactor units operating at 10 locations, producing 23 gigawatts of electricity (gross) or 21.7 net gigawatts (EIA, 2008; US NPAS, 2008).

All of the reactors operate on LEU, aside from one 560 MW BN-600 liquid-sodium fast breeder reactor, originally designed to run on HEU fuel, but being reconfigured for a hybrid (uranium-MOX) core. Russian reactors generally are of three types: VVER pressurized water reactors, small EGP graphite-moderated boiling water reactors, and the RBMK graphite-moderated reactors.

Russia's Current Operating Power Reactors

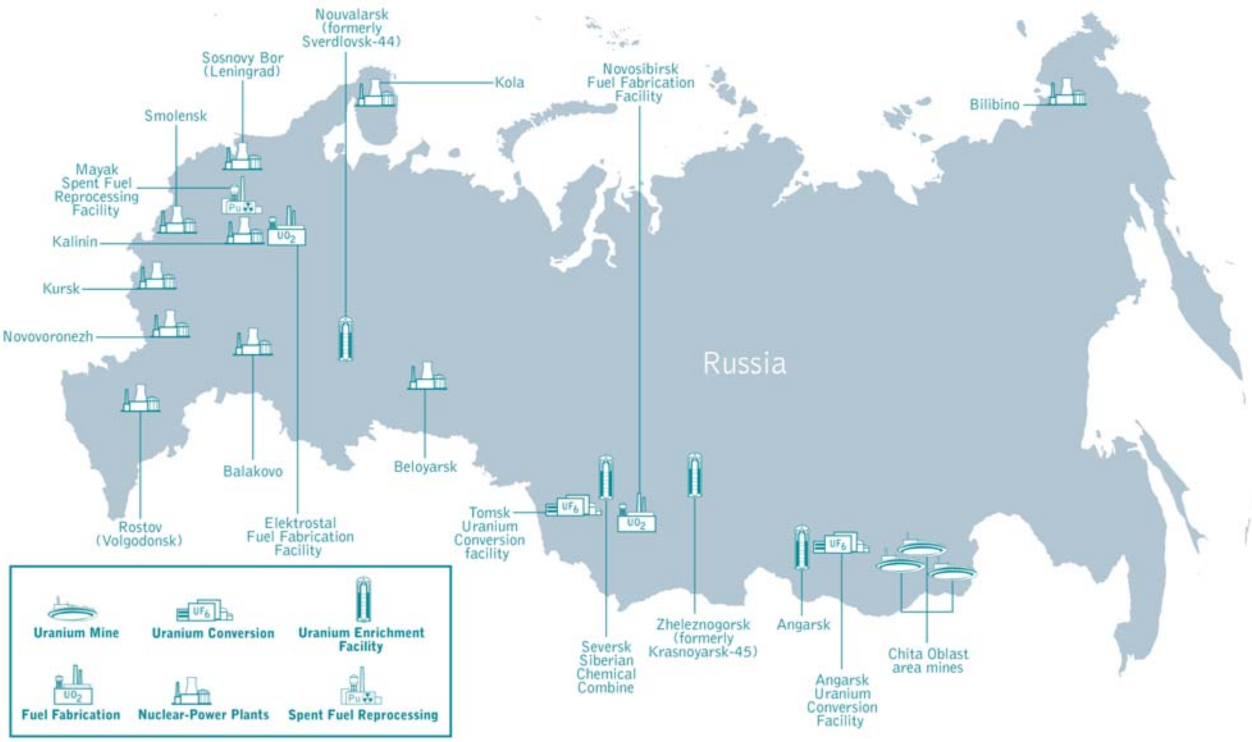
Until recently, Russia had also been operating three plutonium production reactors which generated heat and electricity, two in Seversk and one in Zheleznogorsk. The Seversk reactors were shut down this year and the Zheleznogorsk reactor is slated to be shut down by 2010 under a 1997 US-Russian agreement (US NPAS, 2008).

Russia's immediate plans include completing several plants that have been stalled for decades. Currently, Russia expects one long-stalled VVER-1000 reactor to commence operation by 2010 (Rostov-Volgodonsk-2). Recently, the concrete foundation was laid for the first of two new reactors at Novovoronezh as well as a new reactor near St. Petersburg, and work is underway to complete the long-stalled reactor Kalinin 4 (Nuclear.ru, 2008b; WNA, 2008b;).

The fate of the mostly complete Kursk-5, which originally began construction in 1986 and includes an upgraded RBMK design, is uncertain. Russian officials are eager to see it completed, and in January 2007 the Duma's energy committee recommended that the government fund its completion by 2010 (estimated at nearly US$1 billion). However, EU officials have opposed its completion, as all other RMBK reactors are due to close by 2024. As of March 2008, its fate was said to be contingent upon obtaining adequate funding. That money has not been forthcoming and has also been stymied by the fact that expensive upgrades to the electrical grid will also be required. Rosatom Deputy Director Alexander Lokshin has said that the improvements to the grid would "be comparable with the cost of the reactor construction completion. As one potential solution, Rosatom officials have floated the unlikely prospects of wooing foreign investors (Nuclear.ru, 2008b).

In addition, the world's first floating nuclear power plant was originally slated to be launched this decade – the Sevmash shipyard in Severodvinsk was awarded a contract to build the reactor in May 2006 and was to be the customer for the reactor as well. However, technical and financial problems are expected to lead to a delay of about a year until mid-2011. Various technical problems first appear to have slowed construction and a shortage

Operating Russian Nuclear Power Plants and Fuel Cycle Facilities (November 2008)



of funds seems to have held up building. Finally, in August 2008 Sevmash canceled its contract, saying it was too inundated with federal military contracts to fill the order. Final construction of the partially built plant (the ship's hull and central section, without reactors) is now said to be slated to be transferred to Baltiysky Zavod in St. Petersburg. However, the customer for the first reactor remains uncertain (Bellona, 2008; WNN, 2008a).

Russia has also pledged funds toward the completion of the Belayarsk-4 or BN-800 fast breeder reactor by 2012.

Mining and Fuel Cycle Facilities

Russian officials have claimed that they can undercut world prices for nuclear fuel and services by some 30 percent (WNA, 2008), although given the tendency of Russian officials to make unfulfilled claims, the veracity of these claims is not clear.

Mining

Russia possesses substantial recoverable reserves of uranium-172, 365 tonnes or about five percent of world's "reasonably assured resources" when prices are below US$80/kilogram ("Reasonably assured resources" are those which have been well explored and can be recovered at less than a specified cost). In 2007 Russia became the world's fourth largest uranium producer after Canada, Australia, and Kazakhstan (surpassing Niger), supplying about 3,500 tonnes of low-grade ore annually (Sinitsyna, 2008). Still, Russian reserves are neither cheap enough nor substantial enough to fuel Russia's own domestic needs without substantial imports from larger producers, particularly Kazakhstan and Australia.

Mining is now controlled by AtomRedMedZoloto(ARMZ) which ranks fifth in the world among uranium mining companies in production (3527 tonnes) and second in terms of uranium reserves (more than half a million tonnes). It produces most often in large underground mines in the Trans Baikal region in southeastern Siberia near the Chinese and Mongolian borders. The Priangarsky Mining and Chemical Complex is currently responsible for 90 percent of uranium production in Russia (DOE, 2008).

Recent Russian and international estimates (NEA-IAEA, 2008) have boosted hopes for greater production in the future. As of January 1, 2007, Russia had:

- "Inferred resources" of 373, 269 tonnes of uranium, of which 323,000 tonnes are "reasonably assured" or recoverable at a cost of less than US$80/kilogram. ("Inferred" resources are extensions of deposits whose existence has been established but whose exact characteristics are not sufficiently delineated to classify as reasonably assured.)

- Less certain "prognosticated resources" now amount to 276,500 tonnes of uranium and "speculative resources" to 714,000 tonnes. ("Prognosticated" resources are those expected to occur in well-defined geological trends with known deposits but which have not been explored. "Speculative" resources are those expected somewhere within a given region or geological trend) (NEA-IAEA, 2008).

Russia would like to substantially increase the output of its mines to 10,300 tonnes/year by 2015 and 20,000 tonnes by 2024, but the proposed sites are often remote and difficult to reach. In particular, Russia would like to develop the massive Elton project in the Sakha Republic (Yakutia) to produce as much as 5000 tonnes of uranium per year by 2011, but many of these resources lie deep beneath permafrost (as many as 300-400 metres underground). Required funding is estimated at US$3.5 billion, with half of this amount expected to come from private investment.

During the Soviet era, Moscow was able to count on not only its own reserves, but those of other substantial producers such as Kazakhstan. Since the Soviet collapse, Russia has powered its nuclear reactors and enrichment facilities by mining the easiest reserves and drawing down Soviet stockpiles of uranium such as the HEU downblended by USEC. By 2020, the IAEA and the OECD's Nuclear Energy Agency estimate that Russia will need 8200-9700 tonnes of uranium annually to fuel its domestic reactors (WNA, 2008b; NEA-IAEA, 2008).

In addition to seeking to increase its own uranium mining capacity, AMRZ has reestablished collaboration in this area with former Soviet states, most importantly Kazakhstan. Russia is also pursuing cooperation with companies such as the Canadian firm Cameco, the Japanese firm Matsui, and Namibian firms (DOE, 2008).

Conversion

Russia has the world's largest share of facilities to convert uranium into feedstock suitable for enrichment. It has the ability to process about 30,000 metric tonnes of uranium per year, 18,700 tonnes at Angarsk, 10,000 tonnes at Tomsk.

Enrichment

Russia provides more than 40 percent of the world's enrichment capacity, more than 24 million kg (M) SWU per year, out of an estimated world annual total of 51 M SWU (Schnoebelen, 2008). All of Russia's facilities rely on more modern and efficient gas centrifuge technology rather than older gas diffusion technology that currently is being phased out in the United States and France. This capacity is expected to increase to between 26 and 28.2 M SWU per year by 2010 as new generations of more efficient centrifuges are installed.

Currently less than 40 percent of this capacity is used to provide LEU for Russian-designed reactors at home and abroad. About a quarter is used to produce 1.5 percent enriched uranium for use in downblending HEU to LEU for power reactor fuel in the United States. The remaining 40 percent or so is used to enrich natural uranium and reenrich reprocessed uranium for European customers and to enrich depleted uranium tails (IPFM, 2007).

Russia has four enrichment plants:

- Facilities at *Novouralsk* (formerly Sverdlovsk-44) near Yekaterinburg have nearly half of Russia's separative capacity and will soon be the largest in the world. They produce 10 M separative work units (SWU) per year. They provide fresh LEU as well as downblending weapons-grade HEU to LEU.
- *Zheleznogorsk* (formerly Krasnoyarsk-45), with an annual capacity of 5.8 M SWU, services foreign demand for enriched uranium.
- *Angarsk* (near Irkutsk), with 2.6 M SWU per year, specializes in enriching reprocessed uranium (tails) for Western European companies Urenco and Areva.
- *Seversk* – the Siberian Chemical Combine (near Tomsk), with an annual capacity of 3 M SWU, serves the same purpose as Angarsk.

Rosatom's long-term plan for the nuclear energy industry, approved on September 20, 2008, calls for substantial growth in enrichment capacity to 31.5 M SWU by 2010, 37.5 M SWU by 2020, and 49M SWU by 2030. An independent consultant firm, views these goals as overly optimistic, because of Russia's failure to upgrade some of its aging centrifuges. It expects production to increase only to 27.6 M SWU in 2010 and 31.7 M SWU in 2020 (IBRC, 2008).

Fuel Fabrication Facilities

Russia's fuel fabrication company TVEL claims to supply about one-sixth of the world's nuclear fuel, for more than 70 reactors, making it one of the world's top companies in this field. In 2002, TVEL produced 382 metric tonnes of RBMK fuel and 226.9 metric tonnes of VVER fuel, as well as small quantities of other fuels. Competitors include Britain's BNFL, France's Cogema, Germany's Siemens, Sweden's ABB and Westinghouse, owned by the US and Japan.

Nuclear fuel fabrication is carried out at two plants – Elektrostal and Novosibirsk – with a combined capacity of 2600 tonnes of heavy metal per year. The plant at Elektrostal produces fuel assemblies for both Russian and European reactors and is the principal exporter of fuel assemblies. The Novosibirsk facility produces fuel for the VVER-400 and -1000 reactors. Upgrades worth US$200 million are planned from 2007-2015 (IPFM, 2007; Kudrick, 2008; US NPAS, 2008).

Domestic Legal Changes and Future Direction

Legal Changes

Russia's "nuclear renaissance" can have said to begun in 2006 with two documents and Kiriyenko's ascension to the top nuclear energy post.

The first document was a June 2006 "official use" (not for public circulation) document from (then president) Vladimir Putin entitled, "Program for the Development of Russia's Nuclear Sector," which charted the future course of Russia's nuclear evolution. This approach was then codified in government instruction #1019 R issued by the prime minister's office in July 2006, "Russian Program for the Development of the Nuclear Complex 2007-2010 and to 2015," which provided the template for the funding and development of Russia's nuclear energy industry.

The next year Kiriyenko advanced an idea that had been around for a decade – recombining the nuclear complex into one entity akin to Gazprom in order to centralize control, promote investment in profit-generating projects, and attempt to make the industry self-supporting by 2015. Support for such an idea had also grown because of the need to compete with the increasingly integrated nuclear industry in other countries, particularly the French nuclear giant Areva. In February 2007, Putin signed a law (Federal Law 13FZ, "On particulars of the management and disposition of the property and shares of the organizations that use nuclear energy and appropriate changes to legislative acts of the Russian Federation") making "Atomenergoprom" the vertical holding company for the civilian nuclear sector.

Among the key concepts in the law were that nuclear material would no longer be the monopoly of the state, which clears the way for other entities to use nuclear methods and plants for private purposes, and for some parts of the nuclear industry to become public shareholding companies (with the state maintaining a controlling share). This was particularly noteworthy because Russia's nuclear industry, unlike most Russian industries, was not affected by the controversial privatizations of 1990s. The 2007 law was seen as a different and gradual way of privatizing parts of the industry, and in the meantime generating revenue.

A Putin presidential decree in April 2007, "On Restructuring the Nuclear Power Generation Complex of the Russian Federation" included seven annexes specifying the hierarchy of the nuclear complex and which parts of the nuclear complex would be open to private participation.

By the end of 2007, Rosatom was transformed into a state owned corporation with a managing board (Kiriyenko, etc.) and supervisory board (essentially Kremlin officials) and four major clusters:

1. Nuclear weapons complex;
2. Complex of nuclear and radiation safety;
3. Complex of research and training centres; and
4. Atomenergoprom – by far the largest component. This included 86 organizations, the entire nuclear fuel cycle and the complete civilian nuclear power complex (Khripunov, 2008).

In February 2008, Kiriyenko left the Rosatom agency to become the head of Rosatom State Corporation. Many of the subsidiaries of Atomenergoprom also became joint stock companies, with the potential for attracting private investment.

Privatization of electricity sector

During this period, Russia also moved forward with the partial privatization and restructuring of the electricity giant UES. As of July 2, 2008, UES no longer controls generating capacity. The government has pledged to completely liberalize the electricity market by 2011 (30 percent is liberalized today), which should increase prices for nuclear generation. The scale of the increases is uncertain, however. Tariffs were supposed to increase from the equivalent of 1.1 cents/kilowatt hour in 2001 to 1.9 cents/kilowatt hour in 2005 and 2.4 cents/kilowatt hour in 2015. Only much smaller increases have so far been approved by the government and these have faced wide opposition. After 2011, the Russian government is supposed to retain control of only the power grid, and hydroelectric and nuclear electricity generating capacity.

Planned Reactor Construction

In October 2006, Putin approved a program called "Development of Nuclear Power Industry Complex in Russia for

Table 1: Russia's Future Nuclear Build

Plant	Type	MWe	Under Construction	Planned	Proposed	Commercial Operation
Rostov / Volgodonsk 2	V-320	1000	✓			2009
Severodvinsk	KLT-40S	40 x 2	✓			2010
Kalinin 4	V-320	1000	✓			2011
Beloyarsk 4	BN-800 FBR	800	✓			2012
Novovoronezh II -1	AES-2006 / VVER 1200	1200	✓			2012
Leningrad II -1	AES-2006 / VVER 1200	1170		✓		2013
SUBTOTAL (Under Construction)		**5250**				
Kursk 5	RBMK	1000	✓			2011*
Novovoronezh II -2	AES-2006 / VVER 1200	1200		✓		2013
Rostov /Volgodonsk 3	AES-2006 / VVER 1200	1200		✓		2013
Leningrad II -2	AES-2006 / VVER 1200	1170		✓		2014
Seversk 1	AES-2006 / VVER 1200	1200		✓		2015
Tver 1	AES-2006 / VVER 1200	1200		✓		2015
Baltic 1 (Kaliningrad)	AES-2006 / VVER 1200	1200		✓		2015
Leningrad II -3	AES-2006 / VVER 1200	1200		✓		2015
Rostov /Volgodonsk 4	AES-2006 / VVER 1200	1200		✓		2014
Nizhegorod 1	AES-2006 / VVER 1200	1200		✓		2016
Leningrad II -4	AES-2006 / VVER 1200	1200		✓		2018
Baltic 2 (Kaliningrad)	AES-2006 / VVER 1200	1200		✓		2016
SUBTOTAL (Planned)		**14,170**				
South Ural 1	AES-2006 / VVER 1200	1200			✓	2016
Novovoronezh II -3	AES-2006 / VVER 1200	1200			✓	2017
Tver 2	AES-2006 / VVER 1200	1200			✓	2017
Seversk 2	AES-2006 / VVER 1200	1200			✓	2017
Tsentral 1	AES-2006 / VVER 1200	1200			✓	2017
Kola II -1	VK-300 or VBER 300	300			✓	2017
Nizhegorod 2	AES-2006 / VVER 1200	1200			✓	2018
South Ural 2	AES-2006 / VVER 1200	1200			✓	2018
Kola II -2	VK-300 or VBER 300	300			✓	2018
Novovoronezh II -4	AES-2006 / VVER 1200	1200			✓	2019
Tver 3	AES-2006 / VVER 1200	1200			✓	2019
South Ural 3	AES-2006 / VVER 1200	1200			✓	2019
Tsentral 2	AES-2006 / VVER 1200	1200			✓	2019
Kola II -3	VK-300 or VBER 300	300			✓	2019
Primorsk 1	VK-300 or VBER 300	300			✓	2019
Nizhegorod 3	AES-2006 / VVER 1200	1200			✓	2020
Nizhegorod 4	AES-2006 / VVER 1200	1200			✓	2020
Tsentral 3	AES-2006 / VVER 1200	1200			✓	2019
Tsentral 4	AES-2006 / VVER 1200	1200			✓	2020
South Ural 4	AES-2006 / VVER 1200	1200			✓	2020
Tver 4	AES-2006 / VVER 1200	1200			✓	2020
Kola II -4	VK-300 or VBER 300	300			✓	2020
Primorsk 2	VK-300 or VBER 300	300			✓	2020
Pevek	KLT-40S	40 x 2			✓	2020
SUBTOTAL (Proposed)		**22,280**				

Source: World Nuclear Association, *Nuclear Power in Russia,* October 2008; Rosatom State Corporation's Action Program for a Long-Term Period (2009-15).
*Partly constructed, completion depends in part on financing.

2007-2010 and Further to 2015," outlining plans for the Russian nuclear energy complex. That plan called for nuclear energy to supply 23 percent of the country's energy by 2020, which would require nuclear energy's electrical output to double to more than 51 gigawatts. The plan called for nuclear energy to provide one-quarter of Russia's electricity by 2030.

Achieving this goal would require commissioning two 1200 MWe plants per year from 2011 to 2014 and then at least three per year until 2020. Prior to 2014, in addition to those planned to be under construction by then, the requirement translated to commissioning two additional reactors at Leningrad and one additional one at Novovoronezh.

After the initial plants, short-term construction (i.e. until 2020) is centered on building new VVER-1200 reactors as part of third-generation AES-2006 plants. Concrete for the first such reactor (Leningrad II-1) was poured in October 2008 (Nuclear.Ru, 2008c). The new plants and reactors represent an evolutionary improvement over the current AES-92/VVER-1000. Current plants already often include core catchers, passive safety features and improved protection against earthquakes. The new plants include enhanced safety features related to earthquakes and reducing impact from crashing airliners, as well as some passive safety features, double containment, and core safety. They are also planned to have longer life (50 years), greater power, and improved efficiency. Russian officials have claimed the capital cost for the new reactors would be would be US$1200 per kilowatt hour, although the first reactor cost nearly twice as much at US$2100 per kilowatt hour.

Floating Reactors and VBER-300

Energoatom, the Atomenergoprom subsidiary which controls Russia's nuclear plants, is planning to construct seven further floating plants in addition to the one under construction. Each plant will be equipped with two KLT-40 (35MWe) reactors said to be capable of supplying a city of 200,000 people. Five will be used by Gazprom for offshore oil and gas development and for operations on the Kola and Yamal peninsulas. Two others are planned to supply electricity to Russia's East. Russia plans to complete at least two of these plants from 2010-2020.

The reactors are derived from those used in Russia's unique nuclear icebreakers. But they rely on LEU (less than 20 percent U-235), rather than HEU. The reactors will be mounted on a 21,500 tonne, 144 metre-barge. They are expected to cost US$337 million with 80 percent of the cost financed by Enegroatom and 20 percent by the shipyard.

They are supposed to be refueled every three to four years onsite and at end of a 12-year cycle the whole plant is returned to a shipyard for a two-year overhaul and storage of spent fuel before being returned to service.

Eventually, Russia would like to mount two 295 MWe VBER-300 reactors on a 49,000 tonne barge. In particular, export of combined power and desalination units is planned. Algeria, Argentina, Cape Verde, China, Indonesia, Malaysia and Qatar have been mentioned as possible buyers. Russia would probably operate and retain ownership and simply sell output.

Aside from the floating plants, Russia plans to bring online six land-based VBER-300s, its new medium-power light water reactors, by 2020. These new reactors are based on Russian naval reactors.

Fast Reactors and the Closed Fuel Cycle

Concerned about a lack of uranium and excited by the perceived efficiency of fast and breeder reactors, Russia has long supported a closed fuel cycle. Nearly three decades ago, Soviet Minister of Electrification P.S. Neporozhnii said, "Fast reactors belong to the future. The phoenixes of the twentieth century will bring the masses invaluable benefit" (Josephson, 2000: 47). Not only did the Soviets build the BN-350, then the world's most powerful breeder reactor, in Kazakhstan in the 1970s, but they began construction soon thereafter on ever larger reactors, first the BN-600 and then the BN-800, with the last producing 800 megawatts of electricity. But that was said to be only the beginning. As historian Paul Josephson has written, "When Mikhail Gorbachev left office in 1991, they had blueprints in hand and foundations ready for a massive 1,600 megawatt breeder reactor as the prototype for a network of these machines" (Josephson, 2000: 50).

The BN-800 and the more powerful reactor have yet to be built. Given this history, Russia's claims that fast breeder reactors and MOX fuel will be the foundation of its nuclear program from 2020-2022 and beyond (USNPAS, 2008) must be taken with more than the usual grain of salt.

The government's 2006 nuclear plan calls for finishing construction of the BN-800 by 2012, nearly three decades after it begun. Intended to replace the BN-600, final construction of the reactor is estimated to cost US$1.2 billion and Russian officials have encouraged Japanese and Chinese involvement as a means of obtaining some of the necessary funds. A sodium-cooled fast reactor, the BN-800, will utilize MOX fuel, containing both reactor- and weapons-grade plutonium, as well as burn off other actinides. A BN-1600 reactor (with double the electrical output) is said to be designed for operation from 2020, while Rosatom in July 2008 said it was negotiating establishment of a US$1 billion joint venture to design and build a 100 MW pilot lead-bismuth-cooled breader reactor at Obninsk, developed from Russian submarine technology for operation in 2015 (Breus, 2008c).

In addition, Russia took a lead role in the international GT-MHR (Gas Turbine-Modular Helium Reactor) project in the 1990s, and is attempting to build a prototype of this kind of reactor at Seversk by 2010, with construction of the first module power plant (four 285- Mwe units) by 2015.

Initially, the reactor will be used to burn pure weapons plutonium and replace the plutonium production reactors at Seversk. A longer-term use is seen in burning actinides or in hydrogen production.

Miscellaneous

Rosatom and RUSAL (the world's largest aluminum and alumina producer) are contemplating the construction of a US$10 billion plant involving four 1000 MWe reactors in Russia's Far East to power aluminum smelters and provide electricity to China and North and South Korea. In October 2007, a US$7 billion aluminum-smelting project was announced for the Saratov region, complete with two new 950 MWe nuclear reactors at Balakovo to power it. The future of the project, however, was brought into question by the late 2008 global financial crisis. On October 21, 2008, the deputy head of Rosatom, Alexander Lokshin, said that Rosatom "expects corrections in projects with Rusal in construction of the Balovskaya NPP in the Saratov region as a result of the financial crisis" (Slivyak, 2008).

Russian officials have also discussed constructing almost ten small reactors with a total power of 5 GW to provide heat to Russian cities as well as building VK-300 boiling water reactors to provide both power and desalination.

Funding

To accomplish this ambitious expansion and support exports, the initial plan proposed total spending of a little over 1.3 trillion rubles (about US$54 billion at current exchange rates) through 2015. Of this, 750 billion rubles (US$31 billion) would go to build 26 nuclear power plants in Russia, 420 rubles (US$17 billion) would be used to build 12 reactors for export, and 160 billion rubles (US$7 billion) would be used to build small and medium-sized reactors. About 474 billion rubles (about US$20 billion) of the financing needed would come from the federal budget and the rest (more than half) from the nuclear industry's coffers, loans, or shares in enterprises. After 2015, the Russian nuclear energy industry is supposed to become self-sustaining, with spending on domestic reactors estimated at US$20 billion from 2016 to 2020.

In July 2008, Putin, now prime minister, called for a substantial boost in funding for nuclear power. According to a government resolution approved on September 20, 2008, Russia plans to use 1.264 trillion rubles (US$50.5 billion) of Rosatom's funds for nuclear plant construction and 820 billion rubles (US$32.8 billion) in government funds to carry out the plan (IPFM, 2007; USNPAS, 2008; and WNA, 2008b).

International Changes

Fuel Cycle Initiatives

Revelations earlier this decade about Iran's clandestine uranium-enrichment activities reignited global concerns that the spread of such sensitive fuel cycle technology would lead to nuclear weapons proliferation. States responded with a number of proposals aimed at thwarting the unlimited spread of uranium enrichment and similarly sensitive spent fuel reprocessing technologies. For example, they suggested ways of assuring nuclear fuel supplies and called for establishing international nuclear fuel cycle centers. Russia signed onto several of these proposals.

One proposal that Russia endorsed was the Concept for a Multilateral Mechanism for Reliable Access to Nuclear Fuel, often known as the RANF or the Six-Country proposal. This sought to convince countries that they did not need to build uranium enrichment facilities to preserve their energy security but that they could rely on several layers of assurances that they would not see their supplies of nuclear fuel interrupted as a result of political disputes. The first, or "basic," assurance was seen as the existing and normally-operating commercial market. The RANF mechanism envisioned adding a second layer in which suppliers of enriched uranium would agree to substitute for each other to cover certain supply interruptions (Rauf and Vovchok, 2008). A final third layer of assurance, in both proposals, incorporated the fuel bank concept, by suggesting governments create enriched uranium stocks (either virtual or physical).

In addition, Russia proposed a Global Nuclear Infrastructure Initiative (including establishing an International Uranium Enrichment Centre at Angarsk in Siberia) in 2006, signed onto the Bush administration's Global Nuclear Energy Partnership (GNEP), and is working with the United States on a bilateral global initiative to advance nuclear power.

Global Nuclear Infrastructure Initiative / International Uranium Enrichment Centre

Early in 2006, Putin and Kiriyenko announced the Global Nuclear Infrastructure Initiative (GNII), which envisaged

Russia hosting four types of nuclear fuel cycle service centers as joint ventures partly financed by other countries and involving the IAEA. One would be a proposed International Uranium Enrichment Centre (IUEC). A second would involve reprocessing and storage of spent nuclear fuel. A third would deal with training and certification of nuclear personnel, especially for new nuclear countries. A fourth would involve joint research and development (Breus, 2006; Itar Tass, 2006).

The Angarsk proposal itself existed in two parts: an enrichment centre and a fuel bank. In 2007, the Russian Duma approved enabling legislation that would grant participating countries the right to partake financially in the facility. In addition, Russia began exploring a means through which a separate LEU stockpile could be set aside under IAEA safeguards for the use of member states.

Russia legally established the IUEC in September 2007 as a joint stock company. A deal had already been signed with Kazakhstan by the time shares were issued in November 2007. Kazakhstan purchased 10 percent of the shares. At that time, Armenia also indicated its interest in joining, a step which was taken through an exchange of notes in February 2008. In July 2008, Ukraine also offered to buy a 10 percent share in the Centre and its proposal has been accepted by Kazakhstan. A draft agreement was endorsed by Ukraine's cabinet of ministers in November (Ukraine General Newswire, 2008; Simpson, 2008). Russian officials have said that they anticipate wrapping up negotiations with Ukraine by the end of 2008 (Arminfo, 2008; Kazakhstan Mining Weekly, 2008; Regnum, 2008; Ukraine Business Report Daily, 2008). Russia has broached the possibility of joining the center with several European countries, including Slovenia, Belgium, and Slovenia. (MacLachlan, 2008b). But they have yet to take up the invitation. The eventual plan is for Russia's share to drop to 51 percent as other partners are admitted. In order to address concerns regarding the spread of technology, the IUEC will be structured in such a way that no enrichment technology or classified knowledge will be accessible to the foreign participants. Sergey Kislyak, Russia's ambassador to the United States likened it in a recent interview to "offering a Mercedes if you know how to shift gears and drive the car, but there will be somebody else, specialists, who will take care of your engine" (Arms Control Today, 2008).

In December 2007, the Russian government took the decision to include the enrichment center in the list of facilities it is willing to submit to IAEA safeguards. Safeguards are also to be applied to a 120 tonne LEU stockpile that is to be set aside, as a fuel bank in the event of a supply disruption for political reasons unrelated to nonproliferation. Although an agreement between the IAEA and Russia on the safeguards arrangements was originally expected to be concluded in the first half of 2008 (RIA Novosti, 2007), no such agreement was finalized as of September 2008.

Russia wants the IAEA to apply safeguards to the uranium materials at the facility, including feed uranium, enriched uranium, and uranium tails. At the same time, Moscow wants to ensure that its enrichment technology remains a secret and it remains unclear who will cover the cost of IAEA inspections (Loukianova, 2008; Sokova and Chuen, 2007).

Kiriyenko told the IAEA General Conference on September 29, 2008 that he was confident that the facility would "receive before the end of the year all necessary licenses to go into operation." However, such an agreement has not yet been finalized and appears likely to be held up for at least another few months (RIA Novosti, 2008b; Simpson, 2008). Russian officials say a final agreement has been held up because of a dispute between the Russian government and the IAEA over which countries should be eligible to receive fuel from the facility. IAEA officials say that all IAEA members should be eligible to draw from the fuel bank.

However, Russian law requires Moscow to follow Nuclear Suppliers Group criteria that limits such trade to state that have signed the nuclear Nonproliferation Treaty and have full-scope IAEA safeguards, aside from India which won an exemption from such rules in September 2008.

Global Nuclear Energy Partnership

While preferring its own initiative, Russia has also signed onto US President George W. Bush's Global Nuclear Energy Partnership (GNEP). Bush initially conceived of GNEP as a system in which nuclear suppliers like the United States and Russia would lease nuclear fuel to other states that choose not to engage in enrichment and reprocessing. They would then use advanced reprocessing technologies to recycle the spent fuel and burn the resulting product in advanced fast reactors.

Current reprocessing technologies yield pure or nearly pure plutonium that can be used in fuel for nuclear reactors or to provide fissile material for nuclear weapons. GNEP proposes eventually to build reprocessing facilities able to produce a product that would include retain other elements from the spent fuel along with the plutonium, making it less attractive for weapons production than pure plutonium. But critics note that this fuel would still not be as proliferation-resistant as when the spent fuel is left intact and not reprocessed. They also point out that Russia and France helped to alter the program so that current, but more proliferation-prone reprocessing technologies could also be considered as part of the effort. Russian officials have also been both publicly and privately skeptical that the GNEP effort, as opposed to their own initiatives, will succeed. The Russian ability to participate in the effort will also hinge in part on whether the US Congress ultimately approve a nuclear cooperation agreement between the two countries (see below).

US-Russian Global Cooperation

At a summit in St. Petersburg in July 2006, Putin and Bush called for the two countries to forge a bilateral action plan to further US-Russian global and bilateral nuclear energy cooperation. Six months later, US Secretary of Energy Samuel Bodman and Kiriyenko announced a framework for cooperation.

The plan called for cooperation in designing exportable small- and medium-power reactors, advanced fast spectrum reactors, enhanced and integrated safeguards, new types of fuel for fast spectrum reactors, and new technologies for spent fuel reprocessing and separations, transmutation and waste isolation.

They agreed that short-term research cooperation would focus on the following areas:

1. Developing unified safety and nonproliferation requirements for small and medium-sized reactors;
2. Conducting joint experiments with transuranic fuels and structural materials (for example, irradiating specimens of US-designed transuranic fuels and structural materials in a Russian research reactor to conduct post-irradiation examination);
3. Developing an appropriate set of policies for international fuel service centers (i.e. how do safeguards apply, what are appropriate guarantees to customers, how can they be made commercially attractive, etc.);
4. Developing new monitoring, control, and accounting technologies;
5. Increasing the efficiency and safety of fast spectrum reactors; and
6. Developing unified requirements for methods and technologies in spent nuclear fuel reprocessing and ultimate waste isolation.

In July 2007, Bush and Putin agreed on further steps to promote nuclear energy expansion worldwide while limiting the spread of nuclear technologies that could be exploited to build nuclear weapons. The two countries declared their willingness to provide or facilitate financial assistance, infrastructure support, and regulatory and technical training for those countries looking to benefit from nuclear power programs.

Russia and the United States had hoped that both GNEP and the global US-Russian initiative could be advanced by a US-Russian nuclear cooperation agreement that the two countries signed in May 2008 and that Russian officials had desired for more than a decade. Russia is the only major nuclear energy producer that does not have such an agreement with the United States. The nuclear cooperation agreement is one of several key Russian bilateral initiatives with the United States and one of many important Russian bilateral initiatives with other countries. But the August 2008 conflict between Russia and Georgia and continuing tensions over Russian policy toward Iran have set back prospects for that agreement and more broadly for US-Russian nuclear relations.

Bilateral Initiatives

Cooperation with the US

Bush's signing of the US-Russian nuclear cooperation agreement and subsequent swift action to submit it to the US Congress marked a victory for Russia, but perhaps a transient one. Within a month of the August 2008 Russian-Georgian conflict, Bush said he no longer wanted Congress to consider the agreement in its current session.

On September 8, 2008, US Secretary of State Condoleezza Rice notified Congress that Bush was rescinding a prior presidential determination that had allowed the agreement to go forward. In the statement Secretary Rice said, "Unfortunately, given the current environment, the time is not right for this agreement." "We will reevaluate the situation at a later date as we follow developments closely" (Rice, 2008). Effectively, however, a decision on whether and when to proceed with the agreement will be left to the next president).

In a September 9, 2008 statement, Russia's foreign ministry criticized the US action saying, "We see the decision of President George W. Bush…to pull the agreement on the peaceful use of nuclear energy as mistaken and politicized" (Pomper, 2008).

However, Russian officials did leave the door open to future cooperation. "Whatever the decisions at the current time, we consider that it is a promising area for mutual cooperation and Russia and America will definitely cooperate, if not now then in the future," said First Deputy Prime Minister Igor Shuvalov (Soldatkin, 2008).

It is not yet clear what position the incoming Obama administration will take on the issue although candidate Obama did support the decision to pull the agreement from congressional consideration after the Georgia conflict. Even before the conflict between Russia and Georgia, the agreement already faced considerable opposition from those concerned about Russian policy toward Iran. On June 24, 2008, the House Foreign Affairs Committee approved legislation calling for the agreement to be approved if a number of conditions were met. In particular, the measure would have required the president to certify that Russia was preventing the transfer of nuclear, missile, and other highly sensitive goods to Iran (aside from those involved in the construction of a light-water reactor at Bushehr in Iran).

On a practical level, experts said that the direct and short-term benefits of the agreement were likely to be limited. Most importantly, it would not significantly affect imports of Russian fuel to the United States, which are governed by the "Megatons to Megawatts" agreement (see below), nor would it govern other ongoing nonproliferation efforts.

Nevertheless, the measure promised some benefits for both countries, for hopes for a global nuclear energy "renaissance" and for GNEP. The measure could help provide US companies with another source for nuclear components, labour and expertise at a time that global plans for new nuclear plants have left such resources in short supply. It could benefit Atomenergoprom by allowing the company to take advantage of US expertise in MOX technology and reactor life extension programs and including US safety and control equipment in its nuclear plants, making them more attractive to foreign buyers (Einhorn, 2008).

A nuclear cooperation agreement would also increase the confidence of nuclear researchers in both countries that they could step up cooperation in some areas, such as research into fast reactors without political heat from Congress. For instance, as noted above, US researchers would like to take advantage of Russian expertise and facilities by testing potential new fuels in Russian reactors (Einhorn, 2008).

Unlike other agreements the United States has concluded with Japan and the European nuclear consortium Euratom, the agreement would not allow Russia to reprocess US-origin spent fuel to obtain plutonium, unless it first obtained US consent. Should the executive branch give this permission, however, current US law only requires that Congress be notified of the decision 15 legislative days in advance (Einhorn, 2008).

Nor does the agreement permit transfers of "sensitive nuclear technology" – technology that could be used for weapons production such as uranium enrichment and plutonium reprocessing – without the administration submitting an amendment to the pact to Congress. In that case, lawmakers would have the same 90 days of legislative consideration to which the underlying agreement is now subject (Einhorn, 2008).

The United States and Russia have been discussing such an agreement for more than a decade. Completion had been held up by US displeasure about Russia's cooperation with Iran in missiles, advanced conventional weapons, and initially by its construction of a light-water nuclear reactor at Bushehr. Initial operation of that reactor has been repeatedly delayed but is now said to be set for late 2008 or early 2009.

Bush and Putin agreed to pursue such an agreement in 2006, a year after Russia agreed to try to minimize the possibility that Iran could divert fresh or spent fuel from Bushehr. In 2005, Russia and Iran signed an agreement under which Russia agreed to supply the reactor only with just-in-time supplies of fresh fuel and to take back spent fuel to prevent it from being reprocessed to separate plutonium.

Final agreement on the US/Russia accord was held up for nearly two years as various agencies in the US government haggled over the text and as Washington sought and won Moscow's support in the UN Security Council for several resolutions sanctioning Iran for failing to suspend its uranium-enrichment program or the construction of reprocessing-related facilities. Nevertheless, some Russia-Iran sensitive nuclear cooperation appears to have continued. US officials said that that during a March 2008 visit to Moscow by US Secretary of State Condoleezza Rice and US Secretary of Defense Robert Gates, Russian officials at the highest levels provided explicit assurances that "any sensitive cooperation between Russian entities and Iran would be stopped" (USNPAS, 2008).

US-Russian Plutonium Disposition Agreement

US and Russian officials are still working on finalizing a revised agreement governing how Russia will dispose of dozens of tons of weapons grade plutonium.

In 2000, the United States and Russia each agreed to dispose of 34 metric tons of weapons grade plutonium. However, seven years later no action had been taken on Russia's part to carry out the agreement, after Russia complained about the disposal being conditioned by US requirements and failing to be accompanied by sufficient aid. In November 2007, Washington agreed to recast the accord to reflect more closely Russian preferences on the method of disposition.

Russia has long viewed plutonium as an untapped energy resource and sought to find means to use it as part of the fuel for its planned fast nuclear reactors. These reactors when operating in "breeder" mode are capable of producing more plutonium than they burn. Russia has an estimated stockpile of 120-170 metric tons of weapons-grade plutonium, of which up to 50 tons is considered excess, including the 34 tons set for disposal. Russia has continued to accumulate plutonium extracted from nuclear weapons at the rate of two metric tons per year (Bunn, 2007; Kudrick, 2004).

The United States, on the other hand, has emphasized the arms control benefits of reducing plutonium stockpiles and the proliferation dangers of plutonium, including the threat of theft by terrorists. Initial plans, therefore, had revolved around mixing the plutonium with depleted uranium to create mixed-oxide (MOX) fuel, which Russia would burn in seven light water reactors and in the BN-600 (Kudrick, 2004). However, with its launch of GNEP the Bush administration had warmed to the idea of using plutonium as a source of energy, making the reprocessing of spent fuel to extract plutonium a centerpiece of the initiative.

In a joint statement on November 19, 2007 Bodman and Kiriyenko agreed that they would lean closer to Russia's preferences. Under the plan, the United States will cooperate with Russia to convert the Russian weapons-grade plutonium into MOX. Starting in 2012, Russia would irradiate this fuel, eventually employing at least two reactors, the BN-600 fast reactor currently operating at the Beloyarsk nuclear power plant and the more advanced BN-800 fast reactor under construction at the same site.

The statement said the two countries also intend to continue working together on development of the advanced gas-cooled, high-temperature reactor at Seversk that could also be used to dispose of the plutonium. Such reactors are viewed as more proliferation-resistant because their fuels have a high burn-up rate and their spent fuel is difficult to reprocess.

Under the plan, Russia agreed to dispose of the surplus weapons-grade plutonium "without creating new stocks of separated weapon[s]-grade plutonium." Moscow will operate the fast reactors in a "burner" mode rather than a breeder mode, by removing the breeding blanket of depleted uranium around the reactor core. Officials from the National Nuclear Security Administration, a semi-autonomous part of the Department of Energy, have said that under such a scheme the reactors will still produce plutonium as part of the reaction but consume far more plutonium fuel, thereby reducing the stockpile. Together the reactors would run through about 1.5 tons of plutonium per year.

The initial 2000 Plutonium Management and Disposition Agreement prohibited Russia from reprocessing any spent fuel from the fast reactors until all of the original 34 tons of weapons-grade plutonium had been irradiated. The new plan would continue to state that no fuel from the BN-600 reactor could be reprocessed. But it would permit 30 percent of the spent fuel from the BN-800 reactor to be reprocessed if this were done as part of the kind of advanced reprocessing program that is backed by GNEP. Other details remained to be worked out by negotiators from the two countries.

Any final agreement can be expected to meet resistance in the US Congress. Key House lawmakers such as Representative Peter Visclosky (D-Indiana), chairman of an important House spending panel, raised questions about any Russian effort that would lead to the production of new plutonium.

Under the 2000 agreement, the United States pledged to contribute US$400 million to the Russian effort. But previously, congressional and administration officials had balked at providing funds for a disposition program that involved the fast reactors rather than conventional light-water reactors. Current spending legislation does not provide funds for such an effort.

Still the US Congress has limited leverage in forcing Russia to follow its disposition preferences, given that such funds would only represent around 10-20 percent of the project's total cost.

Russia Uranium Exports to the US and Megatons to Megawatts

The nature and scale of Russia's enriched uranium exports to its largest market have been clouded by recent legislation approved by the US Congress, which in turn responded to several recent US court decisions.

The US Congress approved legislation on September 27, 2008 intended to pressure Russia to continue and expand the "megatons to megawatts" program that downblends Russian weapons-grade highly enriched uranium (HEU) to low-enriched uranium (LEU) fuel for US nuclear power plants.

The uranium legislation, drafted by Senator Pete Domenici (R-New Mexico) and included as part of a bill funding government operations for fiscal year 2009 which began on October 1, 2008, would effectively alter a February 1, 2008 amendment to the agreements that US and Russian negotiators had agreed upon in the early 1990s. That agreement was intended to govern Russia's ability, particularly after 2013, to export LEU to the United States for use in US nuclear power plants. It would eventually concede about 20 percent of the US LEU market to Russia but would not dictate whether this fuel originated as natural uranium or from weapons.

Since 1993, under Megatons to Megawatts and the 1992 suspension agreement, the United States has restricted imports of Russian LEU to uranium downblended from weapons-grade HEU. The program has downblended more than 337 tons of HEU and is slated to downblend another 163 tons before it expires in 2013. But Russia, which would prefer to take the more lucrative path of enriching natural uranium in its underused enrichment facilities, successfully challenged the restrictions at the US Court of International Trade, threatening both the current and future accords. In doing so, Russia has followed a precedent set by the European enrichment consortium Eurodif. The Eurodif case was upheld by the US Court of Appeals for the Federal Circuit in September 2007, but the Bush administration has appealed that case to the US Supreme Court, which has agreed to hear it in November 2008.

However, the Domenici legislation would appear to render the Russian legal case moot. It would provide Russia with incentives to downblend another 300 metric tons of HEU after 2013, enough for more than 10,000 nuclear weapons. How much surplus HEU Russia has is open to dispute. Russian officials have contended to their US counterparts that they would no longer have HEU available to downblend and have refused to provide a total count of such holdings, in part no doubt to preserve their weapons options. However, according to the International Panel on Fissile Materials, Russia has much more than 600 metric tons of HEU in its weapons stockpile not subject to the current agreement compared to about 250 metric tons for the United States (IPFM, 2007).

Domenici's legislation would limit Russia's export of enriched natural uranium after 2013 to 20 percent of the US market until it had reached the 300 metric-ton goal. But if Russia continued to downblend uranium at its current rate, it would grant Russian exporters as much as 25 percent of the US market. The measure also seeks to cut off Russian access to the US market if Russia abandons the February agreement.

In March 2008, US officials warned that if the court decisions were upheld without such legislation, they would affect not only the viability of the 1993 agreement but also threaten the ability of the US government to negotiate future agreements that could lead to further downblending beyond the remaining HEU already slated for conversion.

"While we are committed to facilitating Russia's transition into the US nuclear market as a commercial partner, we believe it should be accomplished in ways that advance our national security, nonproliferation, and energy interests," testified William H. Tobey, deputy administrator for nuclear nonproliferation at the Department of Energy's semiautonomous National Nuclear Security Administration.

The 1992 US-Russian "suspension agreement" was put in place after the former Soviet Union was found to have been "dumping" low-enriched uranium (the fuel for nuclear reactors) in the United States at below market prices. After such a finding, US laws call for raising tariffs on the "dumped" imports, but the tariff increase was suspended in relation to the downblended HEU in keeping with the "megatons to megawatts" agreement (US Federal Register, 1992). Other Russian uranium imports have been subject to prohibitive 112 percent duties.

US utilities and Russia atomic energy officials increasingly have chafed at these restrictions because Russia wants to eliminate the US middleman (USEC) and take full advantage of its vast uranium-enrichment capacity at a time that enriched uranium prices have risen significantly.

Russian officials have pursued both diplomatic and legal strategies to make greater inroads into the US market. Diplomatically, they have sought to ensure that they have access to the US market after the megatons to megawatts agreement ends in 2013 and that they can take the more lucrative path of enriching natural uranium rather than downblending HEU.

TENEX and Rosatom officials have said that the fixed prices for Russian LEU under the HEU deal were costing TENEX substantial revenue each year according to Rosatom and TENEX, and these losses have only increased with rising prices for enriched uranium. Such exports in 2007, for example, brought TENEX about US$759 million in revenue, but would have fetched about US$100 million more on the open market. Although Tenex and USEC, the US firm that markets the uranium in the United States, agreed on market-based terms in the middle of 2008, Russia would prefer to use any downblended uranium in its own plants and export enriched uranium. The new US legislation (unlike the current agreement) would allow any downblending, even if used for Russian reactors, to be counted against the proposed 300 metric tonne total (Rosatom, 2008a).

Russian officials appeared to have succeeded in this vein when US Secretary of Commerce Carlos M. Gutierrez and Kiriyenko on February 1, 2008 signed a pact that will allow uranium that is not downblended from weapons to begin trickling into the US market in 2011. Such imports would be permitted to constitute about 20 percent of total US imports beginning in 2014, when the megatons to megawatts agreement will have expired.

Legally, Russia and US utilities have sought to take advantage of the case involving the European enrichment consortium Eurodif to find cracks in the original antidumping judgment. In the 2005 Eurodif case, the US Court of International Trade (CIT) ruled that imports of uranium mined in other countries but enriched by Eurodif under "SWU contracts" could not be considered under antidumping law because Eurodif was just providing an enrichment service for utilities. Services, unlike goods, are not subject to duties. The international trade court's ruling was upheld in September 2007 by the US Court of Appeals for the Federal Circuit.

Russia's enrichment company won a similar judgment from the CIT in September 2007 after making a similar plea. If upheld, that judgment would have immediately freed Russia to sell to the United States uranium mined by producers such as Kazakhstan and Australia that it has subsequently enriched and with which it has nuclear cooperation agreements.

Tobey acknowledged that Russia has shown little interest in such a follow-on agreement and indicated that an effort in 2002 to strike another downblending agreement foundered on questions relating to cost and Russia's preference to use any downblended uranium to fuel its own power plants, so as to profit from the export trade.

But he said that "while we can't predict whether Russia will be persuaded to enter into a future HEU agreement, we can certainly foresee no progress in the absence of incentives."

Russia's conflict with Georgia in August 2008 may also indirectly affect this issue. The fighting has further drained Western support for Russia's long effort to join the World Trade Organization (WTO), causing Russia to say it is no longer interested in such a step. Russian officials believe that WTO membership would aid Russia's effort to overcome US antidumping restrictions.

Relations with Kazakhstan

As important as Russia's ties are with the United States, in some ways, Russia's most important bilateral nuclear relations lie with its fellow former Soviet Republic, Kazakhstan.

Since Soviet times, the two countries' nuclear industries have been complementary, with Russia converting and enriching Kazakh uranium, which is then made into fuel pellets in Kazakhstan. Their nuclear relationship looks likely to grow even closer, as Kazakhstan has set its sights on becoming the world's largest uranium producer, perhaps as early as 2010. By 2013, the country plans to open 16 new uranium mines. Russia has two joint ventures in Kazakhstan to mine 6000 tons of uranium per year. Kazakhstan is aiming to open its own conversion facilities and it has agreed to take a 10 percent share in Russia's planned International Uranium enrichment center in Angarsk, whose capacity is planned to expand from 2.6 million to 4.3 million and then almost 10 million SWU by 2015. In addition, in 2008 Kazatomprom and Tenex set up a 50-50 joint venture to expand Russia's Angarsk plan (not the IEUC) by an additional 5 million SWU/yr.

Kazakhstan plans to start construction in 2011 of a nuclear plant that will host the first two Russian VBER-300 reactors units with a total capacity of 590 MW. Together, the two countries established Atomnye Stantsii, a joint venture to design small and medium-sized reactors, such as the VBER-300 for sale to developing countries and perhaps other central Asian countries since they are cheaper and easier to build (Kassenova, 2008; Mukhatzhanova, 2007; Rosatom, 2007; WNA, 2008b).

Relations with Japan

Russia and Japan have concluded a nuclear cooperation agreement. But the two countries are waiting for the US-Russian nuclear cooperation agreement to be finalized before they sign their own accord. Atomenergoprom and its subsidiaries have signed two important deals with Japanese companies.

In March 2008 Atomenergoprom signed a general framework agreement with Toshiba under which they will explore collaboration in the civil nuclear power business. The two firms are considering cooperation in areas such as design and engineering for construction of new power plants, manufacturing and maintenance of large equipment, and the "front-end civilian nuclear fuel business." The firms said that eventually this could lead to the establishment of a strategic partnership. Toshiba owns 77 percent of Westinghouse.

In October 2006, Mitsui and Russia agreed to undertake a feasibility study for a uranium mine in eastern Russia to supply Japan with first production from the Yuzhnaya mine in Sakha (Yakutia) Republic envisaged for 2009. The partners are looking for the mine to produce 1000 tons of uranium per year by 2015. If Mitsui exercises its option to take 25 percent ownership of the project, this would represent the first foreign ownership of a Russian mine.

Relations with the European Union

Kiriyenko had expressed hope that Russia and the European Union would continue negotiations in September 2008 for lifting what he said were "hidden quotas" on Russian exports to the EU. He was referring to the 1994 Corfu Declaration, which expired in 2007 and said that was intended to limit Russian nuclear supplies to Europe to 20 percent of the EU market. The EU has mandated that it be revised, and it is often violated in practice but Kiriyenko would like it to be dropped altogether, saying it makes it difficult for Russian suppliers to conclude new contracts. "This document must be liquidated rather than revised," he said on July 29, 2008.

European nuclear officials, however, have said they do not want to give Russia greater access to their market unless they get greater access to the Russian nuclear fuel market. Christian Cleutinx, director general of the Euratom Supply Agency and leader of the European Commission's EU-Russia Energy Dialogue said in November 2008 that "what the Russians mean with reciprocity is asset swaps," where EU companies would take shares in Russian energy enterprises and vice versa. But Cleutinx said that for the EU a partnership requires "transparency for investment and unrestricted access to markets" as stipulated in the EU's Energy Charter Treaty (MacLachlan, 2008c).

Australia and Canadian Uranium Deals

The Russia-Georgia conflict also endangered the future of a nuclear cooperation agreement that Russia and Australia signed in September 2007. The pact could provide Russia with additional uranium for its nuclear power programs worth as much as US$1 billion per year. Kiriyenko said Russia is ready to process 4,000 tons of Australian uranium a year. Putin has said that Russia has "a sufficient" and even "excessive supply of weapons-grade uranium, but plans to build 30 nuclear power stations in the next 15 years and needs…Australian uranium to ensure their operation" (Pomper, 2007).

But Australian Foreign Minister Stephen Smith told the Australian parliament on September 1, 2008, that the future of the agreement would be affected by Russia's relations with Georgia. "When the government comes to consider ratification of the Civil Nuclear Cooperation Agreement with the Russian Federation, we will take into account not just the merits of the agreement, but events which have occurred in Georgia and ongoing events in Georgia and the state of Australia's bilateral relationship with the Russian Federation," according to Smith (AP, 2008).

Prodding the government, the Australian parliament's Treaties Committee urged on September 18, 2008 that uranium sales not move forward until Moscow clearly separates civilian and nuclear facilities and until the International Atomic Energy Agency can carry out inspections in Russia. Such inspections are not required under the nuclear Nonproliferation Treaty in nuclear-weapon states such as Russia.

In November 2007, Cameco signed an agreement with Russia's ARMZ. The two companies are to create joint ventures to explore for and mine uranium in both Russia and Canada, starting with identified deposits in northwestern Russia, and Saskatchewan and Nunavut in Canada.

Other Nuclear Cooperation Agreements and Reactor Exports

Russia has actively pursued nuclear cooperation agreements over the last few years with such countries as Algeria (January 2007), Armenia (February 2008), Egypt (May 2008) and Myanmar (May 2007) (Goldschmidt, 2008). On the other hand, the European Union presented Russia with a draft nuclear trade agreement in 2004, but as of 2006 those negotiations had not progressed (NEA-IAEA, 2008).

Nuclear energy exports have traditionally ranked high in Russia's overall exports, after the predominant oil, gas, and metallurgical industries. In 2001, for example, MINATOM was second only to the military industry as an exporter.

Much of Russia's nuclear exports to date have been in the enrichment and fuel services area, with such exports making up as much as two-thirds of Russian exports

(IBRC, 2003). Nonetheless, given the slow pace of reactor construction elsewhere, Sergei Shmatko, the chief executive of Atomstroyexport (ASE), the export arm of Russia's nuclear industry, claimed in 2007 that his organization was building more reactors than any of its competitors around the world with units under construction in Iran, China, and India (Kramer, 2007), although it is not certain that this claim is accurate. Likewise, Atomstroyexport recently was part of the only bid offered to build Turkey's first nuclear power plant, slated to begin operation by 2015 (Strauss, 2008). The reorganization of the Russian nuclear industry led in October 2007 to the emergence of ASE, a closed joint stock company owned by Atomengroprom (50.2 percent) and Gazprombank (49.8 percent).

Moreover, it's not clear what resources Rosatom will have for exports at a time of financial and technical limits restraining domestic construction. In the short term, Kiriyenko has said he wants to give priority to domestic reactors over exports. "Whereas one or two years ago we were glad about any foreign business offers, we now carefully choose our projects with foreign partners," Kiriyenko said. "We want to give priority to our Russian projects" (Bellona, 2007a).

But in the future, Russia aims to be a "global player," winning 20 percent of the world market and exports of US$8-US$14 billion annually by 2020 (Muzkhatanova, 2007). According to Kiriyenko, Rosatom plans to build about 60 foreign reactors within 25 years. The focus, he said, would be on South-East Asian countries because of their growing demand for energy. Given that constructing a reactor for the international market brings in around US$1.5 to US$2.5 billion, such sales may be necessary for Rosatom to come close to achieving its plans for self-sufficiency by 2015 (Bellona, 2007a).

Russia has recently signed sales agreements with China, Bulgaria, India, Myanmar (Burma), and Ukraine. ASE is also reported to be under consideration to supply Finland's sixth power reactor, and a leading contender to build two large nuclear reactors in Belarus. It is also in talks with Algeria, Argentina, Armenia, Brazil Chile, Egypt, Libya, Malaysia, Mongolia Morocco, Namibia, South Africa, Turkey, and Vietnam. (Goldschmidt, 2008; Kramer, 2007; UNIAN, 2008; WNA, 2008)

China

China has been a significant customer for Russia in recent years, having built two VVER-1000 reactors with Western instruments and control systems at the Tianwan plant in Jiangsu province and enrichment facilities.

In November 2007, Russia signed a deal to help China build its fourth gas centrifuge enrichment facility and to build two more reactors at the Tianwan plant (Bellona, 2007b).

To get those early contracts, Russia charged only US$1 billion each for the initial reactors, but Russian officials say that they are no longer willing to lower reactor prices to win contracts in China. As a Rosatom official told Russia's *Gazeta* in September 2008, "We have paid our market entry fee and we will no longer build anything in the world for free" (Gazeta, 2008).

India

Russia is cooperating with India in the construction of two VVER-100 power reactors at Kudankulam that use western instrument and control systems. Construction delays have pushed back commissioning until late 2008 or 2009. Russia delivered the first three batches of fuel for the power plant in June 2008 (RIA Novosti, 2008a). Russia claims that this cooperative activity is pursuant to a pre-1992 agreement that predated NSG guidelines requiring full-scope IAEA safeguards for such sales to NPT non-nuclear-weapon states (USNPAS, 2008). In 2007, Russia signed a memorandum of intent to build four more units at Kudankulam contingent on the NSG changing its rules vis-à-vis India, the NSG approved those changes in September 2008. On December 5, 2008 in New Delhi Russian President Dmitry Medvedev signed an agreement to provide India with the four new nuclear power plants as part of a nuclear cooperation agreement between the two countries.

In addition to the construction of the four new plants at Kundankulam stipulated under the nuclear cooperation accord, a joint declaration signed by Medvedev and Indian Prime Minister Manmohan Singh indicated an intention to construct nuclear power reactors in other sites in India and "to expand and pursue further areas for bilateral cooperation in the field of the peaceful uses of nuclear energy."

The Indo-Asian News Service quoted Russian ambassador to New Delhi Vyacheslav Trubnikov December 7, 2008 stating that Russia is "ready to build 10 more nuclear plants," should the Indian government decide to do so.

Russia's nuclear cooperation with India also involves supplying nuclear fuel for Indian reactors. Moscow has agreed to provide India with a lifetime supply of fuel for the reactors that it is constructing, as well as a five-year renewable contract to supply fuel for India's US-origin nuclear reactors at Tarapur. Russia has intermittently provided fuel for the Tarapur reactors contrary to NSG rules and US objections. Washington cut off US fuel supplies for the reactors following India's 1974 nuclear test. (Crail, 2009)

Iran

If international conditions permit, Russia is a likely supplier of additional nuclear reactors to Iran. Generally, Russia sees the Persian Gulf as a lucrative market for Russian goods, particularly as it aims to form a natural gas cartel (Goldschmidt, 2008).

Myanmar (Burma)

In May 2007, Russia signed an agreement to build a 10MW light water research reactor in Myanmar. The United States has opposed the deal, because of the nature of Burma's government and the fact that Burma only has a small quantities protocol in effect rather than a more comprehensive safeguards agreement with the IAEA.

Former Eastern Bloc

During the Cold War, exports to Eastern Europe constituted a significant share of Russian nuclear exports. There are currently 64 Soviet- or Russian-designed reactors in the former Eastern bloc, with others under construction. Yet, with the end of the Cold War, these countries lined up to join the European Union. And they came under pressure from the EU to forsake earlier Soviet-designed nuclear technology, which had been tarred by the Chernobyl accident. The EU has required countries as a condition of accession to shut down older Soviet reactors, in particular the RBMK reactors and the first generation VVER reactors. Because of this pressure there are now only three of these reactors in operation today outside of Russia, while 15 operate in Russia.

The World Nuclear Association says this requirement bowed more to political realities than safety needs. "After the Chernobyl accident in 1986, Western governments were quick to point the finger at RBMK and first-generation VVER reactors in Eastern Europe in order to emphasize the high levels of safety built into Western designs. In the emotive discussion of the late 1980s, western safety standards were taken as the unquestioned yardsticks, while in fact the more profound differences were in safety culture" (WNA, 2008a). While there is some truth to this assessment, it is also true that the RBMK reactors, in particular, had profound design flaws. These included the lack of containment structures; a "positive void coefficient" where a reactor's nuclear chain reaction and power output could dangerously increase if cooling water were lost or turned to steam; and poorly conceived control rods.

Still, despite changes in safety culture and upgrades in safety and other technology at many of the reactors, the EU has insisted on the older reactors' closure, often in return for assistance with building other reactors:

- Ukraine had to close the remaining units at Chernobyl by 2000 and Bulgaria ended up having to close four of its older units at Kodluzuy by 2006. Sofia has appealed the decision saying there was no technical basis for claiming two of the reactors were unsafe at a time when Bulgaria is experiencing significant electricity shortages. "It felt like losing family members in their prime," the plant's deputy executive director Kiril Nikolov complained to the BBC (Lungescu, 2008). Sofia's position has been largely endorsed by the IAEA and the World Association of Nuclear Operators inspectors.
- Slovakia has already closed one of its older VVER units and plans to close the other one in 2008.
- In the wake of German reunification in the early 1990s, Germany closed a recently completed East German reactor and four older RMBK reactors as well as six more modern ones under construction.

In addition, Ukraine is looking to end Russia's monopoly over its nuclear fuel supply by having a quarter of its fuel supplied by Westinghouse by 2015. In part, Kiev wants to use this possibility as leverage in price negotiations-the cost of Russian fuel to Ukraine reached world levels in 2008, but it is still considerably less expensive than Westinghouse's. But the fuel gambit is also an attempt to ensure Ukraine's energy security by diversifying suppliers. Ukrainian state nuclear operator Energoatom has been testing fuel assemblies from Westinghouse for three years and Ukraine and Westinghouse signed a contract on March 30, 2008 under which Westinghouse fuel assemblies will be delivered to at least three (and possibly four) Ukrainian VVER-100s between 2011 and 2015. The two countries have floated the possibility of establishing a joint venture for fabrication of VVER-1000 fuel. Ukraine also wants to establish a fuel reserve. In late January, Vasiliy Konstantinov, vice president of TVEL told Ukrainian journalists that his company would have to cancel warranties for its fuel assemblies if they were loaded along with Westinghouse assemblies. Russia built two new VVER-1000 units at Khmelnitsky and Rovno to replace the Chernobyl reactors and they began operating in 2004 (Breus, 2008a; WNA, 2008a).

Still, Russia has not completely lost its market in the region. Despite the developments in Ukraine, TVEL has almost squeezed out Westinghouse as a fuel competitor in the region, taking over contracts in the Czech Republic and Finland.

Indeed, Ukraine's Energy Ministry in October 2008 approved a winning bid from ASE to complete building the Khmelnitsky nuclear power plant by constructing two new VVER-1000 units. Construction of the plant's planned third and fourth reactors had been frozen in 1990 because of fears stemming from the Chernobyl accident. Russia outbid such other builders as Areva and Westinghouse for the project (Reuters, 2008; RIA Novosti, 2008c).

Moreover, Bulgaria and Russia in early 2008 signed a contract for Russia to build two VVER-1000 reactors (with a total output of 1900 MW) at Belene. Construction is expected to begin later in 2008 with the reactors to be commissioned in 2013 and 2014 (BTA, 2008). Construction of a 1000 MW reactor began in 1985, but was suspended in 1989 due to political changes. Building formally stopped in 1992, in part because of concerns over the site's geological stability. Controversy remains over whether environmental and seismic concerns have been adequately addressed (Schneider and Frogatt, 2008). Belene will be the first Russian-built nuclear power plant in EU territory.

In addition, on August 27, 2008 Kiriyenko signed a decree approving construction of an AES-2006 plant with two VVER-1200 reactors in Kaliningrad, a Russian enclave on the Baltic Sea. Kaliningrad is completely separated from other Russian territory and bordered by Poland and Lithuania. Lithuania closed its first RBMK reactor in 2005 and has agreed to close its other reactor (Ignalina-2) in 2009. Although Ignalina currently provides nearly three-quarters of Lithuania's electrical power, the government has yet to line up a replacement source of electricity and may have to rely on far more expensive Russian natural gas. Russian officials, for both political and commercial reasons, would like to eventually supply Lithuania and neighboring countries (including Germany and Poland) with electricity from Kaliningrad (MacLachlan, 2008; Schneider and Frogatt, 2008). Given their security concerns about Russia, Lithuania, Estonia, Latvia, and Poland are hoping to replace the Ignalina reactor with their own reactor in same area Visaginas, which will also be the name of the reactor (WNN, 2008b).

Constraints

Despite Russia's high ambitions for its nuclear program, a "nuclear renaissance" in Russia faces many obstacles. Continuing a tendency from Soviet days, the Russian government has shown a predilection for developing grandiose plans for the expansion of the nuclear energy sector that are not fulfilled. In many ways, these recall Soviet plans for Atommash, a plant that was to mass produce VVER-1000 reactors (eight per year), but which literally sank into the sediments of the Volga river after producing only three reactor pressure vessels.

While the first post-Soviet nuclear plans in 1992 and 1998 called for a total of 38 new nuclear reactors to be built, only three have actually been constructed since that date (Nezavisimaya Gazeta, 2007). Likewise, Russia has planned for its new generation of nuclear reactors to have capabilities that would be superior or equal to that of Western competitors, despite its past failure to meet such goals.

In the short term, Russia faces many of the same constraints as other countries in reviving its nuclear industry, from industrial bottlenecks to skilled labour shortages. As one observer put it, "Given the stagnation of Russia's nuclear industry, slow progress in reactor construction, the limited capacities of machine building plants, and recent setbacks in NPP [nuclear power plant] construction abroad, the targets and optimism concerning large scale construction of NPPs [nuclear power plants] inside and outside of Russia appear unwarranted" (Mukhatzkhanova, 2007).

In the longer term, it is highly questionable whether Russia has the financial resources and technical capabilities to be able to meet its goals to both rapidly develop new reactors and foster a fully self-sustaining nuclear industry by 2015, especially as Russia will have to decommission a large number of aging Soviet nuclear reactors and deal with the growing problem of nuclear waste. Indeed, some analysts have noted that if Russia does not fulfill its ambitious construction plans, it may well produce less nuclear electricity in 2020 than today (Schneider and Froggatt, 2008). And Russia's hopes of building a commercially viable closed-fuel cycle by 2020 also seem likely to be unrealized.

Russia will have to struggle hard to staff an expanded nuclear industry. Russia's recent economic good fortune and the transformation of Rosatom have benefited nuclear energy industry employees, particularly high-level managers who saw their salaries double or more. Rosatom has also created special subsides for younger workers and the government recently announced a plan to encourage the study of nuclear physics and engineering and unify several dozen educational and research institutes into a single national nuclear university. Such efforts have already helped lower the average age of nuclear industry employees from 53 to 48 years old (Nikonov and Khripunov, 2008).

But the industry essentially lost an entire generation of potential nuclear engineers and high-level managers during the lean times of the immediate post-Soviet years. The economic crises slashed funding to higher education and the military – the institutions that made science so prominent and prestigious in the Soviet Union. By the beginning of the 21st century, science was one of the least prestigious institutions in Russia and junior researchers were making less than US$30 a month. The result was a graying of Russia's nuclear complex even beyond those in the West. As Igor Khripunov noted, "As mid-level scientists left for non-science jobs or emigration and many bright young people failed to embrace scientific careers, research teams grew old" (Khripunov and Katzva, 2002).

Similarly, the number of people available to carry out related specialized skills, such as nuclear construction has declined at a time when the nuclear industry must compete aggressively with other industries for skilled workers.

Moreover, it is not clear that Russia has overcome the safety and environmental errors that caused catastrophes in the Soviet era, addressed its problems with spent fuel, or structured its industry to provide adequate security for nuclear materials and facilities in the post-Soviet era.

Technical Capabilities

Reactors: Capable of Proposed Capabilities?

Russia has called for its new reactors to have impressive capabilities, some of which do not seem readily attainable. These include:

- *Producing electricity at a cost of no more than three US cents/kilowatt hour.* A 2003 MIT study said that only with vast improvements could current costs of almost seven US cents/kilowatt hour be reduced to the equivalent of 4.3 US cents per kilowatt hour (MIT, 2003). Although Russian officials claim that construction efficiencies and lower labour costs would allow them to achieve such gains, this target will be difficult to meet.
- *Capital costs under US$ 1000/kilowatt hour.* This number seems too optimistic. To be sure, Russia is likely to face fewer regulatory costs and perhaps lower construction costs. Yet, Moody's, the risk rating agency, has said that "costs associated with the next generation of nuclear build in the United States could be significantly higher than the approximately US$3500/kilowatt hour estimates cited by many industry participants." Indeed, Moody's low estimate for new nuclear capacity in the United States is US$5000 kilowatt/hour and its high estimate is US$6000/kilowatt hour (Moody's, 2007).
- *Service life of at least 50 years.* Russia's current reactors are only designed for a thirty-year life; Western reactors are only designed to last 40 years, although some have sought lifetime extensions. This seems like an achievable target.
- *Utilization rate at least 90 percent.* Western reactors have only just reached this level. Russian reactors have only just reached around 80 percent (Rosatom, 2008c). In the long run, this target seems achievable, but it is not clear how long it will take Russia to meet this goal.

Lack of Large Forgings

Like most other major nuclear energy suppliers, Russia is likely to be constrained in the short-term by some manufacturing bottlenecks, such as limits on large (ingots of 180 to 250 metric tonnes) and ultra-large forgings (350 to 600 metric tonnes) needed for reactor pressure vessels, heavy piping, and steam generators that form the primary coolant circuit in its nuclear reactors.

As one Russian analyst put in an online chat on the Rosatom website, "Unfortunately, the low technical capacities of our machine building industry deter the development of the nuclear sector. Today our demand for new reactors is twice as big as the offer" (Podlevsikh, 2008).

For large and ultra-large forgings Russia relies on OMZ and its Komplekt-Atom-Izhora facility. In 2008 the company began reconstructing its 12,000 tonne hydraulic press, said to be the largest in Europe, and a second stage of work is designed to increase that capacity to 15,000 tonnes. OMZ said in October 2007 that it would double production of large and ultra-large forgings for the VVER-440, VVER-1000, and VVER-1200 reactors from the current rate of two per year. It claimed that it would produce enough other nuclear-related equipment to provide for at least three reactors per year by 2011 and four per year from 2016. However, some critics have said that Russia's actual reactor equipment production rate is far lower. And in any case, it is not clear if Russia's reactors would be suitable for export-that is, capable of winning requisite technical quality assurance certifications from the American Society of Mechanical Engineers. This process can take five to fifteen years (Marshall, 2008; Slivyak, 2008; WNN, 2007).

Two other facilities may have a limited capability to produce additional reactor pressure vessels and other components for the Russian and other markets. Several years ago, OMZ acquired Skoda Power, the division of the Czech industrial giant Skoda that produced reactor equipment during the Soviet era. Prior to the collapse of communism, this plant produced 21 VVER-440s and 3 VVER-1000s. It still produces parts and equipment for existing VVERs and is exploring the prospect of beginning production of components for new reactors (Skoda, 2008).

And then there is the distant possibility of reviving Atommash. After its colossal failures during the Soviet era, this facility was purchased by heavy industry giant Energomash and rehabilitated to produce heavy equipment, particularly for the oil and natural gas industries.

Financial Limitations and Foreign Investment

At the same time that the government has drawn up these ambitious plans, it has also begun to acknowledge some fiscal realities. In September 2007, a government plan said that the government would only have the financial wherewithal to build two (as opposed to three or more) 1200 MWe units annually from 2012-2020. The third units for 2015 and 2016 were re-designated as "proposed." At the other extreme, Russian planners laid out a "maximum scenario," that included as many as five VVER-1200 reactors being built in the 2016-2020 timeframe (WNA, 2008b).

To meet some of the costs, Energoatom has been trying to convince Gazprom to invest in some of the partially completed plants, arguing that their operation will offset natural gas usage and help Gazprom export more gas. Some new plants are designated to help power Gazprom's work, such as an additional plant at Kola near Murmansk, which will have as its primary purpose the development of the Shtokman field, a major oil and gas find located under the arctic waters of the Barents (Digges, 2008).

In February 2008, the Russian government also charged Rosatom and the Ministry of Energy with developing a plan for attracting investment (including foreign investment), with foreign companies being allowed to own up to 49 percent of any joint ventures (WNA, 2008b). In June 2008, Kiriyenko said "we have to overcome a bias, break stereotypes, and reaffirm to all suppliers that the Russian nuclear market is open to competition." According to Kiriyenko, Rosatom was particularly interested in foreign investment in uranium mining, nuclear power plant equipment manufacturing, and development of the proposed Kaliningrad plant. Such investments will not be profitable until electricity rates are raised. Comparing estimated electricity costs in Russia to the results of a recent US report (Keystone, 2007) that the lifecycle levelized costs of electricity from a new US nuclear reactor would amount to about 8-11 US cents (2-3 roubles) per kilowatt hour, while Russian customers pay only 1.65 roubles per kilowatt hour for electricity (Keystone, 2008; Slivyak, 2008).

Russia has already taken some steps in this direction, particularly in the mining arena. It has also established a 40 billion ruble joint venture between Atomenergomash (the Rosatom subsidiary responsible for nuclear plant equipment production) and the French turbine maker Alstom, which will build a plant to manufacture Alstom's turbines to run with VVER reactors. On September 29, 2008 the partnership signed its first contract: an agreement to design the turbine generator package for a new AES-2006 2400 MWe power plant at Seversk which will comprise two 1200 VVER 1200 reactors. Russian analysts portrayed this as an opportunity to gain access to more advanced technologies. Foreign nuclear companies, however, remain skeptical of the degree to which Russia will truly permit them to compete (MacLachlan, 2008a, WNN, 2008c).

The recent global financial and economic crisis, which has hit Russia's financial reserves markets, and economy particularly hard, is also likely to slow financing for nuclear energy as well as demand for electricity. A top Atomenergoprom official told Russian media outlets in late November that Rosatom might amend its plans for future nuclear plant construction to take account of the changes. According to the reports Polushkin claimed that Russia would stick to Rosatom's earlier minimum plan of putting two reactors per year into operation until 2010 (DOE, 2008b).

Nuclear Environmental, Security, Safety, and Legacy Costs: Continuing a Policy of "Deferred Decisions?"

When it was unveiled, Russia's 2007 nuclear plan called for spending 150 billion rubles (over US$6 billion at current rates), on decommissioning, nuclear safety, security, reprocessing, spent fuel and other non-construction and operation costs, but this part of the Russian budget has perennially fallen short of planned expenditure. The money would go toward facilities to treat spent nuclear fuel and radioactive waste, including the construction and refurbishment of storage, reprocessing, and transport capabilities (ITAR-TASS, 2008). For instance, Kuznetsov has estimated that Russia has only spent one-eighth of what it said it would in its plan for the period 2001-2006. Similarly, Igor Khripunov estimated that the Russian government allocated only about 10 percent of the funds that it had planned to spend on the management of spent fuel and radioactive waste in the period 1996-2000. (Kripunov, 2002; Kuznetsov, 2007:33).

More recently, Russian officials have published a concept paper (Russia, 2008) with three options for spending on these activities until 2015:

1. A strategy of deferred decisions: these plans would continue current spending levels, leading to total spending of about 60 billion rubles (US$2-US$3 billion) and would concentrate primarily on "urgent measures to prevent accidents at nuclear and radioactive facilities/sites;"
2. A strategy for development: this plan would lead to total spending of about 132 billion rubles (about US$5 billion); and
3. A strategy of intensive problem solving: a more accelerated version of option 2 with planned spending of about 210 billion rubles (US$9 billion).

Rosatom officials have said they support option 2 in which "sound research, design, and exploration and development activities" help to minimize budget expenditures (Russia, 2008). This option would focus on establishing the basic infrastructure for the management of spent nuclear fuel and radioactive waste, thus reducing growth problems in this area. Almost 50 billion rubles (about US$2 billion) would go toward the establishment of a pilot advanced reprocessing facility, the creation of a pilot deep geologic spent fuel repository in the Kansko- Achingkogo array (in the Krasnoyarsk region); a subsequent final determination of the feasibility of isolating radioactive waste in underground facilities; the establishment of an interim storage facility for holding 38,000 tons of spent fuel, and other means of isolating or burying waste.

Another nearly 80 billion rubles (US$3 billion) would be spent on dealing with the legacy of the Soviet and Russian nuclear programs, including such tasks as dealing with the accumulated volume of spent fuel from Russian-built research reactors; improving physical protection of and accounting for nuclear and radiological materials, including those in transit; rehabilitating radioactively contaminated areas; improving emergency response, continuing production of drugs aimed at preventing radiation sickness such as iodine, and rebuilding medical institutes to assist with radiation accidents.

The third option would seek to establish the necessary conditions and mechanisms to assure nuclear and radiation safety for the long term and attempt to resolve many of the issues by 2015. Measures on spent nuclear fuel and decommissioning of nuclear facilities were expected to be sent to the Duma in 2009.

Lifetime Extensions and Decommissioning

Russia's reactors are antiquated, with an average age of 25 years, only five years short of their planned lifetimes (Schneider and Froggatt, 2008).

Russian reactors are generally licensed for 30 years from when they begin operation. In 2000, plans were announced for extending the lifetime of 12 first-generation reactors (including four RBMK reactors) producing a total of 5.7 GWe. So far, 15-year extensions have been attained for three reactors. The reactors are expected to remain in service until 2015-2020. In addition, two very small reactors, Bilibino-1 and -2 have been granted five-year extensions, only until 2009.

Of particular concern to some EU countries are plans for extending the life of RBMK reactors. In 2006, Rosatom said it was considering lifetime extensions and upgrading for all of its 11 operating RBMK reactors. It claimed that given significant design modifications carried out after the Chernobyl accident, as well as extensive refurbishment, a 45-year lifetime is appropriate for the remaining models. Left unsaid was the fact that these units provide about half of Russia's nuclear-generated electricity. Russian officials are looking for a 20-year extension for Leningrad-3, whose refurbishment is already underway, as well as for Leningrad-4. The Kursk-3 and -4 and Smolensk 1-3 reactors may get similar extensions (WNA, 2008b).

Experts say that if these reactors are to be upgraded, significant changes will be needed, as most of the reactors only had to comply with safety requirements from the 1980s. As one expert, Vladimir Kuznetsov said, "In order to comply with the modern requirements, these power units need upgrading. It is critical to solve a number of safety issues, such as shell containment improvement, management system efficiency, control and energy supply, steam generator resources improvement, and sufficient diagnostic equipment." The significant safety upgrading of Lithuania's two RBMK reactor units at Ignalina demonstrates that such safety upgrading is feasible. While no RBMK can ever reach Western standards, their safety can be improved in a major way if Ignalina's program is followed (Budnitz, 2008; Kuznetsov, 2007:26).

Even if Russia does successfully extend the life of these reactors, it will not be too long before they will have to be decommissioned. There are no reliable estimates for the costs of decommissioning Russian plants. But five Soviet VVR-440 reactors built at the Greifswald plant in East Germany were decommissioned over a 10-year period at a cost of US$3.5 billion (Popova and Menshchikov, 2007).

Other outside estimates provide a lower cost estimate of US$1.6 billion over the 15-year period 2005-2020.

Already five civil reactors are being decommissioned. Four of the reactors were shut down in the 1980s and await dismantlement. In addition, the three shut plutonium production reactors need to be decommissioned.

Safety Culture

Historically, Russian nuclear regulators have been largely toothless. After Chernobyl and the end of the Soviet Union, the new Russian government established the State Committee for Nuclear and Radiation Safety-Gostaomnadzor (GAN) that reported directly to the president. This agency was responsible for licensing, regulation, and operational safety of nuclear facilities, and for regulating the safety in transport of nuclear materials and their accounting. But on the few occasions when it suspended operating licenses, the government's nuclear industry overrode this. Furthermore, in 2004, GAN went from being an independent agency reporting directly to the president to only a small part of a much larger agency, which regulates nearly all safety and environmental issues in Russia, the Federal Technological and Atomic Supervisory Service: Rostechnadzor.

As Matthew Bunn has said, "This step made it much more difficult for nuclear safety or security issues to percolate to the top of the Russian government, or for nuclear regulators to get the visibility they need to push for more budget, more people, more authority, and so on" (Bunn 2008).

In May 2008, Rostechnadzor was absorbed into the Ministry of Natural Resources, putting another bureaucratic layer between the nuclear regulators and the top of the government. It is still not clear who has authority to approve key decisions. Initially, all new and modified nuclear regulations had to be approved by the ministry. That has raised concerns, Bunn said, that "Rosatom may be able to go over Rostechnadzor's head and get the ministry to approve Rosatom-favored versions of new regulations without Rostechnadzor being able to do much about it" (Bunn, 2008).

To be sure, some of the problems that led to Chernobyl-both design and human errors and more mundanely, poor operating performance, seem to have improved, thanks in part to Western assistance. The nuclear industry now provides monthly reports on nuclear incidents and informs local, regional, and national officials immediately of any significant accident. And these numbers appear to have declined (Josephson, 2002).

The IAEA's International Nuclear Event Scale (INES) is a system (from 0-8) establishing the safety significance of nuclear incidents. In 1993, there were 29 events level 1 or higher; in 1994, there were nine; and between 1993 and 2003 no more than four (WNA, 2008b). Similarly, by 2004, the number of unplanned power unit disruptions was only a quarter of what it had been in immediate post-Soviet years. Mechanical errors especially had dropped sharply.

Nonetheless, Russia's operating and safety performance continues to suffer from unusually high levels of human error. For example in 2004, personnel errors represented a significant portion of the failures at Russian plants, particularly RBMK reactors. In 2004, 34 percent of failures were due to personnel, 25 percent due to construction, and 39 percent due to mechanical failure. And accident figures for transport are two to three times higher than in other industrialized countries (Kuznetsov, 2003; Kuznetsov, 2007).

The Russians are making progress, but remain behind the West in their safety-improvement programs at the reactors, in how their operational methods assure safety, and in how their regulatory agency functions (Budnitz, 2008).

Nuclear Liability Issues

The Chernobyl accident was a wake-up call to both Russian and international nuclear authorities concerning liability for nuclear accidents, particularly those like Chernobyl that could affect neighboring countries. But it is a call that has only been partly answered by Moscow. And that worries potential business partners in the Russian nuclear energy industry.

At the time of the Chernobyl accident, Russia had no specific legislation in place that entitled victims in Ukraine, Belarus, and Russia to compensation for radiation and other damage. Nor were there any international liability and compensation regimes to which the Soviet Union belonged under which victims in neighboring countries could claim appropriate compensation. Eventually, Russia passed specific ad hoc legislation to compensate the Chernobyl victims (Matveev, 2006; Schwartz, 2006).

In the post-Soviet era, Russia has put in place four pieces of legislation affecting civil liability for losses and damages caused by radiation:

- 1994 Civil Code of the Russian Federation;
- 1995 Federal Law on the Use of Atomic Energy;

- 1997 Government Resolution on Provisions for Licensing of Activities Involving the Use of Atomic Energy; and
- 1963 Vienna Convention on Civil Liability for Nuclear Damage (ratified in 2005) (Pronkin,2008).

These measures, particularly the ratification of the Vienna Convention, brought Russia closer to international standards in this area. The convention places strict and exclusive liability on nuclear operators for accidents but places a financial ceiling on their liability. The host government is usually expected to cover any additional costs above this ceiling.

But by the time Russia had ratified the treaty, some of its provisions were considered outdated, such as its low US$5 million minimum nuclear operator's liability. Moreover, Russia has not yet approved legislation implementing the treaty (although it was being considered by the Duma in 2008) nor has it approved two 1997 measures intended to buttress it: a protocol commonly called the VC protocol and the Convention on Supplementary Compensation for Nuclear Damage (CSC). The protocol would require that more money be set aside to compensate victims, it would compensate victims outside of the territory of the accident, and it would cover a broader range of damage. The supplementary measure would create a pool to which various national governments would subscribe to provide compensation that exceeded certain levels covered by operators and host states (Schwartz, 2006).

In some ways, the fact that Russia did not sign the 1997 treaties is not surprising-only a handful of states have done so and the United States only ratified the CSC last year (Schwartz, 2006). But because of Russia's past safety problems and murky legal atmosphere, international firms that might supply equipment and technology to Russia are likely to demand a higher level of legal security for participating in the Russian nuclear sector than they might in other countries. In particular, they fear that the Russian government will not compensate victims beyond what operators are required to pay, leaving suppliers, contractors and others liable to lawsuits by Russian or other victims.

As the counsel for a group of major US contractors wrote in a letter to senior Bush administration officials, calling for them to push Russia to ratify the CSC and a new domestic nuclear liability law:

> The various bilateral and multilateral indemnity agreements that have been concluded to date are not considered to provide adequate nuclear liability protection by most large, well-capitalized US companies. No such agreement yet has provided a definite or comprehensive solution to adequate protection of the public in the event of a large nuclear incident or to the nuclear liability risks facing contractors (Brown, 2003).

Nuclear Security Issues

All Russian nuclear plants are protected by internal police (MVD troops), as are most nuclear weapons research and production sites. The formal seriousness with which Rosatom and the Russian government takes security concerns is evidenced by a July 19, 2007 resolution (No. 456) on "Russian Physical Protection Regulations for Nuclear Material, Nuclear Plants, and Storage Sites for Nuclear Material," which replaced decade-old regulations governing the same field (No. 264 of March 7, 1997). This required inter-governmental approval, giving it high legal status.

Alas, there is a gap between what is prescribed in regulations and actual compliance. Experts attribute that to a failure to inculcate an appropriate nuclear security culture for the post-Soviet era. Managers have eliminated some of the old heavy-handed ways, but not found new, more effective ways of managing or motivating employees. Moreover, the government has had little interest in putting sufficient funds into security upgrades and modernization. And nuclear industry employees are susceptible to the same forces of corruption and indifference to the law ("legal nihilism") that afflict Russian society generally (Khripunov, 2004).

Indeed, the Russian public's attitudes to the problems of nuclear security and potential related nuclear terrorism are complex and somewhat contradictory. And these contradictions are demonstrated in public opinion polls. For example in the 2005 IAEA Survey, while 63 percent of Russians said they saw a high risk of nuclear terrorist acts because of insufficient protection, the second highest of any country (only Japan was higher, only 56 percent of Americans and 50 percent of Canadians expressed similar views). Yet in a December 2005 poll by the Moscow-based Levada Center, which asked respondents to name several threats to their country, terrorism per se did not make the list of 24 threats (although it may have been subsumed under the general category of crime), with economic problems and crime rates topping the list. This contrasts with a general trend described in the IAEA survey where terrorism or war represented as great a source of worry or insecurity. As Igor Khripunov explained, "They seem to find other, personal threats more compelling than nuclear terrorism… Unless a catastrophic terrorist event shifts public priorities, these everyday concerns will have a stronger claim on public attention and funds than the more abstract, albeit apocalyptic, menace of nuclear terrorism" (IAEA, 2005; Khripunov, 2007:21-22).

The 2008 change of Rosatom's status from a government ministry to a state-run corporation has raised additional security and nonproliferation concerns. Of particular concern is the fact that the state corporation will also have control over Russia's nuclear weapons complex. Some fear that commercial imperatives will trump security and nonproliferation concerns, particularly given Rosatom's future need for financial self-financing. There is a particular concern that the Russian government will be reluctant to continue paying the costs of the tight security measures that had formerly "closed" many of Russia's nuclear cities to those outside of the nuclear complex (Khripunov and Fernandez, 2008).

The planned floating reactors come with their own set of unique security and safety concerns. For example, will nuclear forces be required to provide adequate security for them? What if there is, for instance, a storm at sea and the reactor's cables come loose threatening the electricity supply needed to operate the reactor? (Slivyak,2008).

Spent Fuel and Reprocessing

Russia has never had a coherent policy on how to deal with its spent fuel. It has allowed spent fuel to nearly fill spent fuel ponds at its reactors, while at the same time attempting to reprocess other spent fuel (IPFM, 2007; Nikitin, 2008). Russian officials have also publicly discussed means of financing reprocessing and spent fuel storage, including establishment of a fund collected through fees on nuclear electricity kilowatt-hours (MacLachlan, 2008).

It has also shifted policy dramatically on how it will deal with other countries' spent fuel. At the turn of the twenty-first century, desperate for foreign exchange, Russia saw the importation of spent fuel from Asia as a potentially highly lucrative endeavour. As Russia's economy improved, Russian officials have increasingly played down this option.

All of Russia's spent fuel policies, so far, have continued to rely on the assumption that Russia will ultimately reprocess its spent fuel and burn the resulting product in sodium-cooled fast reactors. Whether such an approach is technically and financially feasible is open to question. For example, a senior US Department of Energy official recently said that such reactors cost 30 percent more to construct than traditional light-water reactor (Lisowski, 2008).[1] And that leaves aside the fact that it is unproven technology, which in its research phase, and has historically been plagued by accidents.

Spent Fuel Generation

Russia's current reactor fleet produces the following amounts of spent fuel annually:

Table 2: Russia's Growing Spent Fuel Stockpile

Reactor Type	Fuel assemblies	Uranium (in tonnes)	Spent Fuel (in tonnes)
VVER-440	120	14	120
VVER-1000	55	25	150
RBMK	450	58.5	

Source: IPFM, 2007.

The RT-1 reprocessing facility at Mayak is supposed to reprocess annually from 400 tonnes of spent fuel from VVER -440 reactors (93 percent) and the BN-600. However, the facility is in poor condition and only manages to reprocess as little as 80 tons each year. Plans to upgrade the plant so it could also take VVER-1000 fuel were approved and were to be completed in 2008, although it is not clear that this has been accomplished. Upgrading it would require at least US$1 billion (Nikitin, 2008; WNA, 2008b).

At present used fuel from RBMK reactors is stored and not reprocessed.

Russian officials in 2006 proposed that as part of Putin's GNII and the IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycle (INPRO) that they build a pilot International Fuel Treatment Center (INFC). This "new technological platform" would include the BN-600, a pilot advanced pyroprocessing facility at Mayak that would separate plutonium together with minor actinides, and MOX fuel fabrication facilities constructed by the Research Institute of Atomic Reactors at Dimitrovgrad in Central Russia.

The eventual goal would be to build a full-scale reprocessing plant with capacity for up to 3,000 tonnes/year in 2020-2025 period at Mayak or Beloyarsk; a 60 tonne/year commercial MOX fabrication plant at Zheleznogorsk in Siberia; another MOX plant for disposing of military plutonium at Seversk in Siberia, using the same design as a US plant under construction at Savannah River in South Carolina; and burning the MOX fuel in the BN-800 and

[1] Lisowski is deputy assistant secretary of energy for fuel cycle management at the US Department of Energy.

the planned BN-1200 reactors, as well as potentially some light water reactors. Already, Russia has more than 40 tonnes of separated civilian plutonium (MacLachlan and Horner, 2006; IPFM, 2007).

An RT-2 reprocessing plant at Zheleznogorsk which was planned decades ago, but not completed, has been cancelled and is to be dismantled. Its technologies are already outdated and completing it would require another US$4 billion, according to experts (Nikitin, 2008; WNA, 2008b).

In the meantime, spent fuel continues to accumulate in cooling pools at reactor site at levels beyond engineered capacities. Analysts have estimated that without policy changes, 50,000 tonnes of spent fuel from reactors in Russia and abroad will continue to pile up, constituting about 10 percent of the world's entire quantity of spent nuclear fuel (Ponomareva and Digges, 2008; US NPAS, 2008; Kudrick, 2008).

By January 2006, there were 18,500 tonnes of spent fuel in Russia with 12,000 metric tons of spent fuel at reactors (IPFM, 2007; Kuznetsov, 2007).

In 2005, Russia approved construction of an 8600 tonne dry storage facility for used fuel at Zhelesnogorsk. The facility is supposed to be completed in 2010 at a cost of about US$500 million (WNA, 2008b) and initially will take RBMK fuel from the Leningrad and Kursk power plants. In the meantime, well above the engineered capacity of 6000 tonnes of VVER-1000 fuel has been placed in wet storage at Zheleznogorsk (Ponomareva and Digges, 2008). The Russian government has plans to increase capacity to 36,000- 38,000 metric tonnes; this includes 26,500 metric tonnes for RBMK fuel and 11,275 tonnes for VVER-1000 fuel. However, construction stopped in April 2008 because of insufficient funding, in particular a failure to fully account for inflation in paying contractors; Rosatom announced a new tender for the contract on July 2, 2008, with the winner set to be announced the following month (Ponomareva and Digges, 2008).

The Russian government claimed in 2001 that it would have a permanent repository operational by 2020 in the Nizhnekamsk granitoid range in Krasnoyarsk Territory, at a claimed cost of US$100 million (compared to Yucca Mountain at US$50 billion), but no progress appears to have been made on establishing such a site (Kudrick et al., 2004). Recently, Rosatom Deputy Director Yevgeni Yevstratov said Rosatom hoped to table terms of reference for the facility by 2015 with a decision regarding construction made by 2025 and the facility itself completed by 2035 (Nuclear.ru, 2008a).

Spent Fuel Imports

At the height of Russia's economic crisis of the late 1990s, Russian officials had looked at the possibility of storing and probably reprocessing as much as 20,000 tonnes of foreign spent fuel, particularly from South Korea and Taiwan, as a means of earning much needed revenue. Minatom officials had estimated that such imports could bring in as much as $US20 billion (Einhorn, 2008; Ingram, 2006; Bleek, 2001). To facilitate this option, the Duma in 2000 agreed to amend a law which had previously banned the import of spent fuel or nuclear waste for storage or disposal in Russia (fuel could be imported for reprocessing with return of the resulting wastes). Hungary, Finland, Bulgaria, Slovakia, and Ukraine had shipped about 100 tonnes of spent fuel to Russia for from 1992-2003, providing Russia with revenues of about US$200 million annually (Bunn et al., 2001; Kudrick, 2004).

Near the end of the Clinton administration, the United States and Russia had reached agreement in principle on a deal in which, after the conclusion of a nuclear cooperation agreement, Russia would abide by a 20-year moratorium on reprocessing, the United States would provide help with dry cask storage for spent fuel as well funding for joint research and development on a "proliferation-resistant" nuclear fuel cycle. This agreement never came to fruition (Bunn et. al., 2001).

However, with Russia's economy now booming thanks to soaring oil and gas revenues and concerned by the growing amounts of spent fuel on its territory, Rosatom officials in July 2006 declared that Russia would not import foreign spent fuel other than the VVER-440 and VVER-1000 spent fuel it receives under existing contracts with Ukraine, Bulgaria, and other countries.

Rosatom chief spokesman Sergey Novikov also said Russian officials concluded that accepting such fuel would leave Russia with "huge financial liabilities." He added, "Now people understand that it's impossible to calculate the real price for storing foreign spent fuel. We can take it for 60 or 70 years, but what will happen in 100 years? Nobody is able to calculate these expenditures" (MacLachlan and Horner, 2006).

In fact, in new reprocessing contracts with foreign customers Russia has required that it would not accept spent fuel for permanent storage but would only be willing to hold it while it separated out the plutonium.

This has little appeal, according to some experts with the International Panel on Fissile Materials, "Because of the rising price of Russia's spent fuel services, however, and Russia's requirements under new reprocessing contracts to ship back the vitrified high-level waste from reprocessing, remaining customers are making other plans-building dry cask storage" (IPFM, 2007:98-99). In January 2008, Bulgaria and Russia agreed that after reprocessing high-level nuclear waste would be returned to Bulgaria (IPFM, 2008; ITAR-TASS; 2008; BTA, 2008a). Rosatom only charges the equivalent of US$60 a kilogram for reprocessing domestic spent fuel, while foreign partners pay US$360 per kilogram of spent fuel.

Russian officials have held out the possibility that they might accept broader imports of spent fuel in the future. They have indicated that they might be willing to accept spent fuel from future reactor customers if such a stipulation is included in the sales contract. They contend that taking back fuel that originated in Russia would incur less domestic opposition than accepting foreign-origin fuel (Bunn et. al., 2001; USNPAS, 2008).

Reprocessing and Reenriching Uranium Tails, Foreign and Domestic

Russia has been unique in its eagerness to reuse uranium reprocessed from spent fuel or depleted of its U-235 isotope by the enrichment process. Currently Russia and France are the only two countries to reprocess uranium from spent fuel (NEA-IAEA, 2008).

Some 2500 tonnes of uranium from VVER-400, fast neutron, and submarine reactors has so far been recycled in RBMK reactors (WNA, 2008b).

Tenex has been re-enriching uranium tails for the European enrichment consortium Urenco and for Eurodif, the enrichment group based in France. This had drawn public opposition: some 20,000 residents of Irkutsk called on Putin to stop uranium shipments from Western Europe. Tenex has contracts to continue such re-enrichment with Urenco until 2009 and with Eurodif until 2014. Yet, in 2004 Kiriyenko said that the contracts will not be extended, and perhaps end as early as 2009. Already, the shipments have tailed off from the equivalent of 1050 metric tonnes of natural uranium in 2003 (nearly eight percent of such European uranium supplies) to 700 tonnes in 2007 (little more than three percent) (NEA-IAEA, 2008).

"We took this for reprocessing because it was economically profitable," Kiriyenko said in Murmansk in June 2008. "But given the chemical dangers of fluorine, we have decided to cease these imports after the international contracts expire" (Kireeva and Digges, 2008).

The Bellona Foundation environmental group says that very little of the imported depleted uranium hexafluoride has been enriched and the tails should rightly be considered nuclear waste (Alimov and Digges, 2008; Kireeva and Digges, 2008).

Environmental Issues

Russian environmentalists fiercely oppose all proposals for importing spent fuel from abroad, supported by international environmental groups such as Bellona and Greenpeace and apparently by public opinion. Polls commissioned by environmental groups have claimed that 92 percent of Russians are opposed to spent fuel imports (Digges, 2008). In 2001, environmental groups organized a national petition drive that gathered 2.5 million signatures calling for a national referendum on the waste proposal. Russian law required that if received two million signatures, it would be put on ballot. However, Russia's Central Election Commission invalidated 600,000 signatures through technicalities, putting it below the necessary threshold (Bunn et. al, 2001).

In addition, grassroots campaigns in the Krasnoyarsk region near Zehleznogorsk repeatedly stymied attempts to complete the RT-2 reprocessing plant. It was commissioned in 1985 but halted by protests in 1989. Then Russian President Boris Yeltsin again ordered its completion in 1994, but in 1997 a petition in the region collected 100,000 signatures in favor of putting the issue to a referendum. As Minatom lacked the funds to complete it, the reprocessing plant became somewhat of a moot issue until recently, when Russia was said to have cancelled the plant (Bunn et. al, 2001).

While the Chernobyl accident focused attention on the Soviet nuclear industry's poor environmental record, its problems went well beyond that one incident and those problems continue. As Paul Josephson, a historian of Russia's nuclear program noted in 2002, Russia's nuclear energy industry still boasts, "the same willingness to minimize risks, ignore dangers, and embrace radioactive waste that produced the worst of Russia's and Ukraine's environmental degradation" (Josephson, 2002).

Russia's 1170 radioactive waste storage sites account for almost half of the radioactive waste in the world (Popova and Menshchikov, 2007), but Russia has had no coherent policy for dealing with it. Rosatom's deputy director-general Yevgeny Yevstatov said at an April 2008 conference in St. Petersburg that Moscow was planning to send a draft law to the Duma on radioactive waste treatment. The measure would clarify legal authority over the waste, giving the state exclusive ownership and increasing the producer's responsibility for waste storage.

In Russia's closed nuclear cities, waste storage areas, and test sites, death rates from leukemia, lung cancer, and thyroid cancer are as much as seven times higher than elsewhere (Josephson, 2002).

The area near Mayak Chemical Combine in Ozersk is considered the world's most radioactively contaminated site. Mayak (formerly known as Chelyabink-65) facilities were used for weapons for the first Soviet plutonium bomb. Thousands of square kilometres have been contaminated after such incidents as the notorious 1957 Kyshtym accident, the world's second largest radiation catastrophe, when the failure of the cooling system for a tank storing many tonnes of dissolved nuclear waste resulted in a non-nuclear explosion estimated at about 75 tons of TNT (WNA, 2008). That accident killed 200 people and contaminated 50 by 300 square kilometres with highly radioactive strontinum-90 (Kudrik, 2004; Khripunov and Fernandez, 2008). In addition, the area was contaminated by wide-spread dumping of wastes into local rivers and lakes. All told, a nearly 25,000 square kilometre area is believed to be contaminated and has been marked off as the Eastern Urals Radioactive Trace. At least 200,000 people have suffered from radiation exposure in the Chelyabinsk Oblast (region) (Krasnoslobodtseva, 2008).

Seversk Chemical Combine, another major cold-war plutonium producer, has been Russia's most dangerous sources of radionucleide contamination of underground and surface waters.

There have been particular problems at Russia's fuel cycle facilities (Kuznetsov, 2007).

In 2003, GAN temporarily blocked the extension of Mayak's license to reprocess because it was continuing to dump liquid nuclear waste into the environment. The plant was upgraded on the condition that it put in production technology to stop this. Nearly all nuclear power plant sites are contaminated (Josephson, 2002).

Public Views

Given Russia's poor record, public skepticism surrounding nuclear power is not surprising.

Indeed, a "Chernobyl syndrome" continues to pervade the Russian psyche, which Igor Khripunov has described as "an across-the-board distrust of information from government sources coupled with popular anxiety about the safety of nuclear technology" (Khripunov, 2007). The Russian public also lags far behind those of other major nuclear energy producers in its views about the safety and desirability of expanding nuclear power generation. Only 22 percent of Russians surveyed by the IAEA in 2005 agreed with the proposition that "nuclear power is safe and more plants must be built," compared to more than half of South Koreans, 40 percent of Americans, and 34 percent of Canadians. Even the Japanese public, which had a similar skittishness about nuclear expansion, had a far more positive view about retaining current plants. Sixty-one percent of Japanese favored retaining current plants but not building new ones; only 41 percent of Russians did (IAEA, 2005). Similarly, more than 70 percent of Russians oppose building plants in their regions according to a 2007 survey by Romir, which represents Gallup International in Russia (Slivyak, 2008).

For example, sociological studies by the Chelyabinsk Institute find that as little as eight percent of the public believes information on nuclear plant safety provided to them by the local government or managers at the Mayak facility (Krasnoslobodtseva, 2008).

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The Centre for International Governance Innovation
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