Russian Commercial Nuclear Initiatives and U.S. Nuclear Nonproliferation Interests

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Owing to its deep involvement in nonproliferation initiatives in Russia, the United States has an important stake in the commercialization of the Russian nuclear sector. The U.S. government—largely through the Departments of Defense and Energy—has spent more than $6 billion over the last decade to support cooperative nonproliferation programs in Russia. A substantial portion of this money funnels through the Russian Ministry of Atomic Energy (Minatom).

Several proposals in the last few years have aimed to "privatize" Minatom. Generally, the idea is to separate Minatom's defense programs from its nondefense activities and to privatize the nondefense activities in hopes of making them a commercial success. Both Russian President Vladimir Putin and Minister of Atomic Energy Alexandr Rumyantsev have called for growth in domestic nuclear power-generation capacity, increased nuclear power production, expanded nuclear construction activities worldwide, and the development of new nuclear fuel initiatives with profit-making potential. Minatom is proposing this aggressive expansion ostensibly to generate funds that can be used to shore up activities related to defense, fundamental research, and environmental remediation, as well as to support the vast social responsibilities (schools, hospitals, and the like) that it inherited from the Soviet era. Despite these ambitions, however, a close examination reveals that where restructuring may lead is unknown, what privatization might entail is unclear, and whether commercial expansion will pay off is uncertain.

Minatom's commercial ventures are decidedly problematic. Neither electricity sales nor nuclear power plant construction is currently a profit-making enterprise. The current wholesale price of electricity in Russia barely covers the operating cost of nuclear generators. Minatom cannot expand domestic nuclear generation unless the wholesale price of electricity within Russia increases dramatically, and such a change in the electricity price structure obviously faces significant political and social hurdles.

In terms of new capacity, nuclear power is not a sure winner against conventional generation technologies. Hence, even if electricity prices increase to competitive levels, competition itself may significantly curtail plans to expand nuclear generation capacity and output within

Russia. Similarly, Minatom cannot make its foreign nuclear construction ventures a commercial success unless it raises the price of construction. Moreover, nuclear fuel services are not as lucrative as they once were because of sharp declines in the world price of nuclear fuel. Hopes of expanding other fuel processing activities require costly investments in technology and facilities and are not likely to be fulfilled.

On top of difficulties, the proposed privatization of Minatom's nondefense, nuclear enterprises only increases the risk of nuclear proliferation through the threat of corruption, foreign involvement in nuclear material control and production issues, and the increased likelihood of reckless managerial behavior in the face of financial distress. The energy sector in Russia has been racked by institutional failure and scandal, and the threat of such shocks emerging in the nuclear sector must be considered serious.

The purpose of this paper is to lay out the situation that Minatom faces as it sets forth on its roller-coaster ride of commercialization. Our assessment is that the restructuring and reorientation that is going on in Russia is likely to cause Minatom to founder on the rocks of market competition in its nuclear power expansion program. In turn, Minatom is likely to be more responsive to U.S. programs that channel hard cash to its departments and divisions. Understanding the underlying economics of the Russian nuclear industry is a first step in assessing the future effectiveness of U.S. nuclear nonproliferation initiatives.

MINATOM'S INTERNAL STRUCTURE

The industrial activities of Minatom can be classified into three broad areas: nuclear power, nuclear fuel production and fuel cycle services, and weapons.[2] The three main revenue generating activities of Minatom are electricity generation, fresh and spent nuclear fuel processing and services, and construction of nuclear power plants.

Nuclear electricity generation constitutes approximately 40 percent of the revenues of Minatom. Minatom's plan calls for expanding generation from 15 percent to 20 percent of Russia's total electricity output by 2020.[3] To achieve this objective, at least four new reactors are expected to come online, and several older ones are slated to be refurbished. International nuclear power plant construction is another major activity in the Minatom budget. Russia is currently engaged in nuclear power plant construction in several foreign countries, including Iran, India, and China. In 2002, it made a bid on a construction project in Finland, and a decision on that project is expected in mid-2003. Most recently, Russia and Syria have begun discussions about a possible nuclear powered desalination plant in Syria. Atomstroyexport is the power plant construction subsidiary of Minatom. While the company does not publish financial statements, revenues of $424 million have been reported for 2001 and the forecast for 2002 is $900 million.[4]

Russia is a major player in the international nuclear fuel market. Russia enriches natural uranium and sells it to nuclear power plants, primarily in Europe. It sells fresh enriched uranium fuel to nuclear power plants in Russia and to Soviet-designed nuclear power plants in the former Soviet Union and Eastern Europe. It provides spent fuel reprocessing services for Bulgaria and Ukraine.[5] Russia is also engaged in a fuel processing agreement with the United States, known as the Highly Enriched Uranium (HEU) Purchase Agreement. Under the agreement, the United States buys non-weapons-usable, low-enriched uranium from Russia—suitable for use as fuel for nuclear power plants—that Russia has blended down from weapons-grade HEU and has declared excess to its defense needs. The project has its own set of problems, but nonetheless provides substantial revenues to Minatom (around $500 million per year) and has resulted in the down-blending of HEU sufficient to manufacture 6,856 nuclear weapons.[6]

The annual revenues generated in 2001 from uranium production and enrichment services were around $1.5 billion. This includes the HEU deal. The breakdown is shown in Table 1. These revenues flow through two Minatom subsidiaries: Techsnabexport (TENEX) and TVEL Corporation. TENEX serves as executive agent for the Russian Federation in the HEU deal. It is a vertically integrated nuclear fuel company. TVEL engages in the

TABLE 1
EXPORT REVENUES FROM NUCLEAR FUEL, 2001*

Activity	Revenues
Natural uranium	305
Uranium enrichment services	728
Fuel assemblies	464
Spent nuclear fuel imports	50
Total	1,547

*In millions of U.S. dollars.
Source: International Business Relation Corporation (IBR), Department of Nuclear Energy and Nuclear Fuel Cycle, Annual Analytical Survey, Issue #1, Foreign Trade Policy and Authorized Foreign Trade Entities of the Ministry of Russian Federation for Atomic Energy *(Moscow: January 15, 2003), <www.ibrco.ru/ntd/ntd_pub.html>, p. 29.*

production of nuclear fuel assemblies, fuel research and development, and the disposition of nuclear spent fuel of Russian origin. In 2001, TVEL reported profits of $129 million on sales of $590 million, $538 million of which were export revenues.[7]

Russia is also involved in several new nuclear fuel projects. Recently, Russia enacted legislation that paves the way for the country to become an international center for the storage of spent nuclear power plant fuel.[8] Minatom claims that this project can produce substantial revenues. However, commercial success is questionable, even if Russia is able to resolve nuclear proliferation concerns, described below, and receives the support of the United States. Russia is also exploring technologies to implement its long-standing goal of reprocessing new classes of spent nuclear power plant fuel and recycling plutonium separated in this process into new nuclear power plant fuel.[9] The spent fuel storage and plutonium fuel projects are not yet commercially operational.

Table 2 gives a breakdown of Minatom's budget for 2001 and 2002, which highlights its various commercial activities. Based on these numbers, external fuel and construction activities account for about 55 percent of Minatom's budget, while electric generation makes up nearly 40 percent. Fuel and construction projects were budgeted at $2.3 billion in 2001 and $2.5 billion in 2002. The construction projects in India and China included in these totals are specifically funded out of the Russian Federation budget at $140 million per year.

MINATOM'S RELATION TO THE RUSSIAN ENERGY SECTOR

To understand Minatom, it is necessary to relate nuclear energy to other energy supplies in the Russian economy. Such an analysis has become especially important today because both the electricity and natural gas industries are undergoing major restructuring. The electricity industry is made up of the central electric company, Unified Energy System of Russia (UES); a number of vertically integrated regional companies, or *energos*; and the nuclear power stations, all but one of which are operated by Rosenergoatom, a subsidiary of Minatom.[10] The natural gas industry is dominated by Gazprom, which owns most of the proven gas reserves in the country, as well as the system of natural gas pipelines. Both UES and Gazprom are joint-stock companies, in which a portion of shares are owned by the Russian government, while the rest is

TABLE 2
BUDGET FOR THE MINISTRY OF ATOMIC ENERGY*

Category	2001	2002
Electric energy production and selling [1]	1,570	1,800
External commercial activity [2]	2,200	2,400
Credits for NPP construction in India and China [3]	140	140
State budget funding [4]	210	250
Commercial activity of Minatom's entities and organizations at the internal market	90	110
Total	4,210	4,700

*In millions of U.S. dollars.

[1] It is planned that actual payment for the produced and delivered electric energy in 2001 will constitute about 90 percent (incl. 77 percent in cash) and 95 percent (90 percent in cash) in 2002.

[2] List of external commercial activity: Natural and enriched uranium; Uranium enrichment services and reprocessing (conversion) of triuranium octoxide (U_3O_8) into uranium hexaflouride; Recycled uranium enrichment services; Reenrichment services of uranium tails; Fuel deliveries for nuclear reactors; Irradiated nuclear fuel management services; Contaminated metals, metallic constructions and equipment reprocessing services; Services for development and design of atomic reactor components and systems; Radioactive and stable isotopes; Ionizing radiation sources, labeled and deuterated compounds; Calcium metal, zirconium, and other metals and alloys used in the atomic power industry; Charged particle accelerators, gamma radiation units; Special electronic and physical equipment and devices; Flaw detectors; Medical radiological equipment; Processing, laboratory and special protective equipment and instruments for the enterprises of the atomic industry; Construction of nuclear power plants in Iran.

[3] Funding from the Russian Federation State Budget.

[4] Includes nuclear weapons research, development and fabrication; fundamental research; target-oriented federal programs; and nuclear power plant construction in Russia.

Source: Private correspondence with U.S. Department of Energy officials.

vested in private hands. Even though the percentage owned by the government is relatively large, especially by Western standards, the Russian government has found it difficult to exercise control.

UES owns the country's largest conventional generating stations, the high-voltage transmission network, and the dispatch system. Although none of Russia's nuclear power plants is owned or operated by UES, it has considerable control over their financial destinies because, historically, it has controlled their access to Russia's transmission grid (including connections to external markets) and controls the "dispatch" of the generation units. (Dispatch means turning plants on and off in order to match generation output with the demand for electricity). Since UES owns the conventional generation units, it has a profit interest in generating electricity from these sources even if power from nuclear units with available capacity is more economical.

An ongoing restructuring program is intended to create a competitive electricity market. The competitive wholesale market was scheduled to begin by 2004. However, in 2002 the implementation schedule was extended by at least one year. When the restructuring to a competitive market occurs, the plan is to separate generation units from the transmission and dispatch system. Private owners of UES will receive full ownership of the generation units, but will give up all claims to the transmission and dispatch systems. These will become 100 percent government owned.[11] Currently, the government owns 50 percent of UES. A new ministry will be created to operate transmission and dispatch. Also at that time, the Leningrad nuclear power station is to be placed under Rosenergoatom, giving this organization control over all Russian nuclear power plants.[12]

The Russian economy, as well as the natural gas industry, is dominated by Gazprom. It is the largest company in Russia. Gazprom has been torn by scandal and allegations of asset shifting. Restructuring in the gas industry is intended to allow open access to the domestic pipeline system and to institute a competitive wholesale market in natural gas. There is some question about who will be allowed to market gas internationally. Indications are that Gazprom will retain exclusive export rights to Western Europe. The expectation is that domestic competition will erase cross subsidies among consumer groups, and that domestic natural gas prices will increase toward the export price. Currently, the domestic natural gas price is one-tenth of the export price.

ECONOMICS OF MINATOM

Electric Power

Although an important source of revenue for Minatom, nuclear power generation is certainly not a cash cow. Table 3 shows nuclear power generation for the last several years together with the prices charged by the country's two nuclear electric generating entities (Rosenergoatom and Leningrad) on the wholesale market and average electricity prices charged by all power generators. The current electricity price charged by nuclear generators is approximately 1.1¢/kilowatt-hour (kWh) and was only 0.74¢/kWh in 2000.[13] Rates did not increase in 2002, though they may in 2003.[14]

TABLE 3
TARIFFS AND MINATOM ESTIMATED REVENUES FROM NUCLEAR POWER GENERATION

	1999	2000	2001	2002
Nuclear power generation (billions kWh)	111	129	137	139.8
Average retail price for electricity (¢/kWh)	0.96	1.3	1.48	**2
Estimated revenues at the retail prices (millions $)+	1,065	1,671	2,055	2,796
Average wholesale price charged by nuclear generators (¢/kWh)	0.54	0.74	*1.14	***1.1
Estimated revenues at wholesale prices (millions $)+	605	915	1,562	1,537
DOE Estimates (from Table 2; millions $) +			1,570	1,800

* Based on reports for first half of 2001; **As of April 2002; ***As of July 2002.
+ U.S. dollars; 2001 price level
Sources: EcoTass 26/2001,"Nuclear power plants to produce 137 bln kWh in 2001"; U.S. Department of Energy, private correspondence with authors, August 2001; UESR Annual Report 2000, *"Export of Electricity"; Renaissance Capital,* Morning Monitor, *February 26, 2001; and FT Energy Online, Power in Eastern Europe, "Lenergo receives rave Q1 reviews," November 6, 2001; WNA News Briefings, <www.world-nuclear.org>,Dec. 18 –Jan. 7, 2003; Peter Rutland, "The Politics of Regulatory Reform in a Petro State," paper delivered to the Fifth International Conference on Public Sector Transition organized by the Association for Studies in Public Economics, St. Petersburg, May 24-25, 2002; WNA News Briefings,<www.world-nuclear.org>, July 17-23, 2002, from NucNet Business News, 48/02, July 19, 2002.*

Our own estimates, corroborated by statements from Rosenergoatom officials, indicate that the operation and maintenance (O&M) cost of a nuclear power plant in Russia is approximately 1.18¢/kWh.[15] The full, capital-cost recovery price is 4.7¢/kWh.[16] Based on this evidence, nuclear power plants in Russia were losing money out of pocket in 2000 and at best just barely recovering their O&M cost in 2001 and 2002.

Obviously, this situation is not viable in the long run. The short-run phenomenon is attributable to the hangover from the nonpayment problem (many electric power users did not pay their bills in the mid-1990s) and to the fact that much of the cost of nuclear plant operation is internal to, and absorbed by, Minatom.[17] For instance, fuel is supplied to the plants by one of the other divisions of Minatom. Thus, operating losses in the short run are soaked up in the operating budget of Minatom.

However, the long-run implications are discouraging in terms of the economic vitality of Minatom. Restructuring in the wholesale electric market must increase the price paid to nuclear power plants just to keep the existing plants running. The price necessary to make new plants profitable is a good deal higher than that. The main outcome of electricity deregulation must be an increase in electricity prices. Wholesale rates are substantially below the full cost-recovery level. Wholesale rates need to go up fourfold to put them in the range of our estimates of the capital and operating cost of generation. This increase is substantial. It will create shock waves throughout the economy, especially as the cross-subsidies are erased, and it is not likely to happen quickly.[18]

By and large, the current level of wholesale prices is a result of the deep subsidies in the domestic gas market. As noted above, domestic gas prices are one-tenth the export price, and our forecast of the O&M cost of gas-fired electric generation is about 1.15¢/kWh based on this domestic gas price.[19] Obviously, this situation cannot continue forever. The wholesale domestic price of natural gas is expected to increase based on the restructuring under way in the gas industry. This shift will necessarily drive up the price of electricity. However, the wholesale electricity price must increase even more to account for the capital cost of new generation capacity. Ultimately, the average annual wholesale price of electricity must be high enough to support the construction of new generating units, both nuclear and nonnuclear.

Obsolescence of the existing nuclear generating capacity is also a significant concern. Minatom has spent $35 million for a major retrofitting of the Leningrad-4 reactor. Projections have $14 million allocated in the federal budget in 2002 for operations to extend the operating lifetimes of Novovoronezh-3 and -4. Minatom announced that it plans to spend $618.4 million by 2005 in modernizing and extending the service life of its first generation nuclear power plants. It needs about $2.3 billion to complete four additional units that are partially built. Current electricity tariffs are not sufficient to support even these capital projects.

In an attempt to take advantage of the terrorist concerns in Russia, Minatom is trying to obtain funds to increase the anti-terrorist protection of nuclear plants and sites, but the ploy has its own political risks. While the strategy may work in the short term, it will result in increased public awareness of the safety and maintenance problems of nuclear plants. Safety problems at some of the old reactors are the result of design inadequacies. As a result of increased scrutiny, regulatory agencies both within Russia, as well as outside monitors, will likely force expenditures to be made on the older Russian nuclear plants, or they may be forced to shut down.[20]

Minatom hopes that restructuring of the electric industry will allow it access to international sales that will provide an avenue for increased revenues. Minatom is actively pressing to sell more electricity outside of Russia. It has been reported that Rosenergoatom plans to export electricity to Georgia, Finland, and Ukraine. Supply from nuclear power plants to the grid is currently controlled by UES. UES has been granted by law the exclusive control of electricity export, and it has refused to provide Rosenergoatom with transmission and dispatch services to fulfill its contract with Georgia. This dispute is currently being fought in court, and its resolution there has not been reported.[21] UES reached an agreement with Rosenergoatom for the formation of a unified export operator, Inter Rao UES. The draft law on electric industry guarantees the free entry of any independent producer to the foreign market. However, the National Grid Operator of UES declared that

> There is no legislative base for the exports of any independent electricity producer. According to government resolution No. 793, the only organization authorized to export electricity is UES Russia. UES Russia believes that at least during the transitional period it is necessary to maintain centralized trade on foreign markets. . . .The holding company is already trying to create maximum opportunities for exports by independent producers[.][22]

UES is reluctant to allow Minatom independently to market power internationally for two reasons. First, UES wants to have nuclear power capacity at its disposal in satisfying domestic demand. This is valuable because UES does not always pay 100 percent hard currency for the nuclear power that it takes.[23] Second, to the extent that excess capacity exists inside Russia, UES would like to be able to sell this power internationally on its own account.

Restructuring of the electric industry may succeed in sweeping away the political and institutional barriers that have thwarted the export of nuclear power. Nonetheless, Russian electricity exports are small because of the limited effective demand in the neighboring countries and restricted transmission capabilities to countries further afield.[24] Furthermore, the revenues from export are small because the export tariffs are only slightly above domestic prices and not all of the sales are paid for in cash. Finally, Rosenergoatom's capacity to take away a significant share of the electricity export market is considered limited by industry analysts because of "the lack of relationships abroad, general entry barriers for Russian electricity, and UES's political connections both domestically and abroad."[25]

Nuclear Power Plant Construction—Domestic

Competitive Status

Nuclear power provides about 15 percent of Russia's power today. Minatom hopes to expand this to 20 percent over the next seven years, a 33 percent increase in market share. To do so, it anticipates building four more nuclear plants and refurbishing several of the existing reactors. However, unless the wholesale price of electricity increases significantly, construction of new facilities will not be a profit-making venture. Moreover, even if wholesale electric prices increase to competitive levels, nuclear power may be uncompetitive compared to gas-fired generation.

Table 4 shows the breakdown of electricity generation by fuel source for the last ten years and the planned distribution for the future. Historically, gas has dominated production. However, current Russian government plans call for moving away from gas toward coal and nuclear power.

As we noted above, the O&M cost is very similar for both nuclear power and gas-fired generation, but this expense is a sunk-cost, regulatory phenomenon and one in which the safety factors associated with nuclear generation are not adequately taken into account. It is not a relevant comparison. While it is true that the existing nuclear plants do not need revenues based on the cost of new capital to continue to operate, the proposed expansion of nuclear power generation can occur only if new nuclear power plants are built. In this decision, the important consideration is the comparison of the full cost of generation between nuclear and gas generation—that is, the comparison of both full operating and capital expenses.

Based on our estimates, in the *most favorable* scenario for nuclear energy, the full-cost-recovery price for nuclear power is 4.7¢/kWh, while natural-gas-fired generation costs 4.5¢/kWh.[26] Note that this comparison is done at a 10 percent discount rate and based on the export price of gas as opposed to the 2001 domestic price. Renaissance Capital analysts estimated that an appropriate rate for Russia would be 25 percent.[27] At a higher discount rate the competitive edge of gas is even more apparent. Furthermore, as we stated earlier, parity between the domestic and international gas price will likely increase the domestic price of gas, but it is also likely to decrease the export price. In what we consider to be the *most likely* scenario, the full-cost-recovery price comparison of nuclear power to gas-fired generation is 4.9¢/KWh (nuclear) to 3.4¢/kWh (gas). Nuclear is clearly the disadvantaged technology.

Minatom has long argued that the most profitable strategy is to export natural gas to Western Europe and produce electricity in Russia using nuclear fuel. Historically, natural gas sales to Western Europe have been impeded by minimal pipeline capacity. Recently, plans have been made to increase capacity in order to move natural gas westward. However, export capacity can be expanded in gas or electricity. The question is, which gen-

TABLE 4
RUSSIAN ELECTRICITY PRODUCTION BY FUEL SOURCE*

	1990	2000	2020**
Gas	512 (47)	374 (42)	(34)
Coal	157 (15)	151 (17)	(29)
Hydro	166 (15)	160 (18)	(12)
Nuclear	118 (11)	134 (15)	(21)
Oil	129 (12)	62 (7)	(3)
Other	0 (0)	9 (1)	(1)
Total	1,082 (100)	890 (100)	(100)

* Billions of kilowatt hours (percent total output).
** Projected.
Source: International Energy Agency, Russia Energy Survey 2002 *(Paris: OECD/IEA, 2002) and BP p.l.c.*, BP Statistical Review of World Energy *(London: BP, June 2002).*

eration technology is more competitive in Russia. Based on our cost comparisons, it is reasonable to predict that the competitive wholesale price of electricity will not be high enough to justify the construction of new, "greenfield" nuclear power plants in Russia on purely economic grounds.

While a completely new plant might not be economically justifiable, it is likely that the four commercial reactors now under construction will be finished. A large part of their construction costs has already been expended; the marginal payoff from the money spent finishing them is high. Assuming that reform and competition does bring higher electricity prices, Minatom will gain some additional revenues by completing these plants. Similarly, increases in the wholesale electricity price may afford revenues to allow for the refurbishment of the existing nuclear power plants. While the economics of reconditioning existing nuclear plants are idiosyncratic, as a general rule, reconditioning is likely to be cheaper than new construction.[28] Finally, the new nuclear technologies that are in various stages of development are all unlikely to move forward rapidly.[29]

Minatom has claimed that Russia is making a structural shift toward nuclear power, and that the government is determined to promote nuclear power plants.[30] In May 2000, the Russian government approved Minatom's nuclear development policy and incorporated it in the overall energy strategy to 2020.[31] The strategy states that Russia will expand its nuclear generation in the next 20 years and shift electric power generation away from other sources of energy like oil and gas. The strategy thus aims to reduce Russia's overdependence on natural gas for power generation.[32] However, voices in the Russian government and Russian public opinion have started to question the viability and cost competitiveness of the nuclear power option. An audit at Rosenergoatom in late 2001 addressed the issue of economic soundness of nuclear energy. Statements by the Comptroller's Office expressed caution concerning cost estimates that favor nuclear over gas.[33] In a contemporaneous interview, Rosenergoatom president Erik Pozdyshev admitted that under "normal cost assumptions" nuclear power cannot compete with gas.[34]

One thing to watch will be investment in conventional generation. In 2001, UES began pushing a "5000 Megawatt" plan involving twelve projects that it hopes to sell to international investors with the help of PricewaterhouseCoopers.[35] Despite this campaign, as of early 2003, there is no sign of new private foreign investment in the Russian energy market. And if international investors are reluctant to invest in new conventional facilities, it is even less likely that they will put money in Russian nuclear power plants.

Safety Issues

As noted above, regulatory agencies within Russia, as well as outside monitors, will likely force Rosenergoatom to make expenditures to upgrade safety systems at old nuclear plants or will force them to shut down. One environmental group has been set up specifically to scrutinize the Leningrad plant.[36] If the Leningrad plant or any of the other older facilities are forced to close because of the expense of upgrading the facility, it seems unlikely that any new nuclear construction will be initiated.

In its attempt to secure more budgetary funds for safety and security, Minatom is playing a risky game. Minatom publicly asserts that it needs funds to increase the safety of the existing nuclear reactors. First it needs funds to repair and upgrade the old reactors to alleviate safety problems that are the result of design inadequacies. Second, in an attempt to take advantage of the terrorist concerns in Russia, it is trying to obtain funds to increase the antiterrorist protection of nuclear plants and sites. While the strategy may work in the short term, it will inevitably result in increased public awareness of the safety and maintenance problems of nuclear plants.

There are good reasons to believe that safety concerns at nuclear power plant sites are well-founded. As an indication of how bad things may be, Rumyantsev is considering changing the form of ownership of nuclear facilities to some mixed state and private structure for the parts of the nuclear site that do not pose security threats (because of strategic importance or involving classified matters). A Russian magazine reported that:

> Several sector officials propose leaving only the reactors as state property and "exchanging" all the rest of the infrastructure for investment money. They believe that this is the only way that money can be found to improve the physical protection of nuclear facilities, since not one [nuclear electric power station] in Russia corresponds with the regulations.…In [Rumyantsev's] opinion, one could privatize the buildings, pools, turbines, and other things not directly related to the reactor units themselves.[37]

Previously, Rumyantsev had seemed to favor an increase in the control of the Ministry and state over the nuclear plants for economic and safety reasons and was reluctant to consider privatization schemes with respect to power plants. This new tack suggests that if Minatom's scramble for funds is not successful, it will shortly reach a

point where the lack of maintenance and refurbishment funds becomes critical.

Nuclear Power Plant Construction—International

Minatom is actively promoting nuclear power plant construction internationally. Currently, there are Russian nuclear power construction projects underway in Iran, China, and India. Additional projects are being considered in each of these countries. Also, Minatom is preparing to bid on a nuclear construction project in Finland, where it will be competing against Germany, France, Britain, and Sweden. Construction projects in Kazakhstan and the Ukraine are also slated. Finally, the Russian Foreign Ministry announced in January 2003 that talks would begin with Syria on building a nuclear power plant.[38] Objectively, these projects must be viewed with a certain amount of skepticism. The previous section argued that nuclear power does not appear to be economically viable in Russia. This conclusion does not mean that it is necessarily inefficient in other countries, but it does raise the question.

We have done a rough comparison of the estimated cost of nuclear facilities to the amounts that Minatom is reportedly receiving for these construction activities. By our estimates, the base construction cost in Russia of a VVER-1000 plant is $1.4 billion. Interest during construction (at 10 percent), contingencies, and the discounted value of decommissioning run the costs to the purchaser up to $2.2 billion. Two units built at the same site and within the same time frame can be expected to lower costs by 10 percent. For some projects, Russia is reportedly supplying the equipment only. We can approximately separate the cost of equipment and buildings based on data from the U.S. experience. The average equipment cost for U.S. plants was 77 percent of the total and the cost for buildings was 23 percent. Based on this experience, the equipment cost of a Russian VVER-1000 reactor is around $1.1 billion. Financing on the equipment share of cost during construction would raise the total on the equipment to roughly $1.7 billion.

India

In July 2000, Russia and India finally agreed on the terms for the construction of two VVER-1000 reactors at the Kudankulam nuclear power plant. The construction was estimated to cost India $3 billion. The initial agreement had been signed in the 1980s.[39] The construction of the reactors began in January 2002.[40] The first reactor is scheduled to be commissioned in 2007. Kudankulam-2 is set to begin operating in 2008.[41] Russia will design the plant and supply 90 percent of the equipment and materials. Russia will supply most of this equipment and material on credit, funds for equipment fabrication being allocated to Minatom from the Russian federal budget. The terms of credit are very favorable to India, causing outcries from critics of the project in Russia. The announced contract price is $1.5 billion to $2 billion.[42] In 2000, President Putin signed an agreement with Indian Prime Minister Vajpayaee to cooperate in nuclear research. Putin asserted that the Kudandulam project is only the beginning of Russo- Indian nuclear cooperation.[43]

Nevertheless, it is very unlikely that the construction of the two reactors at Kudandulam will prove a profitable venture for Minatom. By our estimates, should Russia supply only the equipment and given a 10 percent discount for the construction of two units on the site, the cost would be around $1.9 billion total for both units, not counting financing during construction. Reports from India assert that the Russian government is in fact carrying the construction financing.[44] Providing such concessionary financing will run the project significantly into the red from the Russian perspective. Our estimate of the total cost to Russia is more than $3 billion for the two units.

China

In 1999 Russia started the construction of the first two VVER-1000 reactors at the Jiangsu Tianwan nuclear power plant at Lianyungang in northeast China. They are scheduled for commissioning in 2004 and 2005. Total cost of the two reactors is expected to be $3.2 billion, financed by $1.3 billion in loans from the Russian government at a rate of 4 percent, $1 billion in commercial loans, and $600 million in a loan from the China Development Bank.[45] Russia, which is supplying the technology and the reactor itself, will receive $2.4 billion for the two units.[46] China is responsible for construction and installation.

China currently has six operational reactors with a combined net capacity of 4,380 megawatts (MW).[47] Three of these came online in 2002. Five additional reactors representing 4,200 MW of capacity are under construction. One was scheduled to come online at the end of 2002 and the rest annually through 2005. At one time China envisaged an ambitious nuclear development plan for 2001-2006 with several new reactors to be built. How-

ever, in 2000 China considered imposing a moratorium on reactor orders in its five-year plan because of a slowing economy and a lower-than-forecast increase in electricity demand.[48] In 1999 Russia and China also agreed to build a gas centrifuge uranium enrichment plant in Shaanxi province in China and to cooperate in the development of new-generation gas centrifuges.[49]

Based on our estimates, Russia may be enjoying a modest profit on its construction activities at Jiangsu Tianwan. Assuming that it is supplying only equipment at a total cost of $1.9 billion for the two units, the contract price affords some surplus to Russia.[50] On the other hand, financing more than half of the contract price at four percent arguably erodes most or even all the surplus. For instance, the cost of lending China $1.3 billion at four percent for 10 years, if the true cost of the money to Russia is 10 percent, is $350 million. If the term of the loan is 20 years, the cost of the loan at 10 percent would be $520 million. Hence, even though the stated contract price seems attractive, the terms make it somewhat less so. Furthermore, it is not clear how the construction financing is being handled. If the Russian government is financing the cost of construction up to the startup of the power plant, the project cannot be profitable given the stated contract price. The delivered cost, counting financing for the two units, is more than $3 billion. In fact, the budget items listed in Table 2 suggest that Russia may be carrying the construction costs.

Iran

In 1995 Russia and Iran signed an $800 million contract for the completion of a partially built Siemens 1,000 MW nuclear reactor at Bushehr, Iran. In 2000, Russia began the construction of the reactor that was scheduled to be commissioned in 2002, but now appears most likely to go online in 2004.[51] The unit was delivered to the site in late 2001. The possibility of three new reactors to be built on the site for $3.5 billion has also been discussed. Talks for at least another reactor are due to begin in December 2001, according to a Minatom official. Russia is training Iranian specialists to operate the plant. Russia and Iran have also held talks about joint development of a uranium mine and an enrichment facility. The originally announced contract price of $800 million for the Bushehr-1 reactor is below cost by our estimates. It is not clear if the price has increased since it was originally announced in 1995. The prospect of building three additional units at this site for an additional cost of $3.5 billion is also below cost, assuming that Russia is supplying all of the material and equipment. If this represents the contract price for the equipment alone, it is closer to the cost recovery level, but only if Russia is paid up front rather than financing the project during construction.[52]

Summary

Besides India, China, and Iran, Minatom is trying to expand its nuclear technology exports to Ukraine, Kazakhstan, Syria, Libya, Peru, Indonesia, both Koreas, and Vietnam.[53] Minatom claims that "construction of nuclear power stations in Iran, China, India, Kazakhstan and Ukraine will provide $42 billion in 2002-2005 and $24 billion in 2006-2010."[54] These numbers seem wildly exaggerated, given that only $5.2 billion worth of construction is currently under contract in Iran, China, and India.

Why Russia is willing to build nuclear plants around the world at an apparent financial loss is not clear. Possibly, it is to gather political influence in these various countries. Perhaps some Russian officials believe that these plants are loss leaders—that is, a way of gaining a toehold in a growing market, in which current losses may be recouped later. In a short-run sense, Minatom may see many of the resources used in the construction of international power plants as sunk costs. The technology has been developed. The scientists and engineers are on staff. Nonetheless, our analysis concludes that the foreign construction program appears to be a money drain for Minatom and/or the Russian government.

Nuclear Fuel

Minatom's nuclear fuel complex groups together a large range of activities, including production of nuclear fuel and nuclear materials, nuclear fuel cycle development, nuclear fuel storage and reprocessing, controlled thermonuclear fusion research, and plasma physics. Russia is a major world supplier of nuclear reactor fuel and uranium enrichment services. It is also seeking to develop new fuel initiatives, including the possibility of becoming a spent fuel repository for the world. Expansion of nuclear fuel projects is one of Minatom's strategic goals.

Our estimates are that Russia currently sells more than $1.5 billion worth of nuclear fuel and related services per year. Part of this revenue comes from enrichment of natural uranium and reprocessing of spent fuel. Minatom's principal customers for enrichment services are in Western Europe, while the former Soviet and Soviet-bloc states

are the main purchasers of fabricated fresh uranium fuel and reprocessing services. Another major component of Minatom's fuel and fuel services revenue comes from the HEU Purchase Agreement with the United States.

Producing, enriching, and reprocessing nuclear fuel are important cash-generating activities for Minatom. However, the expansion of fuel initiatives beyond the ones that are currently operational is problematic. These new, purely domestic initiatives include fabricating mixed plutonium-uranium oxide (MOX) fuel; using plutonium extracted from nuclear power plant fuel; building new-design fast reactors to burn MOX; and refitting traditional VVER nuclear power plants to burn MOX. In addition, on the international front are the spent-fuel storage project and the weapons-grade plutonium initiative. All of these projects require substantial investments for research, development, and testing of the technologies and construction of relevant facilities. The commercial viability of these projects is questionable, however. Funds for the projects are not obviously available in Minatom's budget, and promises of international funding have not materialized.

Closed Fuel Cycle

Russia has been and continues to be committed to a closed nuclear fuel cycle and to exploiting stocks of weapons-usable plutonium generated in spent fuel from nuclear power plants.[55] In a closed fuel cycle, spent low-enriched uranium nuclear power plant fuel is reprocessed to separate the plutonium and reusable uranium from high-level radioactive waste products. The plutonium can then be reused in a new cycle of nuclear power plant fuel—MOX—reducing the need for fresh low-enriched uranium. Another variant is to use MOX in breeder reactors, which can produce more plutonium than they consume.

In principle, the closed fuel cycle would substantially expand Russia's supply of nuclear fuel material, and thus increase the nation's resource base. However, the technology for exploiting the closed fuel cycle is seen as uneconomical by the private market internationally and has been rejected by most countries that use nuclear power in favor of the once-through fuel cycle.[56] Under this approach, after a period of interim storage, spent nuclear power plant fuel is permanently disposed of directly in a special repository. The United States and several other states also favor this approach because it avoids the security and proliferation risks that could arise from the commerce in weapons-usable plutonium that would be generated by a closed fuel cycle.

A closed nuclear power fuel cycle in Russia would require substantial investment to become operational, but has little prospect of becoming financially self-sustaining. Nevertheless, although it is not commercially viable, Russia's commitment to this approach has influenced another major initiative mentioned earlier, the U.S.-Russian Plutonium Disposition Program. This program aims to dispose of excess plutonium from Russia's nuclear weapons program by fabricating it into MOX fuel and burning it in existing Russian nuclear power plants and breeder reactors. This activity would require extensive external financial support and is being pursued in conjunction with a similar project in the United States to dispose of a comparable amount of excess U.S. military plutonium. The United States has promised some financial support for Russia and is seeking additional aid from Western Europe. If the project moves forward, it could bring a new revenue stream into Minatom's budget.

Under this program the two countries will each dispose of 34 metric tons of weapons-grade plutonium that they have declared to be excess to their defense needs. The material is to be fabricated into MOX fuel—Russia has rejected the alternative of mixing the material with radioactive waste and emplacing it in a geologic nuclear waste repository—and burned in Russian VVER-1000 reactors and in Russia's BN-600 breeder reactor. Both reactor types will require certain modifications to accommodate the MOX fuel, and critics claim this conversion involves unproven, though not necessarily impractical, technology.[57] Russia claims to need $2 billion to convert the VVER reactors and build a pilot and then a full-scale plant to fabricate the MOX fuel. Plutonium would be burned at a rate of two tons per year, requiring a total of at least twenty years to implement the initiative, once construction schedules are included.

Recently, after a year in which the fate of the project was uncertain due to the high costs involved, the Bush administration renewed its interest in the agreement. The United States is now working with other potential donors, principally the European Union and Japan, to obtain the necessary funding.[58] As suggested above, although the new initiative will be possible only through substantial international governmental subsidies, it will have the effect of bringing substantial new budgetary

resources to Minatom and enabling it to engage its expert labor force in several important new projects.

International Spent Fuel Storage

Against a backdrop of public outcry, in July 2001, President Putin ignored public opinion and signed a new law allowing Russia to import spent nuclear fuel for processing and/or temporary storage. "Temporary" is not defined in the law. Critics claim that this will turn Russia into the world's nuclear garbage dump, but Minatom sees it as a potential profit opportunity.

A 1992 law forbade Russia to import and store nuclear materials. The only exceptions were the former East bloc states whose reactors Russia supplied and with which Russia was allowed to continue existing spent fuel take-back arrangements. Under those arrangements, spent fuel from Soviet-era VVER-440 reactors was being shipped to the Mayak Production Association in Chelyabisnk Oblast and reprocessed. The resulting plutonium was then stored at Mayak for potential future use as MOX fuel, and none was returned to the exporting countries. High-level radioactive waste from the reprocessing, however, was vitrified and eventually returned to the exporting country.[59] Russia currently reprocesses spent fuel discharged from its own VVER-440 power reactors at the Mayak site and stores spent fuel discharged from its VVER-1000 reactors at a centralized storage facility in Zelezhnogorsk, located in Krasnoyarsk Kray.

The international spent fuel storage project (which will include VVER-1000 fuel and that from modern Western-designed reactors in several countries) has several problematic aspects. First, Russia does not have the facilities to handle large-scale, temporary spent fuel storage; the possible subsequent reprocessing of this material; or the final disposal of either spent fuel or the waste products from its reprocessing. Nor is it clear how Russia will be able to raise the necessary funds to build them. According to the feasibility study supplied by Minatom, the cost of a new plant for storing and reprocessing imported spent fuel is $1.96 billion. The proposed RT-2 reprocessing plant and associated spent fuel storage facility, to be built in Zelezhnogorsk, is projected to handle 1,500 tons of spent fuel per year and it will take 20 years to complete. A Minatom official has declared recently that

> . . . up to US$3.4 billion are needed within the next 30 years to develop the country's spent nuclear fuel reprocessing industry. . . .Some US$1.1 billion is needed in the period up to 2010 . . .This money would come from electricity tariffs and income raised through the import of spent nuclear fuel. [60]

However, according to a recent report delivered to President Putin by the Yabloko Party leader Grigory Yavlinsky (henceforth, the Spent Fuel Memorandum), the actual cost of building the plant is approximately $6 billion.[61] Also, the Spent Fuel Memorandum claims that Minatom has grossly underestimated transport and insurance costs and concludes that, taking all the expenditures into consideration, "the production cost of storage and [re]processing will exceed by 2-3 times the declared prices on imported spent fuel in the amount of $600-$1,000 per kilogram."[62]

Second, as noted above, turning Russia into a nuclear waste repository is not politically popular. Russia is under substantial political pressure from grass-roots organizations opposed to turning Russia into a nuclear waste repository. It is interesting to note that the Spent Fuel Memorandum has a strong ecological flavor. It cites the opinion of experts of the State Ecology Expert Commission that "the technological equipment for [re]processing [spent nuclear fuel] which is proposed for installation still needs to be designed and even developed anew,"[63] and that "Russia does not have a technology for processing fuel assemblies of the Western type."[64]

Third, Russia needs the explicit approval of the United States for the reprocessing and storage of U.S.-origin fuel (which would be imported from Switzerland, Germany, Taiwan, and South Korea, whom Minatom hopes will be the leading customers for spent fuel services). Through its bilateral nuclear cooperation agreements with its civil nuclear trading partners, the United States has retained consent rights over 90 percent of the fuel that could be imported into Russia from the West. That is, outside of the former Communist bloc, nearly all of the spent fuel that exists in the world has at some point been controlled by the United States. Consequently, the United States must consent to the ultimate destination of this material. Countries will not send nuclear waste to Russia for reprocessing and temporary storage unless the United States explicitly signs off on the project. Because reprocessing results in the accumulation of separated plutonium, increasing security risks, the United States has advised Russia that it will not approve the transfer to Russia of spent fuel over which it retains consent rights if the material is to be reprocessed. Moreover, the United States has also advised Minatom that it will not approve such transfers even without reprocessing, until Russia ends its nuclear cooperation with Iran, which the United States believes is contributing to Iran's efforts to develop nuclear

weapons. The offer "to loosen import restrictions on the estimated 70%-90% of the world's [spent nuclear fuel] that is controlled by the United States" if "the Russians end their sensitive cooperation with Iran," was repeated in February 2003.[65] Because Russia has not taken sufficient steps to reduce or end this cooperation to address Washington's concerns, the international spent fuel storage initiative appears to be frozen at this time.

The HEU Deal

The HEU Purchase Agreement was signed on February 18, 1993.[66] The initial implementing contract was signed by the United States Enrichment Corporation (USEC) and TENEX, acting as agents for the United States and Russia, respectively.[67] According to the contract, TENEX was to blend down 500 metric tons of weapons-grade HEU into LEU.[68] When the agreement was signed, Russia was expected to receive about $12 billion in the HEU purchase. From 1994 through December 2002, USEC received from Russia about 5,027 metric tons of LEU blended-down from approximately 171 metric tons of HEU. USEC paid TENEX about $2.5 billion and the U.S. Department of Energy has paid TENEX approximately $1 billion.[69]

From Russia's perspective the deal has generated nearly $3.5 billion, of which two-thirds went to Minatom and one-third to the federal treasury. Thirty percent of Minatom revenues from the deal (20 percent of the total) has been used to finance the conversion programs of Minatom.[70] However, an agent-principal problem exists in USEC's involvement in the HEU deal. As a private enterprise, we expect that USEC will attempt to maximize shareholder wealth. In buying reactor fuel from Russia to supply U.S. utilities, USEC has passed up cheaper supply opportunities in order to effectuate the national security objectives of the HEU Deal. Consequently, profits have been reduced. As expressed in the Government Accounting Office (GAO) report on the HEU deal: "USEC continues to face challenges in balancing its commercial objectives with the national security interests of United States."[71] Moreover, the sword cuts on both sides. Given its mandate to broker sales of Russian fuel in the United States, USEC has curtailed its own enrichment activities.[72] Half of USEC's annual sales of LEU come from Russia, and almost 40 percent of total U.S. sales of nuclear fuel have Russian provenance. The fact that "the United States also faces a growing dependence on Russian origin material for nuclear fuel" is a concern for some.[73]

USEC and TENEX reached an agreement in June 2002 over the price USEC will pay for the enrichment component of the HEU deal from 2002 to 2013. The agreement links Minatom's sales price to the international commercial market in enriched uranium. Under the new contract, USEC will continue to pay $90.42 per separative work unit (SWU) through 2002. Beginning in 2003 and for the duration of the contract, price per SWU will be determined by taking into account the average market price for uranium over the three preceding years to avoid negative impacts of world price fluctuations. Until 2013, USEC is obliged to purchase at least 5.5 million SWU, or about 30 metric tons of HEU, from Russia annually.[74]

This arrangement would mean a decline in the price compared to what USEC has paid in the past under previous contracts. According to USEC sources, as a consequence of this agreement, "Russia will receive at least $7.5 billion over the 20-year term of the HEU agreement."[75] Therefore, as a consequence of both the new agreement (driven by the sharp decline in the world price of uranium) Russia will earn less from the HEU deal than it initially hoped. Nonetheless, the HEU project will remain a major source of hard currency.

PRIVATIZATION

The Russian experience over the last decade is a textbook study in the absence of property rights. Since the fall of communism, the economy has been riddled with charges of corruption. The nature of this corruption has characteristically taken the form of asset shifting. After the fall of communism, joint stock companies (JSCs) were formed from formerly state-owned enterprises. The federal government retained shares in these JSCs, but control was passed to private individuals, who held shares in the enterprise. Some shares were sold to foreign entities. Under private control, cash flow from these enterprises has been diverted to private pockets.

The nuclear sector has its own history of privatization. The direction of reform in the sector is unclear and a proliferation threat clearly exists. The curious tale of Unit 4 at the Balakovo nuclear power plant is an example.[76] Apparently, this unit is privately owned and continues to operate on a lease agreement in spite of a federal law that prohibits private ownership of nuclear facilities. During a cash shortage in 1992, work on the unit was stopped. A private company with 80,000 shareholders, 40,000 of whom were nuclear sector employees, was formed to raise money to complete construction. In 1993, the company purchased the turbine, presumably for an amount equal to the cost of completing the construction. The unit has operated since that time and dividends have been paid to

the shareholders of this company. While the amount of these dividends has not been reported, claims of revenue skimming have been lodged. The law forbidding private ownership of nuclear facilities was passed in 1995 without provision for dealing with Unit 4 at Balakovo. While Minatom plans to buy back the turbine, no money has yet been paid.

Similiarly, Minatom's fuel exporting subsidiary, TENEX, is currently structured as a joint-stock company in which employees reportedly own 49 percent of the shares and the government retains 51 percent.[77] The history of private ownership is not as well reported here as for Balakovo-4, nor is it clear how this structure is legal. The other fuel exporting subsidiary, TVEL, is said to be 100 percent government-owned. Even so, both of these subsidiaries have had a great deal of operating discretion.

In a major move, President Putin announced plans in 2001 to reintegrate subsidiary enterprises of Minatom, including TVEL and TENEX. Privately-owned shares were to be bought back by the government, and while the details of these transactions are not known at this time, it does appear that the government has taken control of the voting rights of the privately-owned shares in TENEX. In addition, the head of TENEX and the first deputy minister at Minatom were replaced in 2001 amid allegations of missing revenues.[78]

The structure of oversight and control within Minatom was directly criticized in the Spent Fuel Memorandum prepared by Yabloko. It says:

> . . .Minatom is an archaic department, which has not been reformed since Soviet times and which by virtue of its organizational structure, unjustified secrecy, functional "omnivorous nature," and low fiscal discipline—is not capable of resolving. . .complex administrative tasks[.][79]

Putin seems sympathetic to this complaint and appears to be making moves to increase control. The March 2001 appointment of Rumyantsev, the former head of the Kurchatov Institute, as head of Minatom was in itself a move away from the old-boy network associated with past scandals and allegations of asset shifting. Even so, it is not yet clear that a true anticorruption movement has taken hold in Minatom. Renewed calls for privatization of components of nuclear power plants must be viewed with caution.

SUMMARY

Based on this analysis, the financial future of Russia's nuclear industry is not bright. This conclusion emerges from a review of the restructuring of the Russian energy sector, restructuring within Minatom, and Russia's own nondefense business enterprise initiatives: electricity generation, nuclear power plant construction, and nuclear fuel processing.

Reform of the energy sector may yield benefits for Minatom in the short run but will expose the nuclear sector to the harsh realities of competition in the long run. In the best case, reform of the wholesale electricity market will result in cash flows sufficient to provide adequate maintenance so that the existing plants will continue to produce. However, it is possible that the cash flows will not be large enough to allow for major upgrades in equipment. Considering both capital and operating costs, nuclear power in Russia does not look particularly attractive from an investment perspective compared to other energy options, even if wholesale rates increase to cost-recovery levels.

The fundamentals of nuclear power that confront Russia domestically are also at play internationally. Although Russia is engaged in several power plant construction projects abroad, they are of dubious economic value. The terms under which these projects are being pursued do not appear to be cost-effective, and it appears that Russia has agreed to build these facilities at a loss. Possibly this was done to pursue foreign policy objectives, or perhaps to gain a presence in the international nuclear construction market. At all events, Minatom will have to charge more in the future to make these ventures a commercial success. Finally, the nuclear fuel business is unlikely to generate as much revenue in the future as it has in the past.

For all of these reasons, our conclusion is that the U.S. initiatives that provide Minatom with hard cash will have significant leverage over the next five to ten years. It is very likely that Minatom will not be able to raise significant funds from private investors, and it is certainly possible that privatization will have the all too common effect of diverting cash into private pockets. Hence, the money from U.S. programs, with their attendant oversight, will not only help control nuclear proliferation directly, but will also help stabilize the Russian nuclear sector and through that, contribute to the stabilization of the entire Russian economy.

Even so, significant policy questions remain. What form should U.S. subsidies take? Should the United States invest directly and in which projects? Oversight of funds is clearly important. Funds simply dumped into Minatom are likely to be diverted from their intended purpose unless it is carefully audited. Other questions are also trou-

bling: Can the United States encourage private investment in the Russian nuclear industry and avoid conflicts of interest like those some see in the HEU deal? And, perhaps, the most fundamental question is how far does the United States wish to go to sustain Minatom's civilian nuclear programs, perceived by many to be a grossly inefficient holdover from Soviet period? In many cases, Washington is underwriting nonproliferation efforts in Russia—such as securing nuclear materials—that Russia should be paying for itself. The impact of such U.S. efforts may be to subsidize Minatom's money-losing nuclear ventures, including the sale of reactors to India and Iran, that the United States opposes.

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[2] The Nuclear Power Complex comprises several departments coordinated directly by the Minister of Atomic Energy. Rosenergoatom and Nuclear Facilities Construction are the most important. Rosenergoatom coordinates the operation of Russia's civilian nuclear power plants (which does not include the electricity producing reactors at Seversk and Zelezhnogorsk). The Nuclear Fuel Complex includes the following programs: fuel for atomic power, nuclear power fuel cycle development, promising technologies, high energy physics, controlled thermonuclear fusion and plasma physics, radiation safety, nuclear material production and utilization, nuclear fuel storage, and reprocessing services export development. The Nuclear Weapons Complex is responsible for Minatom activities that support Russian military nuclear capabilities, including naval propulsion reactors.

[3] International Energy Agency (IEA), *Russia Energy Survey 2002*, in cooperation with the Energy Charter (Paris: OECD/IEA, 2002), p. 183.

[4] International Business Relation Corporation (IBR), Department of Nuclear Energy and Nuclear Fuel Cycle, Annual Analytical Survey, Issue #1, *Foreign Trade Policy and Authorized Foreign Trade Entities of the Ministry of Russian Federation for Atomic Energy* (Moscow: IBR, January 15, 2003), p. 89, <www.ibrco.ru/ntd/ntd_pub.html>.

[5] Reprocessing is the chemical separation of plutonium and unused uranium from spent nuclear fuel using chemical processes. The activity also generates high-level radioactive waste. The recovered plutonium and the uranium have potential value for use as nuclear power plant fuels, although, as discussed below, the economics of this fuel cycle are uncertain, at best. Because separated plutonium can also be used as the core of a nuclear weapon, reprocessing raises important security issues.

[6] One metric ton of HEU will make 40 nuclear warheads. See USEC Inc., Megatons to Megawatts, Fact Sheet: US-Russian Megatons to Megawatts Program, December 31, 2002, <www.usec.com>.

[7] See IBR, *Foreign Trade Policy*, pp. 112-113. Also see Nuclear Threat Initiative (NTI), "Russia: TVEL Joint Stock Company (JSC TVEL, OAO TVEL)," Center for Nonproliferation Studies, NIS Nuclear Profiles Database, < http://www.nti.org/db/nisprofs/russia/fissmat/ufuel/tvel.htm >. TVEL is a joint stock company, 100 percent state owned, created in 1996.

[8] *SpentFUEL* (July 16, 2001), p.3; *UxWeekly* (July 16, 2001), p.1; *Nuclear Market Review* (July 13, 2001), p. 2 in WNA News Briefings (July 11-17, 2001), <www.world-nuclear.org>.

[9] There is also an initiative to down-blend weapons-grade plutonium into mixed oxide fuel. It is generally accepted that this program is not commercially viable and will require large subsidies. The United States has promised financial support and is seeking to raise support from Western Europe. Even though the project is not intended to be commercially viable, it could generate positive cash flows for Minatom.

[10] UES is RAO EES Rossi, or the Unified Energy Systems of Russia. Under electricity industry restructuring, Rosenergoatom is slated to take control of the Leningrad plant; this may have already happened. There are a few other power producing plants, such as the reactors at Seversk and Zelezhnogorsk, that operate independently.

[11] One recent report suggests that some private ownership claims in the transmission and dispatch systems may remain after restructuring, reflecting a change in the reform agenda. However, the report asserts that these systems, nonetheless, will be fully controlled by the government. See Denis Pinchuk, "Electricity Reform Takes Off," Rosbalt News Agency, February 22, 2003, translated by Robin Jones.

[12] *NucNet Business News* 19 (March 18, 2002) in WNA News Briefings (March 13-19, 2002), <www.world-nuclear.org>.

[13] For 2001, the U.S. Department of Energy projected Rosenergoatom electricity revenues at about $1.6 billion; this figure implies a wholesale electricity price of 1.1¢/kWh. This projection is in line with Russian reports which give a tariff of 1.14¢/kWh. See Aleksandr Vasilyev, "Cost Advantage of Nuclear Power Disputed," *Novaya Gazeta,* November 15, 2001, in FBIS-CEP-01-379. The same number has been reported more recently in Nikolai Krupenik "Investment in Russia's Atomic Energy to Grow 5 Times by 2010," ITAR-TASS, September 25, 2002, in FBIS -CEP-02-383 (September 25, 2002).

[14] The expected tariffs growth in the electricity sector for 2003 are 20 percent for the wholesale tariff and 14 percent for the retail tariff. Gas prices paid by the domestic industrial consumers are expected to go up by 20 percent. NERA, *Global Energy Regulation* 42 (November 2002), p. 10, <www.nera.com>.

[15] Irina Rybalchenko, "Rosenergoatom Gets Additional Powers," *Kommersant* (Moscow), September 11, 2001, p. 4; in "Rosenergoatom to Undergo Reorganization," FBIS-CEP-01-347 (September 11, 2002). A slightly higher number comes from a different source: "On 25 January [2000], Deputy Atomic Minister Bulat Nigmatullin told Prime-TASS that the tariffs on electricity generated by nuclear plants shall be raised 1.6 times because the tariffs do not cover a plant's basic costs," Radio Free Europe/Radio Liberty, News Line, Russia, January 26, 2000. Based on the 1999 tariff of 0.54¢/kWh, this statement implies a tariff of 1.4¢/kWh to cover the "basic costs."

[16] Electricity costs are analyzed in Oana Diaconu and M.T. Maloney, "Is Nuclear Power Viable—In Russia?" *Electricity Journal* 16 (January/February 2003), pp. 80-87. The full unit cost of nuclear generation is estimated to be 4.71¢/kWh, which is broken down into 3.69¢ for capital cost and 1.02¢ for O&M, including fuel. Arthur Andersen, in its April 2001 Russian Electricity Sector Reform report about UES tariffs, said, "Substantial increases in tariffs, 1.5x-2.5x measured by actual exchange rates, will be required to make essential new, privately-financed investments economic." Ibid., p. 7. By our estimates, even this is not enough to cover the capital and operating costs of a new nuclear plant.

[17] Oil and coal prices were liberalized in 1992, but gas and electricity prices remained regulated and have been maintained well under competitive levels. The attempt to increase prices in the 1990s created a situation in which electricity users did not pay their bills. This was called the "non-payment problem." In 1998 Gazprom received only 15 percent of its sales in cash. The main debtors were the power generators, with 40 percent of the debts at the beginning of 2000, plagued, in turn, by nonpayments from their own customers. In 1999 UES cash payments stood at 20 percent. The industry operated on various forms of noncash payments such as offsets, barter, and promissory notes. However, the situation began improving in 2000 and is now practically resolved. Both UES and Gazprom have cash payment rates close to 100 percent. At the height of the nonpayment problem, however, it is likely that the costs of the nuclear plants not covered by revenues were simply washed through the rest of Minatom's budget. For instance, if the nuclear plants were not paid for the power they produced and sold to UES, they did not have the currency to pay Minatom for the fuel they used.

[18] On May 21, 2001, the minister of Economic Development and Trade forecast tariffs to increase 100 to 120 percent through 2004. Renaissance Capital, *Morning Monitor*, May 22, 2001, citing an Interfax news story, <www.rencap.com>.

[19] See Diaconu and Maloney, "Nuclear power," p. 84. This estimate is obtained using the current Russian domestic gas price and a heat-exchange factor associated with the oldest 25th percentile of natural gas boiler generation units operat-

ing in the United States.

[20] One environmental group has been set up specifically to scrutinize the Leningrad plant. It cites evidence of numerous safety violations there. This plant is scheduled for international inspection in 2002, and some issues must be addressed. Galina Stolyarova, "Greens Attack Funding of St. Pete Nuke Plant," *Moscow Times,* August 3, 2001, in *RANSAC Nuclear News*, <www.ransac.org/new-website/pub/nuclearnews/08.03.01.html>. The results of these specific inspections have not been reported. However, Rumyantsev referred in general to results of inspections in a call for more funding to protect nuclear facilities. See ITAR-TASS, "Security at Russian NPPs at risk," March 5, 2003, <www.bellona.no/en/20393.html#28877>.

[21] In August 2001 the Anti-Monopoly Ministry ruled that UES was guilty of violating anti-monopoly laws for the refusal to honor the Rosenergoatom contract. UES appealed and the legal battle has continued. The UES monopoly over the electricity exports will end once the restructuring of the power sector is complete, but that fact may be the largest impediment to restructuring. While it may seem odd that two government entities are fighting in court to settle a turf dispute, similar situations have been known to occur in the United States. Recall the snail darter incident between the Tennessee Valley Authority and the U.S. Environmental Protection Agency.

[22]Interfax, "National grid operator in favor of liberalizing electricity exports after the reform of the Russian energy industry," August 9, 2002, in UES, *News Agencies About UESR* , <www.raoees.ru/en/news/pub_uesr>.

[23] UES is collecting over 100 percent of the current electricity charges from its customers, but it still refuses to pay Rosenergoatom 100 percent. See UES, "Balance Sheet of RAO UES," *Annual Report 2001,* <www.rao-ees.ru/en/business/report2001/>, and "UES to sign debt restructuring deal with Rosenergoatom," *Power in Eastern Europe* 60 (June 2001), p. 19.

[24] UES, "Export of Electricity," *Annual Report 2000*, January 15, 2002, <www.rao-ees.ru/en/business/report2000>.

[25] Renaissance Capital, "UESR appeals Anti Monopoly Ministry ruling," *Morning Monitor*, September 19, 2001, <www.rencap.com>.

[26] See Diaconu & Maloney, "Nuclear Power," p. 86. In the scenario that gives the narrowest margin between gas and nuclear generation, the capital cost of gas turbines is assumed to be 60 percent higher than their price in the United States, and the price of natural gas is assumed to be 10 times higher than the current domestic price in Russia. Moreover, operating costs at nuclear plants are estimated to be lower than their current level due to increases in load factors. The likelihood of the best-case scenario coming into play seems remote.

[27] AlfaBank, "Mosenergo: Solid Prospects Even Without Restructuring," *Equity Market Report*, May 26, 2000, page 8. "We assume a discount rate of 25% in 2000. By 2009 we expect the risk of investing in Russia's stock market to decline to a point where the appropriate blue chip discount rate returns to its 1997 level of 16%."

[28] Minatom has spent $35 million for a major back fitting of the Leningrad-4 reactor. *NucNet News* 207 (July 3, 2001) in WNA News Briefings (June 27- July 3, 2001), <www.world-nuclear.org>. Projections have $14 million allocated in the federal budget in 2002 for operations to extend the operating lifetimes of Novovoronezh-3 and -4. Minatom announced that it plans to spend $618.4 million by 2005 in modernizing and extending the service life of its first-generation nuclear power plants. It is estimated that Russia needed about $2.3 billion to complete the four units that are partially built. Xinhua/NewsEdge Corp (May 26, 2000) in WNA News Briefings (May 24-30, 2000), <www.world-nuclear.org>.

[29] These include the BN-800 and BREST-1200 breeder reactors, conversion of the VVER reactors to MOX fuel, and the GT-MHR. Minatom announced in February 2001 that construction of the Beloyarsk-4 BN-800 reactor would be "actively restarted" in 2001 and allocated some funds for this and for the construction of Volgodonsk-2. *NucNet News* 47 (February 13, 2001) in WNA News Briefings (February 7-13, 2001), <www.world-nuclear.org>. But these projects are a long way from completion. They are discussed in more detail in the section on nuclear fuel.

[30] IEA, "Russia Energy Survey," p.182.

[31] Ministry of Atomic Power Engineering of the Russian Federation, *Strategy for the Development of Power Engineering in Russia for the First Half of the 21st Century, Principal Provisions* (Moscow: TSNIIatominform, 2000); Ministry of Energy of the Russian Federation, *Main Provisions of the Russian Energy Strategy to 2020* (Moscow: IES, 2001).

[32] IEA, "Russia Energy Survey," pp. 182-186.

[33] Milana Davydova, interview with Mikhail Ivanovich Beskhmelnitsyn, auditor from Comptroller's Office "We Plan to Audit YeES RAO in Earnest," *Gazeta* (Moscow), November 14, 2001; in "Russian Auditor Beskhmelnitsyn on Audit Schedule, Tax Evasion," FBIS-CEP-01-341 (November 14, 2001).

[34] Mikhail Klasson, interview with Rosenergoatom President Erik Pozdyshev, "Terrorists Will Not Blow Up a Nuclear Power Plants," *Vremya MN* (Moscow) October 10, 2001; in "Rosenergoatom President Discusses Nuclear Safety, Terrorist Threat," FBIS-CEP-01-423 (October 10, 2001).

[35] Interfax Daily Business Report, "UES considers attracting investment to be priority," October 22, 2001, <http://www.interfax.ru>.

[36] The internal nuclear regulatory agency is Gosatomnadzor, the Federal Inspectorate for Nuclear and Radiation Safety, currently headed by Yu. G. Vishnevskiy. This agency is widely perceived as being nothing more than a puppet of Minatom. Even so, this may be changing. We think that there are growing environmental interests in Russia (see note 20 above). These interests may be able to turn Gosatomnadzor into a more powerful regulatory force.

[37] Nikolay Gorelov, "Nuclear Privatization," *Vremya Novostey* (Moscow), November 12, 2001; in "Privatization of Nuclear Facilities Suggested To Raise Funds For Safety Improvements," FBIS -CEP-01-303 (November 12, 2001).

[38] Interfax, "Russia Could Build Nuclear Power Plant in Syria," January 14, 2003, <http://www.interfax.ru>.

[39] For an early account of the genesis of the Kudankulam deal, see Adam Moody, "The Indian-Russian Light Water Reactor Deal," *Nonproliferation Review* 5 (Fall 1997), pp. 112-122.

[40] ITAR-TASS, "Russian plant begins work on two atomic reactors for India," January 3, 2002, in FBIS -CEP-02-082, January 2, 2002.

[41]*Ux Weekly* (July 30, 2000) in WNA News Briefings (July 25–August 1), <www.world-nuclear.org>.

[42] Early reports set the figure at $2 billion. More recent reports put the figure at $1.5 billion. See ITAR-TASS, "Russia to supply two reactors for India's nuclear power station," February 12, 2002, in FBIS -CEP-02-210 (February 12, 2002).

[43] The sale has been criticized as inconsistent with the Nuclear Supplier Group Guidelines, which ban nuclear sales to states that are considered Non-Nuclear Weapon States under the Treaty on the Non-Proliferation of Nuclear Weapons, but that have not accepted International Atomic Energy Agency (IAEA) inspections on all of their nuclear activities. Russia has justified Kudankulam 1 & 2 sales as coming under a contract signed prior to this NSG rule, which was adopted in 1992, and therefore exempt from its requirements. Expansion of nuclear power cooperation with India would be difficult to justify under this exemption, however.

[44] Girish Kuber, "Russia Pledges Soft Loans for Nuclear Power Project in Tamil Nadu," *Economic Times* (New Delhi), December 6, 2001, in FBIS-SAP-01-015 (December 6, 2001).

[45] Uranium Information Center (UIC), "Construction starts on new Chinese nuclear plant," *UIC Newsletter* 6 (November/December 1999).

[46] "Russia and India entering into negotiations on a contract to draft working documentation for the Kudankulam NPP project," Nuclear.ru, November 26, 2001, <old.nuclear.ru/eng/news/full/16.shtml>.

[47] IAEA, "Power Reactor Information System," <www.iaea.org/programmes/a2/index.html>.

[48]*FreshFUEL* (March 26, 2001), p. 6 in WNA News Briefings (March 21-27), <www.world-nuclear.org>.

[49]*NucNet News* 52, (January 28, 2001) in WNA News Briefings (January 24-30), <www.world-nuclear.org>.

[50] Specifically, we assume that the equipment cost is 77 percent of the total (not counting financing), that multiunit construction enjoys a 10 percent scale economy, and that the base cost is $1.375 billion for a single unit.

[51] *Nucleonics Week* (March 21, 2002), p. 8 in WNA News Briefings (March 20-26, 2002), <www.world-nuclear.org>.

[52] The United States has strongly criticized Russia's cooperation with Iran on the Bushehr project, arguing that it provides training and skills that Iran may use to advance a clandestine nuclear weapons program and that it offers a cover for the transfer of nuclear-weapons-relevant technology. See Alena Kornysheva, "United States Gives Russia its Nuclear Waste," *Kommersant* (Moscow) September 16, 2002, p.14; in "US Seen Offering To Compensate Russia if It Halts Nuclear Cooperation With Iran," FBIS-CEP-02-279 (September 16, 2002) and also , "Iran: Russia to Build Five More Nuclear Reactors for Tehran," *Global Security Newswire*, July 29, 2002, <www.nti.org/d_newswire/issues/2002/7/29/4s.html>.

[53] Russia and the Ukraine have agreed to cooperate on the completion of the Khmelnitski-2 and Rovno-4 nuclear power plants. Russia will supply equipment, materials, and a loan, but the details of the contract are still being negotiated. The power plants are to be completed in 2-3 years at a cost of $600 million. Ukraine has also continued the talks with EBRD about a loan for the completion of the two units. *NucNet Business News* 88 (October 8, 2001) in WNA News Briefings (October 3-9, 2001), <www.world-nuclear.org>. Also, Minatom announced its intention to participate in an international bidding to build a fifth nuclear power plant in Finland. See "Russia to bid for Finnish reactor contract," Center for Nonproliferation Studies, NIS Nuclear Profiles Database, September 7, 2002<http://www.nti.org/db/nisprofs/russia/exports/general/nuexdev.htm>.

[54] "Russia sees nuclear power as key to energy efficiency, according to the federal purpose-oriented programme adopted by the Government," Russian Nuclear Site, November 28, 2001, <http://old.nuclear.ru>.

[55] Weapons-grade plutonium is seen as an "immensely valuable energy raw material that will still prove useful to Russia when reserves of natural fuel are exhausted in the world." "International Disagreements," *Segodnya* (Moscow), January 12, 2001, in FBIS-CEP0-01-178 (January 12, 2001).

[56] Most other nuclear power–using countries have abandoned the concept of a closed fuel cycle because of the poor economics of the project and the current oversupply of uranium. An OECD study in 1994 estimated that the reprocessing option is twice as expensive as the direct disposal option. OECD/NEA, *The Economics of Nuclear Fuel*, (Paris: OECD,1994). The same conclusion was reached in a French study of MOX fuel. Jean Michel Charpin, Benjamin Dessus, and Rene Pellat, *Economic Forecast Study of the Nuclear Power Option*, Report to the Prime Minister (Paris: Commissariat General du Plan, 2000), p. 99. Currently, 30 reactors in Europe are using MOX and 20 more are licensed to use it in the future, but overall support for this approach is waning rapidly. Japan also plans to use MOX in the future, but is having difficult implementing this program.

[57] "There is neither experience, nor facilities for MOX fuel fabrication for [conventional] reactors in Russia." Anatoly S. Diakov, "Disposition of weapons-grade plutonium in Russia: Evaluation of different options," Center for Arms Control, Energy and Environmental Studies at MIPT (1999), <www.armscontrol.ru/start/publications/ad0309.htm>. From the same article, Russian "experts at GosAtomNazdor (Russian Nuclear Regulation Agency) and from the Institute of Physics and Power Engineering in Obninske expressed doubts that VVER-1000 could be easily modified at moderate cost and licensed to accept plutonium fuel."

[58] The basis for further cooperation on this issue was established at the G8 Summit, June 2002, where the G8 leaders issued, "The G8 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction," Statement by G8 Leaders, Kananaskis G8 Summit, June 2002, <www.g8.gc.ca/kananaskis/globpart-en.asp>.

[59] In a December 2002 meeting with Russian ecological groups, Rumyantsev said that at the present time spent nuclear fuel comes to Russia from Bulgaria and Ukraine. He reported prices of $620/kg from Bulgaria and around $350/kg from Ukraine. "Total revenue from OYaT [Russian acronym for spent nuclear fuel] deliveries in 2002 amounted to around $50 million, of which, in accordance with legislation in effect, 25 percent of this amount must in an obligatory procedure be directed toward realizing regional ecological programs." Interfax, "Russian imports spent nuclear fuel only from Bulgaria, Ukraine," December 20, 2002, in FBIS-CEP-02-165 (December 20, 2002). Also see "Bulgaria Signs Spent Nuclear Fuel Housecleaning Deal with Russia," *RANSAC Nuclear News*, August 14, 2002, <www.ransac.org>. The latter source makes the point that some of the former communist countries that have bought nuclear fuel from Russia will become EU members in the next few years. Under EU legislation "member states of the EU can export their waste to other countries as long as the receiving country has the legal, regulatory and technical capability to manage it safely, and has agreed to the import—a position known as EURATOM Directive 92/3. Under this directive, such imports have to be authorized by the European Commission….Although the European Commission has not yet adopted any formal position on the export of spent nuclear fuel to the Russians, the line that is now generally followed, according to officials, is that Russia is not currently in a position to guarantee the safety and security of any such imports, as its facilities are thought to be inadequate for the safe management of spent fuel generated within the country."

[60] NucNet Business News (July12, 2002) in WNA News Briefings (July 10-16, 2002), <www.world-nuclear.org>.

[61] "Text of Proposal for Changes to Spent Nuclear Import Legislation," *Novaya Gazeta* (Moscow), August 4, 2002, in FBIS-CEP-02-201 (August 4, 2002). The official document, "Memorandum on the need to adopt amendments to laws regulating the import of spent nuclear fuel from abroad," has been submitted to Vladimir Putin by Yabloko Party leader Grigory Yavlinsky.

[62] Ibid., Section 1.4, "Expenditures for handling OyaT."

[63] Ibid., Section 1.1, "Cost of Creating new capacities for processing of OyaT (The RT-2 plant in Krasnoyarsk, with production capacity of 1,500 tonnes of OYaT per year)."

[64] Ibid., Section 2.2, "Presence of technology for processing fuel assemblies of the Western type."

[65] Charles Digges, "US publicly offers SNF to Russia if Moscow abandons Iran," Bellona Foundation, February 5, 2003, <www.bellona.no/en/international/russia/nuke_industry/waste_imports/28221.html>.

[66] The agreement is formally known as "The Agreement Between the Government of United States of America and the Government of the Russian Federation Concerning the Disposition of Highly Enriched Uranium Extracted from Nuclear Weapons." See United States General Accounting Office (GAO), "Nuclear Nonproliferation, Implications of the U.S. Purchase of Russian Highly Enriched Uranium," Report to the Chairman, Committee on Commerce, House of Representatives, December 2000. See also, Richard Falkenrath, "Uranium Blues," *Milken Institute Review* 2, Fourth Quarter 2000, pp. 34-48.

[67] Years ago, the United States built three uranium enrichment plants to serve the military and later to produce uranium for the nuclear power industry. The Energy Policy Act of 1992 mandated the creation of a government-owned corporation called the United States Enrichment Corporation. This corporation started to operate the energy departments of the enrichment plants in Paducah, Kentucky, and of the Portsmouth plant, in Piketon, Ohio, in 1993. The third one, at Oak Ridge Tennessee, was shut down in the 1980s. USEC was privatized in 1998; 100 million shares were offered to the public at $14.25/share. The stock price fell to $4.50 in 2000. See Falkenrath, "Uranium Blues," p. 36.

[68] Uranium with more than 20 percent uranium-235 (U-235) is HEU, but weapons-grade must be over 93 percent U-235, so it is a subset of HEU.

[69] "US and Russian Officials Give Status Report on HEU program," October 4, 2002, Center for Nonproliferation Studies, NIS Nuclear Profiles Database,<www.nti.org/db/nisprofs/russia/fissmat/heudeal/heudev.htm>. Also, GAO, "Nuclear Nonproliferation," Table 1, pp. 9 and 13.

[70] Oleg Bukharin, et al., *Helping Russia Downsize its Nuclear Complex: A Focus on the Closed Nuclear Cities*, Report of the International Conference, Princeton University, March 14-15, 2000, (Princeton, NJ: Program on Nuclear Policy Alternatives/CIS/CEES, June 2000), p. 18, footnote 19, cited an interview with Lev Ryabec, "We must save the best," *Gorodskoy Kuryer* (Sarov), March 5, 1998, as a source for the split of revenue from HEU.

[71] GAO, "Nuclear Nonproliferation," p. 5.

[72] Ibid., p. 5. USEC announced in June 2000 that, because of a global overcapacity in uranium enrichment and lower demand in an increasingly competitive market, it would cease enrichment operations at its Portsmouth facility in June 2001. In October 2000, DOE announced that it would spend some part of $630 million to maintain the Portsmouth plan in "cold standby" for five years.

[73] Ibid., p. 27.

[74] "Governments approve new HEU purchase contract," June 20, 2002, Center for Nonproliferation Studies, NIS Nuclear Profiles Database, <www.nti.org>. See also USEC, "U.S. and Russia Approve New Market-based Pricing Terms to Convert Warheads to Nuclear Fuel," News Release, June 19, 2002, <www.usec.com>.

[75] USEC, "U.S. and Russia Approve New Market-based Pricing."

[76] The details of this story come from Mikhail Trubin, "The Nuclear Mavrodi—An MMM Has Been Set Up Under the Atomic Energy Ministry's Protection," *Nezavisimaya Gazeta* (Moscow), August 12, 2002, in FBIS-CEP-02-273 (August 12, 2002) and "Investigation of the role of ERKO in a dubious NPP privatization story," *Izvestiya* (Moscow), February 13, 2002, translation by A. Dianov, U.S. Department of Energy.

[77] IBR, *Foreign Trade*, especially the interview with Mr. Valery V. Bogdan, Deputy General director of TENEX, pp. 69-71.

[78] In late January 2001, Valentin Ivanov was ousted as first deputy minister of Minatom. Shortly before, Revmir Frayshtut, director of TENEX, stepped down. Frayshtut reported to Ivanov. Sergey Leskov, "Atomic Ministry Official Dismissed for Lobbying," *Izvestiya* (Moscow), February 1, 2002, in FBIS-CEP-02-197 (February 1, 2002). Allegations of corruption were reported to us by U.S. Department of Energy officials.

[79] *Novaya Gazeta*, "Text of Proposal," point 5, appendix 1.