Non-Fossil Fuel Technologies 4

Fossil fuels dominate energy supply in the former East Bloc, just as they do in the West. Some of the major energy issues, however, concern non-fossil technologies. Nuclear safety and proliferation issues could pose global risks. Electric powerplants are key elements in the energy picture, requiring major modernization to meet environmental standards. Renewable energy is promising in the long term.

NUCLEAR POWER TECHNOLOGIES

Nuclear energy was a high priority in the Soviet Union. It was seen as an advantageous spinoff from the necessary development of military nuclear capability, an alternative to fossil fuel resources, and a symbol of modernity. The role that nuclear energy plays in each country is listed in chapter 2.

This report discusses two major considerations relating to nuclear energy. The first is safety. Soviet reactors have proved to be substantially less safe than Western reactors. As Chernobyl has shown, a major nuclear accident can threaten millions of people, even hundreds of miles away. However, improving safety is difficult, complex, and often expensive.

The second is nuclear weapons proliferation. Soviet weapons, materials, or expertise could become available because of potentially inadequate control in the former Soviet Union (FSU). Analyzing that risk is beyond the scope of this report. However, research and analysis on nuclear safety in the civilian sector is a logical area for employing former weapons designers, thereby reducing the danger of proliferation.

There are other nuclear power issues such as economics, public acceptance, and nuclear waste. Nuclear waste is already a subject of technological cooperation between the United States and Rus-

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sia but is beyond the scope of this study. Some critics believe that nuclear power should be phased out as quickly as possible, and that any cooperation that will tend to prolong its use here and in the former East Bloc is undesirable. This section neither accepts nor rejects that view. It merely lays out the issues related to nuclear reactor safety and weapons proliferation and discusses what can be done to address them.

| Nuclear Safety

The pattern of nuclear power technology development in the Soviet Union was similar to that of the United States: maritime and small power reactors were constructed in the 1950s; pressurized water reactors (PWR) and boiling water reactors (BWR) were tested in the 1960s; and widespread deployment occurred in the 1970s. However, Soviet nuclear designs were largely indigenous, unlike almost all other reactors in the world that were derived from U.S. technology. Therefore, Soviet reactor designs, although based on similar concepts, evolved quite differently from those in the West. Furthermore, the institutional environment for designing, constructing, and operating nuclear powerplants was completely unlike anything in the West.

Western observers have generally concluded that the reactors in the former East Bloc are significantly less safe than Western reactors. The explosion at Chernobyl and other accidents have reinforced this view. The disruption from the breakup of the Soviet Union and the economic crisis affecting the entire region have aggravated the problems as Russian operators and engineers have returned home and spare parts have become unavailable.

Since the Chernobyl accident in 1986, Western countries have increased efforts to reduce the risk of another major accident, particularly one on the scale of Chernobyl. Even an accident that disabled a reactor with very little offsite contamination, such as at Three Mile Island, would be a major economic blow to a region the United States is trying to help.

Some reactors had been scheduled to be shut down, largely for safety reasons, but economic realities have made this difficult. All these countries suffer from severe energy shortages, and nuclear reactors have been an essential element in keeping electric power available. As noted in chapter 2, in six of these countries, nuclear is a higher fraction of the power supply than in the United States (about 20 percent). Shutting reactors down without adequate alternatives (new generating capacity or improved efficiency of electricity use) would aggravate the economic crisis. None of these countries can afford to replace all operable but risky plants with new ones. Even Ukraine, with its special sensitivity toward nuclear safety, has deferred the planned shutdown of the two remaining Chernobyl reactors and may consider repairing the Unit 2 reactor, which was severely damaged by fire in 1990 (the 1986 explosion destroyed the Unit 4 reactor). In addition, Armenia is giving serious consideration to rehabilitating two reactors shut down because of safety concerns following a major earthquake in 1988.[1] The only other recent shutdowns for safety reasons have been in the former East Germany.

Nuclear safety is a complex subject. Accidents can arise from a variety of faults involving design, construction, operation, and maintenance. While there is no consensus in the United States about how safe reactors are, or how safe they should be, regulation and public involvement has been much stronger than in the former East Bloc. There has been exhaustive analysis of reactor designs here

[1] The damage then was slight, and the reactors were still operable. However, the powerplant was not very close to the earthquake epicenter. Apparently, it was decided then to close the reactors because they might not ride out a stronger earthquake. More damage has occurred from subsequent deterioration, and seismic resistance must be upgraded.

and in other Western countries, a process for learning from mistakes, and considerable incremental improvement.[2] Operations and maintenance have also improved, as evidenced by the greatly improved performance of U.S. reactors.[3]

Evaluation and comparison of reactors based on different technology and under different regulatory and institutional systems are much less certain. However, it does appear that the evolutionary improvement experienced in the West was not duplicated in the Soviet Union. Reactor designs were improved, but not as rapidly. There does not appear to have been an organized policy for backfits to address safety deficiencies as they were identified,[4] or even a strong regulatory authority. Operations and maintenance were never held to high standards, and are actually slipping, in part due to the economic crisis.

However, the situation is not entirely grim. The Soviet-built plants in Hungary and Finland have been among the most reliable in the world.[5] Furthermore, there are different approaches to safety. Soviet reactors have some advantages and can, at least in theory, achieve safety levels equivalent to Western reactors. Except for basic items such as containment vessels and emergency core cooling systems, the presence or lack of a specific safety feature does not necessarily greatly affect overall safety. Each reactor must be analyzed in its entirety. U.S. assistance must be designed to account for specific technological needs, for the recipient's ability to make use of the assistance, and for the role that nuclear energy plays in each country.

Improving safety in operating reactors requires a variety of activities:

- identifying and fixing specific problems on individual reactors,
- enhancing analytical skills and regulatory expertise and authority,
- upgrading operations and maintenance of reactors,
- infusing the entire enterprise with a commitment to excellence.

This section reviews the safety problems of reactors in the former East Bloc and what can be done about them by the United States and other Western countries. It identifies specific technologies and expertise that would be useful in reducing risks and the current activities to transfer them.[6]

Design Safety Problems

Two main types of reactors were produced by the FSU—the RBMK and the VVER (both are Russian acronyms). The RBMK is graphite moderated and water cooled. Its fuel assemblies are in tubes inside graphite blocks, somewhat like the high-temperature gas reactor (HTGR). Water flows up through the tubes and emerges as a steam/water mixture. The steam is separated and drives a turbine, as in a BWR. Spent fuel is re-

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[2] These issues were discussed in: U.S. Congress, Office of Technology Assessment, *Nuclear Power in an Age of Uncertainty*, OTA-E-216 (Washington, DC: U.S. Government Printing Office, February 1984). Subsequent developments have largely confirmed that analysis. Also see: U.S. Congress, Office of Technology Assessment, *Aging Nuclear Powerplants: Plant Life and Decommissioning.* OTA-E-575 (Washington, DC: U.S. Government Printing Office, September 1993).

[3] Institute Of Nuclear Power operations, *Annual Report 1993*, " 1993 Performance Indications for the U.S. Nuclear Utility Industry," March 1994.

[4] U.S. Department of Energy, *Department of Energy's Team's Analysis of Soviet Designed VVERs*, DOE/NE-0086 (Washington, DC: ~t ber 1988).

[5] Reliability and safety are not equivalent. A reactor can achieve high reliability if i! is operated despite safety problems—until an accident occurs. However, under a stringent safety regime, (here is a significant correlation between the two because many of the measures needed to improve safety (e.g., intensive operator training and scrupulous maintenance) also improve reliability.

[6] Further detail is included in Richard Wilson, "Nuclear Power Safety in Central and Eastern Europe," OTA contractor report, (September 1993).

TABLE 4-1: RBMK Reactors in the Former East Bloc

Russia	Model	start operation	MWe
Kursk 1	1	*1976*	1000
Kursk 2	1	1978	1000
Kursk 3	2	1983	1000
Kursk 4	2	1985	1000
Leningrad 1	1	1973	1000
Leningrad 2	1	1975	1000
Leningrad 3	2	1980	1000
Leningrad 4	2	1981	1000
Smolensk 1	2	1982	1000
Smolensk 2	2	1985	1000
Smolensk 3	3	1990	1000
Ukraine			
Chernobyl 1	1	1971	1000
Chernobyl 2	1	1971 (shutdown)	1000
Chernobyl 3	2	1975	1000
Chernobyl 4	3	1983 (destroyed in 1986)	1000
Lithuania			
Ignalina 1	2	1983	1500
Ignalina 2	2	1986	1500

SOURCE: Richard Wilson, '(Nuclear Power Safety in Central and Eastern Europe," OTA contractor report, September 1993.

placed while the reactor is operating, unlike U.S. reactors, which must be shut down for refueling.

The RBMK design evolved from early plutonium production reactors. It was never built outside the Soviet Union, possibly because of concerns that it could be used to generate weapons-grade plutonium. The reactors at Chernobyl in Ukraine are of this type. The design has no direct counterpart in the West. RBMKs exist in Russia, Ukraine, and Lithuania. In addition to these operating reactors, construction has ceased or slowed at Kursk 6, Smolensk 4, and Ignalina 3, in part because of public opposition following the Chernobyl accident.

The second type, the VVER, is similar conceptually to the PWR, the dominant reactor of the West. It is water moderated and cooled, and evolved from reactors used for icebreakers and submarines. This reactor has been exported, including to Finland, Hungary, and Bulgaria. The former Czechoslovakia later assimilated the design and constructed several independently. Several models are extant. The oldest is the 440/230, which was followed by the 440/213, both at 440 megawatts of electricity (MWe). The latest model is the 1000 MWe VVER-1OOO.

Tables 4-1 and 4-2 list the reactors of greatest concern. These tables do not include other types of reactors, such as the Canadian-built heavy-water reactors in Romania.

There are two main areas of concern with the RBMK: core neutronics and the hydraulics of the pressure tubes. The first refers to the nuclear reactions in the core. The RBMK has a positive void coefficient, meaning that if water is lost from the core, the reaction tends to speed up. Both water and graphite are moderators (which slow neutrons so that they will be more likely to cause another fissioning when they strike a uranium atom), but water also absorbs some neutrons. Western reactors are designed so that water must be present for the reaction to continue. If some is removed from the core, either through excessive boiling or a loss-of-coolant accident, the reactor will shut down (a characteristic known as a negative void coefficient). This is an inherently stable design, and such stability was a prime criterion in the early days of nuclear energy, when many different reactor concepts were investigated.[7] In the RBMK, graphite provides all the necessary moderation. As water is lost, the number of neutrons increases

7 U.S. reactors are inherently safe in terms of the chain reaction; the reactor will automatically shut down the chain reaction If coolant is lost. The major safety problem following a loss-of-coolant accident comes from decay of the fission products—the highly radioactive waste from the chain reaction. Fission products produce sufficient heat as they decay that the reactor fuel can melt (as at Three Mile Island) unless cooling is maintained.

TABLE 4-2: Older VVER Reactors in the Former East Bloc

	Unit	Model	Start operation
Armenia			
Armenia	1	230	1977
	2	230	1980
Bulgaria			
Kozloduy	1	230	1974
	2	230	1975
	3	230	1980
	4	230	1982
Czech Republic			
Dukovany	1	213	1985
	2	213	1986
	3	213	1986
	4	213	1987
Hungary			
Paks	1	213	1983
	2	213	1984
	3	213	1986
	4	213	1987
Russia			
Kola	1	230	1973
	2	230	1974
	3	213	1982
	4	213	1984
Novovornezh	3	230	1972
	4	230	1973
Slovakia			
Bohunice	1	230	1978
	2	230	1980
	3	213	1984
	4	213	1985
Mochovce	1	213	1994
Ukraine			
Rovno	1	213	1980
	2	213	1981

SOURCE Richard Wilson, "Nuclear Power Safety in Central and Eastern Europe," OTA contractor report, September 1993

because absorption decreases, thereby increasing the chain reaction. Under some conditions, such as occurred at Chernobyl Unit 4, this is an inherently unstable design: the chain reaction can multiply rapidly, leading to an explosion. This accident might have been prevented had the design precluded too many control rods from being withdrawn from the core, or if operators had been thoroughly trained to recognize the risk.[8]

The obvious solution is to remove enough graphite so that the reaction shuts down if water is not present. However, this would be extremely difficult in an existing reactor that is structurally dependent on the graphite and where all work would have to be done by remote control. Fixed neutron absorbers (to supplement the movable control rods) are being installed in the cores instead, and the operational reactivity margin is being increased. Improved monitoring and controls would also be beneficial.

Two other weaknesses are already being corrected. First, each control rod had a graphite tip to match the surrounding moderator below the core when fully inserted. Unfortunately, control rods are reinserted from the top, and this graphite tip adds to the core reactivity as it passes through, apparently the proximate cause of the Chernobyl explosion. These rods can be modified to remove the extra graphite, but it has not yet been confirmed if all RBMKs have been modified.

The second correction was to add a fast-acting scram system to all RBMK reactors. The original shutdown rods were suspended by a cable that winds around a drum. About 20 seconds were required to insert the rods. The new system will allow a much faster shutdown in case of emergency, possibly forestalling a major accident.

The major hydraulic concern is over the possibility of fuel channel rupture. These tubes are at high pressure, and rupture can have serious consequences. Reactivity increases, as discussed above; and, if several tubes rupture simultaneously, pressure in the cavity below the reactor cover can increase enough to lift the head off, breaking all the tubes and lifting out the control rods, as happened at Chernobyl. Additional pressure relief capacity is being added to reduce, though not eliminate, this risk. Russian RBMK specialists

[8] Richard Wilson, *Nuclear Power Safety*, pp 7-8,

contend that there are no mechanisms by which several tubes could rupture simultaneously (common mode failure). Detailed analysis is required to verify this conclusion, since the consequences of such a failure would be catastrophic. Only three tube ruptures have occurred in the entire operating experience of RBMKs, indicating that a multitube rupture is a low-probability event. The U.S.-pioneered probabilistic risk assessment (PRA) could be very useful in quantifying this risk. In addition, steps to reduce the risks that any tubes will rupture are warranted. Improved testing, monitoring, and valve systems are under consideration.

The oldest VVER reactors, the 440-megawatt model 230, lack some of the basic safety features of Western reactors, in particular, emergency core cooling systems (to keep the core from melting after a loss-of-coolant accident) and containment vessels (to prevent the escape of radioactive materials after a severe accident). Pipe breaks that could be handled easily by a Western reactor would cause a serious accident in one of these reactors. It is not practical to install these safety features on an existing plant. Furthermore, the reactor vessel is susceptible to radiation-induced embrittlement, introducing the risk of a fracture in the vessel such that any core cooling would be impossible. Finally, these reactors were not designed for the level of seismicity that exists at some sites, including Armenia (especially the older Unit 1) and Bulgaria.

However, it also should be noted that even the older Soviet reactors have some positive features, including a large water inventory and a low power density. These features can help them ride out problems such as "station blackout" (extended loss of power to run the pumps that cool the core) that could cause accidents at U.S. reactors. In addition, while lacking a containment vessel, the model 230 has an "accident localization system," which condenses steam and reduces the release of radioactivity following the break of most pipes in the reactor system.

The newer model 213 included an emergency core cooling system and an improved accident localization system, but not a full containment except when sold abroad to Finland and Cuba (construction of Cuba's two reactors has been suspended). This reactor could withstand a considerably larger pipe break than the model 230. The reactor vessel was also improved.

A comparison of key features of the 440 with standard U.S. PWRs is shown in table 4-3.

The VVER-1OOO design incorporates a full containment vessel and rapid acting scram systems. In other ways it is also more like a Western PWR. With some modifications, such as increased fire protection and improved protection of critical instrumentation and control circuits, this design might approximate Western safety standards.

Other Safety Issues

Even well-designed plants can be risky. Sloppy construction can result in unexpected weak points or in unexpected behavior. Poorly trained operators can turn a minor mishap into a major accident. Inadequate maintenance can allow deterioration of critical systems. Safety is primarily a function of people—people operating and maintaining the plant well and being prepared to catch problems before they become serious, people analyzing plants to recognize a deficiency before it causes any problems, and managers farsighted and tough enough to insist that their organizations do things right. Not only are well-operated plants safer, but they can function more smoothly, producing more power, which can be critical during this period of energy problems.

In this regard, most Soviet nuclear plants appear to have significant problems. Quality control was weak in many industries in the Soviet Union, and nuclear plants do not appear to be the exception. Construction was poor, regulation almost nonexistent, and no one seems to have been in charge of ensuring that safety was paramount. Although less easy to document than design problems, operating problems can present even greater safety risks. Russian plants operated at a consis-

TABLE 4–3: Summary Comparison of VVER–440 with Typical U.S. PWR Accident Mitigation Features

System or function	VVER-440 model V230	VVER-440 model V213	Two loop U.S. PWR
Reactor Protection System	4 systems	Same as model V230	2 independent, multifunction systems. Ten separate trips input to an interlock for additional reactor trip.
Emergency Core Cooling System (ECCS)	No Emergency Core Cooling System. Periodic water makeup system provides limited replenishment of primary coolant emergency.	Three high-pressure injection pumps. Three low-pressure shutdown cooling pumps.	Safety Injection (S1) system. Two high-pressure, two low-pressure pumps.
Emergency Feed-water (EFW) System	None.	Two pumps. Two supplementary EFW pumps.	Two subsystems
Emergency Power Sources	Two 6kV diesel generators, One is assumed to run continually.	Three 6 kV diesel generators. One is in hot standby, one in cold standby, and one in reserve.	Two emergency diesel generators.
	Two 220V DC station batteries.	Three 220V DC station batteries.	Two fully redundant 125V DC systems and station batteries.
Localizatlon/Contain merit System	Accident localization system. Pressure suppression by means of spray system,	Accident localization system. Pressure suppression by means of bubbler tower and spray system.	Full containment for primary system.
Spray System	Spray pumps discharge into the accident localization system.	Three spray pumps.	Two pumps.
Missile Barriers	None.	None.	Concrete missile shields.
Combustible Gas Control	None.	None.	A hydrogen gas control system.
Post Loss-of-coolant Accident (LOCA) Decay Heat Removal	Decay heat removal heat exchangers in spray systems.	Decay heat removal heat exchangers in ECCS/spray system.	Decay heat removal using reactor heat removal system with containment spray system.

SOURCE Derived from U S Department of Energy (DOE), *Department of Energy's Team's Analysis of Soviet Designed VVERs*, DOE/NE-0086, October 1988

tently high level from 1990 through 1993.[9] However a good operation record is no guarantee against operating failures (as at Chernobyl).

An essential element in assuring safe operation is instilling a culture of excellence in the entire enterprise in each country. Unfortunately, this is the most difficult form of technology transfer to define and to transfer. Yet it is critical because nuclear plants have to be built and operated to the highest standards to be both productive and safe.

[9] *Nuclear* Engineering *International*, vol. 39, No. 478, May 1994, p.15.

Such standards cannot be imposed solely by regulations; they require a voluntary commitment by everyone involved. The U.S. industry has made great improvements in achieving this dedication, but continuing poor performance at some U.S. nuclear stations indicates that the lessons have not been fully assimilated here.

Assimilation of a culture of excellence will be even more difficult in the former East Bloc. To some degree, the commitment will be encouraged by the previous activities. It can also be promoted by frequent contacts between individuals in various Eastern and Western nuclear enterprises, especially at the powerplants. Encouraging visits of operators to U.S. nuclear powerplants for training and exposure to U.S. procedures will be a significant help.

Safety Assistance

U.S. safety assistance comes both directly from the Federal Government and through other agencies and private organizations. The U.S. Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC) got involved after the Chernobyl accident with a review of reactor designs to identify safety deficiencies and discussions with Soviet nuclear officials. This activity has continued with the VVER reactors.

A Joint Coordinating Committee for Civilian Nuclear Reactor Safety (JCCCNRS) was established in accordance with a 1988 memorandum of cooperation between the United States and the Soviet Union. NRC and DOE are the main U.S. members. Following the breakup of the Soviet Union, this agreement was redirected to both Russia and Ukraine and extended for 5 years. There is no agreement with Armenia, Lithuania, or Kazakhstan, which has an experimental liquid metal reactor and a nuclear desalination plant. Negotiations are currently under way. The NRC has agreements with Hungary, the Czech Republic, and Slovakia.

The JCCCNRS has established a variety of working groups, which met with their Russian counterparts for information exchanges. The four current groups address:

- radiation embrittlement, structural integrity and life extension of reactor pressure vessels,
- severe accidents,
- health effects and environmental considerations,
- plant aging and life extension.

The U.S. program shifted from cooperative exchanges to specific assistance after the May 1992 conference in Lisbon on assistance to the New Independent States. The "Lisbon Initiative" includes:

- operational safety improvements for the VVER-440/Model 230 reactors, including training and emergency procedures,
- establishing a regional training center in both Russia and Ukraine, including computer-based simulators,
- modifications to reduce risk at selected RBMK and Model 230 reactors,
- fire safety, starting with two plants in Russia and Ukraine, and
- improving regulation and safety standards.

Improved training, maintenance, and other procedures can partially compensate for equipment and manufacturing deficiencies. Well-trained operators can avoid damaging mistakes and can react appropriately to incipient accidents. The NRC is providing advice and assistance to the emerging regulatory agencies, while DOE has focused on activities to assist operations. The U.S. program includes training of operators and regulators, exchanges of information and people, including a program with U.S. utilities coordinated by

10 Similarly, a properly designed and built reactor is less likely to suffer a major accident even if operated ineptly. However, because of the potential consequences of a major accident, all reactors should be designed, built, and operated to the highest standards. Unfortunately, most Soviet reactors fail all three of these standards.

the Institute for Nuclear Power Operations (INPO), an entity organized by the U.S. industry following the accident at Three Mile Island. These programs have brought Russian and Ukrainian operators to this country to visit U.S. powerplants and vice versa. Recently, equipment to enhance safety has been purchased.

One of the largest and most useful U.S. financial contributions to date has been for reactor simulators. These devices are extremely helpful in training reactor operators by simulating normal and accident conditions. Operators can practice and become proficient in handling events only rarely experienced at actual reactors. Soviet simulators had been for routine operations only. Abnormal events are much more complicated to simulate. U.S. assistance was important in the construction of an RBMK simulator now at Smolensk (Russia) and a VVER 1000 simulator at Zaporozhye (Ukraine).

Regional training centers now being established will be at Balakovo in Russia and Khmelnitskiy in Ukraine (both sites operate VVER- 1000 reactors). The United States is funding the development of training programs and simulators at the centers. Both should become operational by early 1996.

U.S. help is also important in preparing a manual for emergency operating procedures for the Novoronezh VVER 440/230 reactor. This is intended as a prototype for other reactors in Russia.

Inadequate fire protection is a major deficiency. The Soviets had not paid much attention to fire safety, and even systems that were supposed to be fireproof turned out to be flammable (a problem not unknown in the United States). There have been several serious fires in Soviet reactors. U.S. personnel have inspected Russian and Ukrainian plants and made recommendations for upgrades, some of which are surprisingly basic, such as replacing wood fire doors at Smolensk with steel doors.

Total funding supplied by the U.S. Agency for International Development (AID) for nuclear safety assistance was $25 million in fiscal year 1992 ($22 million for DOE, the rest for NRC) and $19 million in fiscal year 1993 ($14 million to DOE the rest for NRC). In addition, reactor simulators cost $11 million in fiscal year 1993 (funds supplied by the Department of Defense). Congress has appropriated $100 million for fiscal year 1994. This funding should permit some limited safety upgrades at reactors.

The regulatory assistance by the NRC is designed to fill a major void. None of the East Bloc countries had a strong, independent regulatory agency that had the authority to shut down unsafe plants unilaterally. However, Hungary, Bulgaria, and the Czech Republic have regulatory bodies sufficiently strong to get high-level government attention paid to safety concerns. For example, the Bulgarian regulatory body has twice been able to get reactors shut down.

In May 1993, Presidents Clinton and Yeltsin agreed to establish the Joint Commission on Technological Cooperation in Energy and Space. The commission is chaired by Vice President Gore and Prime Minister Chernomyrdin of Russia. Improving nuclear plant safety and regulation will be major interests of the commission. The commission has agreed to a joint study on Russian energy alternatives (funded by AID) to set the context for decisions on reactor safety.

The United States has supplied only a small part of the total assistance. The International Atomic Energy Agency (IAEA) provides active help. An IAEA inspection team alerted the West to the very dangerous situation in the older Bulgarian reactors in 1991. It is analyzing other former East Bloc reactors to determine the need for upgrades. However, the IAEA does not have the resources or mandate to supply more than advice. Moreover, the United States has opposed giving the IAEA a more forceful regulatory role on the grounds that safety regulation is a national role.

The European Union has allocated a total of about $500 mill ion for nuclear safety teams to visit reactors and install equipment to improve safety, including $13 million for upgrading Bulgarian reactors.

The Group of 7 Industrialized Nations (G-7) agreed in March 1992 on an action plan to upgrade the safety of Soviet-designed reactors. In Decem-

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The Temelin Nuclear Powerplant, a VVER-1000 under construction in the Czech Republic with major assistance by Westinghouse Electric Corp.

ber 1992, (after extensive negotiations) the G-7 agreed to establish a fund for upgrading reactors in the former East Bloc. A total of 118.4 million ECU ($136 million) has been contributed so far, led by Germany (ECU 31.4m), the European Union (ECU 20m), and France (ECU 15m). The United States has contributed ECU 2m.[11] The fund, called the Nuclear Safety Account (NSA), is administered through the European Bank for Reconstruction and Development (EBRD). The first grant (about $28 million) has gone to Bulgaria for upgrades to the Kozloduy reactors. The grant was contingent on Bulgaria indicating its intention (but not pledging) to close units 1 and 2 by 1997 and 3 and 4 by 1998. Reliable alternative power should be available by then, including Kozloduy units 5 and 6. This grant will pay for fire protection, inspection equipment, safety valves, electrical components, a new emergency feedwater system, and control room equipment. The second grant, $38 million in February 1994, was for Lithuania to upgrade the Ignalina RBMK plant with new instrumentation, fire protection, and a training simulator.

The World Association of Nuclear Operators (WANO), essentially an international INPO, is also encouraging the exchange of safety information and expertise. WANO's U.S. office is colocated with INPO.

■ Nuclear Weapons Proliferation

One of the most serious threats to international stability resulting from the breakup of the Soviet Union is the possibility that nuclear weapons may fall into the hands of irresponsible, hostile nations, or even terrorist groups. Even if the weapons themselves are adequately safeguarded, special nuclear material (plutonium or highly enriched uranium), parts, or expertise for weapons manufacture may become available.

As weapons are dismantled, large amounts of plutonium and highly enriched uranium (HEU) are removed. This material must either be protected or burned up in a reactor. HEU can be used as fuel in conventional reactors by blending it with ordinary uranium, resulting in low-enriched uranium. HEU has substantial value since its use replaces the normal enrichment process. The United States has offered to purchase such uranium from the FSU, in part to encourage the dismantlement of weapons. However, some details of the agreement still need to be resolved. Plutonium is more difficult to use in commercial reactors because its use changes the fuel cycle and requires stringent safeguarding. If it is not used to generate power, it must be indefinitely stored and carefully guarded. Russia plans to build a large storage facility for both HEU and plutonium from weapons and is studying options for plutonium disposal. These issues, including cooperation with Russia on dismantlement, are discussed in a recent OTA report.[12]

Much smuggling has been reported from the FSU, including some nuclear materials, though no

[11] E@ *European Energy Report*, "Nuclear Safety Account Grants Lithuania's Ignalina Leeway" Issue 29, February 1994, pp. 4-5.

[12] U.S. Congress, Office of Technology Assessment, *Dismantling the Bomb and Managing the Nuclear Materials*, OTA-O-572 (Washington, DC: U.S. Government Printing Office, September 1993).

significant transactions of nuclear weapons or weapons-grade materials have been documented. Many observers are very concerned because the economic and political disruption may have reduced the effectiveness of controls. Military personnel, civilian workers in arms plants, and nuclear weapons scientists are suffering from the overall economic problems as well as the partial demilitarization. It is possible that someone may be tempted to sell out to a renegade nation engaged in a clandestine nuclear weapons program.

Russia has inherited the nuclear weapons state status of the Soviet Union, but three de facto weapons states (Ukraine, Belarus, and Kazakhstan) have been created, at least temporarily. Leaders of these three have promised to turn their weapons over to Russia, but this agreement has proved difficult to put into practice, especially in Ukraine. This diffusion of authority further complicates control.

Ukraine's large civilian nuclear infrastructure presents an additional complication. To become a nonweapons state, Ukraine must not only give up its weapons but place its civilian nuclear plants under international safeguards to ensure that nuclear materials are not diverted. Ukraine's large civilian nuclear program will place an additional burden on the IAEA.

In Russia, the military and civilian nuclear sectors are both within the Ministry of Atomic Energy, and some nuclear facilities have dual purposes. For example, the Tomsk reactors were built to produce plutonium, but they also supply steam for the city's district heating plant. Russia no longer needs the plutonium but hasn't yet closed the reactors because the heat is still needed.

Using unemployed weapons scientists and engineers in the nuclear power industry could be a constructive way to reduce the likelihood that they may contribute to proliferation. Improving nuclear safety will entail considerable research and analysis. Many of the weapons scientists and engineers have expertise that would be useful in reactor safety. However, it is not clear how many can make the transition to an enterprise with very different objectives and constraints. Developing an industrywide commitment to excellence may be easier with new employees than with retrained weapons experts. Using the weapons experts in research and development may be the best solution.

The United States and several other countries have agreed to fund two international science and technology centers, in Moscow and Kiev, to provide constructive work for former weapons scientists and engineers. Ratification of the agreement stalled in the Russian Parliament, but President Yeltsin promulgated it in December 1993. Ratification is even less advanced in Ukraine. If this center cannot be maintained, alternative mechanisms could be considered, such as direct R&D cooperation with existing institutions.

A forthcoming OTA report, *Proliferation Issues and the Former Soviet Union, will* discuss these issues in more detail.

Considerations for the Future

Current activities will help reduce nuclear safety risks, but they are not proceeding as rapidly as desirable. Recipients have generally praised the United States for the effectiveness of its assistance. However, coordination among multilateral donors could be improved. Funding for projects to improve safety, especially for expensive plant modifications, has been slow. In fact, nuclear officials in the former East B1OC reportedl y are getting quite tired of visits that seem more intended to procure information than to supply help.

The first question is how hard to push for the closure of the oldest, riskiest reactors (RBMKs and VVER/230s). It is clear that these reactors are well below Western safety standards. However, the actual level of risk is not well enough understood to permit an analytical comparison of the costs and benefits of shutting them down. The countries that operate them are reluctant to close them because they see the energy as vital until replacement power is available. Chronic energy shortages are very debilitating for an economy and pose their own risks to public health and safety. '3 A case can be made that the nuclear risks must be high before a responsible government should close plants and thereby subject its people to a significant, long-term shortage.

No one really knows if the risks of another Chernobyl accident are that high. Chernobyl Unit 4 was grossly abused during a unique test. Such conditions are unlikely to be repeated. Thus, this one accident is not necessarily a guarantee that others will follow. The first PRA is only now being done for the RBMK, but it probably will be years before the data are adequate for an overall risk evaluation. PRAs are useful only if they consider the design, the quality of the components, and the behavior of the operators. The latter two factors require extensive databases for valid analyses.

However, there is no controversy over the conclusion that the RBMKs are much more prone to accidents than Western reactors, and that such accidents are more likely to turn into catastrophes because of the lack of containment and the limited accident mitigation capability. **If** the risk of a major accident is one in a thousand years of operation (a very high risk level, which is assumed here for illustrative purposes), then the 15 RBMKs collectively present a risk of 1.5 percent per year. If they are operated for another 10 years, there is about a 14-percent chance that one of them will suffer another major accident. While that means that there is better than a five out of six chance that an accident won't happen, the risk is much too high by Western standards, especially if the consequences of the accident would be equivalent to that of Chernobyl. More accurate risk analysis is important for improving our understanding of the problem. However, analysis should not be a substitute for action in making needed improvements in reactors that are likely to continue operating.

Replacement power would probably involve either natural gas or coal or the completion of newer, safer reactors currently under construction. Building new powerplants, even gas turbines, is very expensive, and none of these countries has the funds to do that. The World Bank suggested that $18 billion would be required to replace the plants by 2000, exclusive of fuel costs. None of the gas-importing countries can afford to pay for the gas they already need, and Russia would prefer to export the gas for hard currency rather than bum it at home. Coal plants are much more expensive to build than gas plants, and would require additional funds for the pollution control systems (e.g., flue gas desulfurization) necessary to avoid worsening the environmental devastation in the region.

An alternative would be to emphasize energy efficiency to reduce the demand for electric power. As discussed in a prior OTA report", the potential for efficiency gains is huge in all the formerly centrally planned economies. Aggressive efficiency programs almost certainly could reduce demand for electricity significantly, at least until economic growth resumes. With a surplus of generating capacity, local policy makers can decide which plants to shut down, based on economics, safety, public concern, environmental considerations, and national priorities. When all these factors are taken into consideration, nuclear plants might or might not be the highest priority to shut down. They are generally cheaper to operate than fossil-fuel plants, and pollution from coal and some oil-fired plants is very damaging. The risk of a nuclear accident at any individual reactor site must be weighed against the costs of closing it. Although

[13] U.S. Congress, Office of Technology Assessment, *Physical Vulnerability of Electric Systems to Natural Disaster and Sabotage*, OTA-*E-453* (Washington, DC: U.S. Government Printing Office, June 1990).

[14] U.S. Congress, Office of Technology Assessment, *Energy Efficiency Technologies for Central and Eastern* Europe, OTA-E-562 (Washington, DC: U.S. Government Printing Office, May 1993).

the collective risk appears high, the risk entailed by anyone plant may not appear unreasonably high to its operator.

For the time being,it appears likely that most or all of these reactors will continue to operate unless the West contributes far more assistance than it has yet considered. Upgrading thereto Western safety levels would be even more expensive than replacing them—$24 billion, according to the World Bank. One possible compromise may be to provide grants to upgrade the newer plants and correct the worst problems in the older plants, with closure of the latter as soon as practical, as is planned for the NSA grant to Bulgaria. Until recently, it had been assumed that several of the riskiest plants, such as the two operable reactors at Chernobyl, would be shut down soon. Thus, little has been done to upgrade their safety. The recent Ukrainian decision to continue operations results in the worst possible situation, at least until the modifications at other RBMKs are implemented there, too. Ukraine has agreed to shut the reactors down when the power is no longer needed but has not committed to a firm schedule.

Increased assistance would have several advantages, most obviously in reducing the risk of a serious nuclear accident. It would also provide business opportunities for the U.S. nuclear industry, possibly leading to even greater sales later. The sale of instrumentation and control systems and nuclear fuel for two Czech reactors by Westinghouse Electric Corp. is an example of the type of business that may emerge (see box 4-1). For Westinghouse, the Temelin project represents not only a foothold in the market, but also a demonstration project to convince other countries in the region, most notably Russia and Ukraine, of the effectiveness and need for such comprehensive modernization programs.

The market in the West for nuclear power generation technology is flat, but the former East Bloc, which includes 25 percent of the world's pressurized light water reactors, represents a potential multibillion-dollar market. Supplying equipment and services to foreign reactors helps U.S. companies remain in business, which would help keep U.S. reactors on line and increase the possibility of a nuclear revival later. Whether this is an advantage or a disadvantage depends on one's views of nuclear power.

One barrier to material assistance in the FSU is the concern of companies installing safety upgrades that if an accident happens despite the upgrade, the Western company could be held liable for all damages. Since the cost of the damages could far exceed the value of the business involved, companies will insist on limiting their liability. This has been done in the United States with the Price-Anderson Act, which also provides a no-fault mechanism for reimbursing those hurt by a nuclear accident. Negotiations are underway with Russia, Ukraine, and the Baltics to address this issue, and some agreements have been reached on liability provisions for U.S. companies providing assistance.

Increased assistance could also provide opportunities for former weapons scientists and engineers to work on constructive projects using their expertise. If these experts can be employed in nuclear reactor safety efforts, proliferation risks will be reduced. The creation of one or several centers for nuclear safety analysis could provide the double benefit of producing useful information and contributing to international stability.

There are two main disadvantages to increased assistance. First, the cost would increase commensurately at a time of serious U.S. budget constraints. Second, some people believe that no amount of improvement can make these reactors sufficiently safe and advocate shutting down at least the riskiest ones in the very near future; any remedial measures could prolong their operation and thus be counterproductive. Some critics object to assistance because it would support the industry in this country or promote its prospects. Thus, any proposal to increase support is likely to be controversial.

Opposition emerged to the Westinghouse sale to the Czech Republic, in particular to Eximbank (the Export-Import Bank of the United States) financing. The Austrian government prepared and

BOX 4-1: The Temelin Nuclear Powerplant

After the collapse of the Communist government in 1989, the Czech Power Co. (CEZ) had to decide whether to complete construction of a Soviet-designed WER 1000 nuclear powerplant at the village of Temelin. Units 3 and 4 were canceled because the power was not needed, but units 1 and 2 were more than 50 percent complete. A safety review determined that modifications were necessary to upgrade the plant to Western standards. CEZ decided that the cost of modifying and completing the two reactors was reasonable. Furthermore, the plant would have environmental advantages since up to 2,000 MWe of coal-fired capacity in Bohemia could be closed, eliminating a major source of pollution in a heavily polluted section of the country.

The utility solicited competitive bids for new instrumentation and control (I&C) systems and nuclear fuel. Westinghouse Electric offered the West's most advanced technology at competitive prices and won the contract. In May 1992, the company signed a $419-million contract to provide new I&C and Western-manufactured fuel for the Temelin plant. Westinghouse applied for a $31 7-million Eximbank guarantee for a loan from a consortium of commercial banks.

Opposition to the project developed, primarily over safety concerns. The government of Austria protested the sale on the grounds that the original Soviet design was unsafe and that melding Western technology onto a half-finished plant would not adequately improve it. A U.S. interagency technical review concluded that Temelin would meet standards. Eximbank approved the application in January 1994, subject to congressional review. Congress took no action by the deadline in March 1994, which was tantamount to approving it.

Safety Issues

According to a International Atomic Energy Agency review, the WER 1000 design has both deficiencies and advantages compared with Western standards. The modifications address the deficiencies. However, as Austria points out, ' some concerns (e.g., protecting key components against Internal missiles that might be generated by an explosion) may not be addressed because critical structures are already built. Furthermore, a major effort is required to integrate the Westinghouse modifications, and much information will be needed from the original Soviet designers. It is not clear if all the necessary data and assumptions will be available. Finally, problems in quality control of the construction to date leave concerns that hidden problems may compromise safety.

CEZ responds that adequate data are available from Russia and that the upgrades will be shown to make the plant meet high standards of safety.[2] Furthermore, the US. participation (several U.S. companies besides Westinghouse are involved) will assure high-level designs and workmanship. In fact, one of the major reasons Westinghouse got involved was to promote nuclear safety, especially since a major accident in the former East Bloc could have negative consequences for the nuclear industry in the United States and elsewhere.

U.S. Government Role

Financial guarantees have proved crucial to this project. Political risks and economic uncertainties limit commercial banks' willingness to lend capital for projects in the region, and nuclear power projects are generally viewed as especially risky. Westinghouse believes that U.S. government involvement is vital in facilitating the upgrading of the nuclear power sector in the former East bloc and that a systematic overall strategy is required rather than an ad hoc approach focused only on short-term repairs to the most dangerous facilities.

Critics of nuclear power prefer to end government export support. However, the public has few opportunities to intervene on exports, unlike domestic nuclear power actvities. Export financing is an indirect route for expressing concern. The U.S. government has taken the position that nuclear safety is a sovereign issue, to be determined by individual countries.

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1 Advisors on the Special Delegation of the Government of Austria, "Technical Memorandum regarding the Temelin Nuclear Power Plant "

2 CEZ, *Information on the Temelin NPP*, unpublished report

delivered a list of concerns,[15] based largely on deficiencies in the design identified by the IAEA and a review by a U.S. consultant. Austria was unable to obtain all the reports needed for its evaluation, and the concerns listed generally stem from unanswered questions on how the deficiencies identified earlier will be handled. In this case, Eximbank decided that the interagency review was sufficient y positive and approved the loan. Temelin will be a new nuclear powerplant and can be expected to operate for many years. Thus it is particularly controversial. Assistance to existing powerplants maybe less controversial, especially because they are likely to operate whether or not they are improved.

DOE and NRC would be the agencies most appropriate for enhanced assistance programs for direct improvements in safety since they are already involved. If new energy supplies to replace the most dangerous reactors are considered, funding will have to be increased, probably to well above the $100 million level for the next decade. Much of this might be funneled through AID. DOC and Eximbank would have a major role. The Department of State also has an important role with overall strategy and coordination with other countries.

One factor that needs to be addressed, whatever level of assistance is selected, is coordination with other donor countries and multilateral organizations. There have been many complaints of redundant visits and discussions. When the needs are so great and the resources so limited, it is important not to waste efforts. This need is widely recognized, and steps are being taken. In particular, the Group of 24 Nations (G-24) has set up a Nuclear Safety Committee in Brussels to coordinate assistance. This is an area that will require continued oversight.

Two final areas of cooperation should be mentioned because they have the potential for providing very useful information to the United States. The first is on health effects of radiation. The Chernobyl accident and other nuclear catastrophes have exposed a great many people to radiation. Studies of public health effects could be expanded with additional funding. Collecting and analyzing this data will improve U.S. understanding of this important area of science. The JCCCNRS has a working group on the subject, but funding is very limited. In January 1994, Russia and the United States signed an agreement for the exchange of information on health and environmental effects of radiation, which should be useful.

The second, annealing of reactor vessels, is of interest as U.S. reactors age.[16] Neutrons generated in the core impinge on the reactor vessel and gradually embrittle it. After many years, the vessels become so brittle that they could crack under certain conditions and lose their ability to maintain cooling in the core, leading to a meltdown. If the lifetimes of the current generation of reactors are extended, reactor vessels may have to be annealed to reduce the brittleness. Russia has already done this on several reactors because their design and materials leave them more subject to embrittlement. This has been an active subject of discussion (including a working group of the JCCCNRS), and Russia has already provided considerable information to American researchers. Further cooperation could be valuable.

ELECTRIC POWER TECHNOLOGIES

Unlike fossil energy supply discussed in chapter 3, electric power is well developed in every country of the former East Bloc. Generating capacity (but not fuel supply) is adequate almost everywhere, if only because demand has dropped with economic decline. Transmission and distribution

[15] Advisors on the Special Delegation of the Government of Austria, "Technical Memorandum regarding the Temelin Nuclear Power Plant," unpublished document February 1994.

[16] Annealing involves heating the reactor vessel to a high temperature, which repairs damage to the metal. It is difficult to do because the reactor vessel is very large, and both geometry and radiation limit access.

TABLE 4-4: Electric Power Capacity and Production

	Capacity Gwe		Production billion kWh		
Country	1991	1990	1992	1991	1990
Russia	213.0	213.3	1018.0	1072	1082
Ukraine	54.4	55.6	253.0	279	299
Kazakhstan	NA	17.9	81.0	86	87
Moldova	3.7	3.7	11.0	NA	NA
Belarus	5.8	5.8	37.6	NA	NA
Kyrgyzstan	NA	3.7	11.8	NA	NA
Turkmenistan	NA	3.2	13.1	NA	NA
Uzbekistan	11.6	11.3	50.9	NA	NA
Tajikistan	NA	4.6	16.8	NA	NA
Armenia	NA	3.8	6.8	NA	NA
Georgia	NA	4.2	11.5	NA	NA
Azerbaijan	5.8	5.8	19.8	NA	NA
Latvia	2.1	2.1	8.5	NA	NA
Estonia	NA	3.5	15.9	NA	NA
Lithuania	5.1	5.1	28.2	NA	NA

NA = Not Available

SOURCE Matthew J. Sagers, *PlanEcon Energy Outlook for the former Soviet Union,* (Washington, DC June 1993)

systems are largely equivalent, or even superior, to those of the West. Lenin asserted that "Communism is Soviet Government plus the electrification of the whole country."[17] Electric power thereafter had a high priority among the central planners.

Nevertheless, the sector has severe problems. In particular, many fossil fuel-generating plants operate poorly and are among the worst sources of pollution in the region. Furthermore, a high fraction are nearing the end of their expected lifetimes and must be replaced. Finally, as in other sectors, management is unfamiliar with the concepts of operating under a market economy, such as finance, customer relations, pricing, and regulation.

Reliable, high-quality, electric power is essential for any modem economy. Upgrading electrical systems will make an important contribution to realizing the U.S. goal of revitalizing these economies. The surge in retrofitting old plants and building new ones that must occur with revitalization should provide many commercial sales. U.S. electrical equipment manufacturers could have an unusual opportunity to export, unlike in Western Europe, where markets are largely closed to foreign companies.

I Status of the Electric Power Sector

Generating capacity and recent production are shown in table 4-4. Production has declined in all these countries because of reduced demand and sometimes fuel and parts shortages.

These statistics depict a relatively well-endowed sector, especially in comparison with other energy sectors. In fact, in some countries, such as Lithuania and Ukraine, electricity is much

17 Leslie Lamarre, '*connecting With Russian T& D," *EPR/ Journal*, Jan/Feb 1992, p. 28.

less subject to interruptions than are oil and natural gas, which must be imported from Russia. Many countries have indigenous sources of coal and hydroelectricity, and nuclear fuel is relatively cheap even if imported. In other areas, including Georgia, Armenia, and Eastern Siberia, severe shortages of electricity have occurred because of fuel shortages, mostly due to ethnic struggles or delays in construction.[18]

However, as in so many other sectors of these economies, much equipment is old and in poor condition. As discussed above, over 20,000 MWe of nuclear capacity are likely to be shut down over the next decade. Most fossil fuel technology (though not all) is also well below Western standards. As Central European countries move toward integrating their economies (and their electric grids) with Western Europe, they will have to meet much higher environmental standards. Some powerplants can be retrofitted with pollution control equipment, but others will have to be replaced.

The major problem inhibiting rehabilitation is the lack of capital. Powerplants are expensive. None of these countries can afford to rebuild their electric power systems with so many competing needs for very limited capital. Electricity can still be produced, and the inefficiency and pollution of current facilities seem like minor problems compared with massive unemployment and lack of heat.

The power companies themselves are unable to undertake costly construction because their revenues are still based mostly on what users can pay and generally do not cover costs. Only in the Czech Republic has any significant move toward privatization of the electric sector taken place. In general, market reforms in the electric utility sector depend on market reforms in the country as a whole, and these have not been progressing very rapidly anywhere. The status of market reform in various countries is detailed in the country -specific discussions below and is summarized in table 4-5. Countries are listed in order of progress in electric sector reform. Note that in the case of utilities, privatization is not a prerequisite for market reforms. Many utilities in Western Europe and the United States are government-owned, but still operate effectively in a market economy.

Russia

The Soviet Union controlled its entire electric system from Moscow through the Ministry of Energy and Electrification. Eleven Regional Unified Energy Systems were responsible for generating and delivering the power within their jurisdictions. Three main transmission networks—the "national" integrated power grid extending over 3,000 miles from the border with Poland to Lake Baikal in central Siberia, the Central Asian grid, and the Far East grid-cover most of the FSU. After 1991, ownership of the various components devolved to the new republics, but the national grid is still operated as an integrated unit, much like the main U.S. grids.

In 1993, the first step toward privatization was taken when the Russian Joint Stock Company for Power and Electrification (RAO ESS) was created. It owns and operates the51 largest powerplants and the transmission grid. The plan is to sell 20 percent of the company to Russian citizens for vouchers that already have been distributed. Thirty percent will be assigned to regional development organizations, and the remaining 50 percent will be retained by the Federal government, presumably temporarily.

Poland

Poland has reorganized but not privatized its power industry. Formerly, almost all activities—mining, power production, transmission, and distribution—were centralized in the Union of Power and Brown Coal. This inefficient structure

[18] Matthew J. Sagers, "The Energy Industries Of the Former USSR: A Mid-Year Survey," *Post-Soviet Geography*, vol. 34, No. 6, 1993, pp. 403-407.

TABLE 4-5: Status of Reforms Affecting Electric Power

Country	General market reforms	Power sector reforms	Comments
Czech Republic	yes	yes	Generating utility already partly private.
Hungary	yes	plans	Moving to mixed private/ govt ownership.
Poland	yes	plans	Variety of ownership structures possible.
Slovenia	yes	plans	
Slovakia	yes	plans	
Russia	some	plans	May use Czech-type vouchers,
Ukraine	some	no	
Bulgaria	yes	no	

SOURCE Office of Technology Assessment, 1994

has been split up. Power is generated by 28 enterprises, which sell their power to the Polish Power Grid Co. There are 33 distribution companies that buy power from the grid and sell to final consumers. Poland has embarked on a considerably more radical reorganization than has been attempted in the United States, though several European countries, such as the Netherlands, are following a similar scheme. An earlier OTA report analyzed such a plan.[19]

Czech Republic

The Czechoslovakian government had carried out a reorganization of the state power industry similar to that of Poland. The former power company had owned and operated almost all powerplants, the transmission and distribution grids, and some electrical equipment manufacturing plants. Following the national and industry breakups, The Czech Power Company (CEZ) controls only generation and transmission, and eight regional distribution utilities deliver the power to customers. CEZ has been organized as a private corporation, and one-third of the stock has been sold publicly. The distribution utilities are expected to be fully privatized by the end of 1994.

Hungary

The Hungarian Electricity Board (MVMT) maintains central control. Subsidiary companies are responsible for power generation, transmission, and distribution. The subsidiary utilities are nominally independent, but MVMT regulates revenue flow between producers and distributors. A plan for privatization has been announced, but little progress has yet been made. The government is likely to retain up to 50 percent of the shares in the companies.

Hungary has insufficient generating capacity for its own needs and imports about 30 percent of its power from Ukraine. This will conflict with joining the Western European power grid because

19 U.S. *Congress,* Office of Technology Assessment, *Electric Power Wheeling and Dealing: Technological Considerations for Increased Competition,* OTA-E-409 (Washington, DC: U.S. Government Printing Office, May 1989).

individual members are expected to generate most of their own power or import it from other members. New facilities and transmission lines would have to be built.

Technology Needs and Cooperation

Many technologies used for generating electric power are behind Western standards, in large part because relatively few new plants have been constructed in recent years. Modernization is required across the region. The most pressing needs for non-nuclear technologies involve clean coal, gas turbines, and demand-side management. In addition, expertise in operating and regulating market-based utilities is almost completely absent.

There are many opportunities for Western investment and cooperation in the FSU electric power sector. Russia and Ukraine are actively seeking joint ventures and cooperative agreements to modernize their electric power industries. But Western involvement has been limited by sector restructuring and political and economic uncertainties. To date, Western companies have focused their efforts on data collection and market evaluations. Nevertheless, several joint ventures have been established and more are sure to follow.

Clean Coal

Coal is the major domestic energy resource for many countries, and wide-scale use is inevitable. However, a large fraction of the pollution in Central Europe results from the uncontrolled combustion of coal in powerplants. These plants will have to be either replaced or upgraded with environmental protection equipment such as flue gas desulfurization (FGD) systems (pollution control technologies are discussed in the following chapter). The market for replacement and refurbishment of coal-fired powerplants could be very large.

Coal can be burned quite cleanly (except for carbon dioxide emissions) with the proper equipment. The United States has pioneered clean-coal technologies with a large program at DOE. Some of this expertise has already been made available to Poland (see box 4-2). Coal cleaning, an attractive option for near-term reduction of pollution, was discussed in chapter 3. Fluidized-bed combustion (FBC) and integrated gasification combined cycle (IGCC) are relatively new technologies that can be employed in new plants, resulting in efficient power production and very low levels of emissions. FBC and IGCC technologies are emerging as competitors to conventional coal-fired plants, particularly in areas where high-sulfur coals are used and emissions are strictly limited. Moreover, the IGCC technology requires less land and water than conventional scrubber-equipped coal-fired powerplants.

The United States is highly competitive in these new technologies and in conventional, pulverized-coal combustion with FGD. Westinghouse Electric Corp. formed a joint venture with a Polish partner in 1992 to retrofit seven power stations with new control and desulfurization systems. The contract will be worth about $2 billion.

Gas Turbines

Shifting to the use of natural gas instead of coal or heavy oil in electric power stations is an option for Russia and other gas-producing countries. However, gas is also a major earner of foreign exchange, and burning it at home will reduce exports. Hence, its use must be as efficient as possible. Modem, high-efficiency gas turbines, introduced recently by American manufacturers, are based largely on aircraft engines. They are rapidly becoming the technology of choice for new generating capacity in this country because the captital costs are much lower per kilowatt than coal or nuclear plants, they can be installed quickly in small quantities as demand grows, they bum natural gas, which is still quite plentiful, and they produce only low levels of pollution.

Russian and Ukrainian military aircraft engine factories, currently largely idle, could convert to the production of turbine generators. Western finance and technology are needed to set up the new assembly lines that would allow rapid production. Several recent joint ventures illustrate the potential for gas turbine production in Russia. Siemens,

BOX 4-2: DOE's Retrofit Of A Coal-fired Powerplant

Krakow, Poland, suffers from severe air quality problems, due largely to the burning of coal for electricity production and space heating. In 1989, President Bush visited Krakow and pledged U.S. support to help clean up the air. The Support for East European Democracy (SEED) Act of 1989 authorized $10 million for DOE to retrofit a coal-fired powerplant there. This section of the Act was intended both to help cleanup Krakow's air and to promote U.S. clean coal technology, by specifying that the retrofit "shall be carried out by one or more United States companies using United States technology and equipment manufactured in the United States."

In 1990, DOE and Polish officials signed an agreement establishing a Bilateral Steering Committee to oversee the retrofit. The committee selected the Skawina Power Station near Krakow, for the retrofit. Skawina has 11 boilers of 50-MWe each. In August of 1990, DOE requested proposals from U.S. companies for clean coal technologies that would reduce sulfur dioxide ($S0_2$) emissions from one boiler by 65 percent.

The legislation left the definition of "U.S. companies" to DOE, and it proved difficult. DOE's initial definition was a company incorporated under U.S. laws and with at least 50% of the voting stock held by U.S. citizens or firms. However, this definition would have excluded all but a very small number of firms. Furthermore, determining stock ownership, especially if the stock was held by mutual funds, would have been difficult. DOE dropped the stock ownership requirement. By one estimate, this change allowed an additional six companies to be eligible for the project.

In May 1991, DOE awarded a $7.8 million contract to AirPol Inc., of Teterboro, New Jersey, a subsidiary of FLS miljo of Denmark, to design and install a flue-gas desulfurization unit. AirPol then showed that an additional boiler could be easily retrofitted by simply enlarging the size of the desulfurization unit. The Polish government agreed to cover the additional $3.9 million to extend the system to a second 50-MW boiler. Airpol worked closely with several Polish companies, including Mostosal and Elektrim. The modification will allow the boilers to meet Poland's stringent 1998 $S0_2$ emission limits.

In November 1993, the new system was dedicated. Testing is under way and the system is expected to be fully operational by Spring 1994.

a Germany company, and St. Petersburg Metallic Plant formed a joint venture to produce gas turbines. Asea Brown Boveria (ABB), an international company with a 20-percent U.S. component, is also very active in the Russian market. One of ABB's most recent activities is the formation of ABB Uniturbo, a joint venture to produce gas turbines.

The advantages for Russia would be improved technology that could replace polluting and unsafe generating stations and meet new needs at low cost. In addition, production of advanced turbines could become a major economic asset, helping in stabilization. For the West, participation in the form of investment and licensing would create an economic opportunity not otherwise available. The U.S. national interest would also be served because international stability will improve if military factories are redirected to civilian goals instead of selling arms.[20] Russian-made turbines need not be directly competitive with U.S.-made models if the technology keeps improving, as appears possible.

Demand-Side Management

Many U.S. electric utilities promote energy efficiency by their customers. They provide information and sometimes financial support for customers to install equipment that reduces their

20 Robert H. Socolow, *Conversion to Electric Power Objectives of the Russian Production Lines for Gas Turbines for Military Aircraft*, unpublished notes from conversations in April 1992 with academicians Oleg Favorsky and Alexander Sheindlin.

TABLE 4-6: Potential U.S. Results from Electricity-Savings Technologies

	Electrlcity savinga	
	Low ease	High case
Residential end uses sector		
Space heating	**32.2%**	54.8°A
Water heating	**32.3**	66.2
Central air conditioning	**29.1**	34.4
Room air conditioning	18.5	32.3
Dishwashers	5.2	26.3
Cooking	7.9	18.2
Refrigeration	22.1	48.0
Freezer	24.0	32.4
Residual appliances	27.8	40.0
Total residential*	27.1%	45.5%
Industrial end uses		
Motor drives	28.5%	45.0%
Electrolytic	18.8	29.7
Process heating	7.9	13.3
Lighting	16.7	33.3
Total industrial*	23.7%	38.3%
Commercial end uses		
Heating	12.7%	23.6%
Cooling	30.0	70.0
Ventilation	30.0	50.0
Water heating	40.0	60.0
Cooking	20.0	30.0
Refrigeration	12.2	34.1
Lighting	22.2	55.6
Miscellaneous	18.2	36.4
Total commercial*	22.5%	48.6%
Total*	24.4%	43.9%

● **Totals are weighted averages**

SOURCE: U S Congress, Off Ice of Technology Assessment, *Energy Efficiency Challenges and Opportunities for Electric Utilities*, **OTA-E-561 (Washington, DC: U S. Government Printing Office, September 1993)**

use of electricity.[21] Over the past 15 years, public utility commissions and utilities (realizing that prices will stay lower with lower growth because new plants have become so much more expensive than existing ones) have pioneered the concept of demand-side management (DSM), where electric utilities help their customers improve efficiency. Utilities have been given incentives to ensure that their interests correspond to their customers' interests.

Power companies in the former East Bloc are also accustomed to managing their customers' consumption, but their approach used directives, not incentives. Until the late 1980s, demand grew rapidly, and construction did not always keep pace. Shortages often developed, and large customers had to be rationed. Sometimes residential areas were blacked out or, as in Romania, restricted to a very limited number of light bulbs and appliances. Over the past several years, demand has dropped with economic activity. Restrictions have been minimal in most areas, though fuel shortages for powerplants are increasingly likely to revive them in some countries.

Interest is growing in ways to reduce demand to minimize the new plants that must be built and to reduce pollution. DSM and the closely related concept integrated resource planning (IRP)-a planning process that evaluates both supply and demand options to determine the most economical and reliable system—have largely been developed in the United States. Applications for efficient technologies and the range of savings that could result in the United States are shown in table 4-6. Savings in Central Europe and the FSU should be even higher because efficiency has been ignored for so long.

DSM techniques include information programs to alert customers to potential energy savings measures, rebates or loans to help finance improvements, and performance contracts with energy service companies to install energy-saving equipment at customers' facilities. Implementation of these techniques depends primarily on utility management understanding of the opportunities available and having the appropri-

21 The U.S. experience with DSM is described in detail in a recent OTA report: U.S. Congress, Office of Technology Assessment, *Energy Efficiency: Challenges and Opportunities for Electric Utilities*, OTA-E-561 (Washington, DC: U.S. Government Printing Office, September 1993).

TABLE 4-7: Utility Partnerships Under the AID/USEA Programs

U.S. partner	East Bloc Partner
Central and Eastern Europe	
Houston Power and Lighting	Czech Power Works
Southern Electric International	Slovak Power Enterprise
Commonwealth Edison	Polish Power Grid
Central Maine Power	Bulgarian Power Authority
New England Electric Company	Hungarian Electric Companies, Ltd.
Boston Edison	Rumanian Electric Co.
Central Vermont Public Service	Latvenergo (Latvia)
FSU	
Pennsylvania Power and Light	Kievenergo (Ukraine)
Cincinnati Gas & Electric	Kazakhstananegro
National Hydropower Association	State Energy Co. of Kirgizstan
Edison Electric Institute	RAO EES Rossii (Russia)
American Gas Association	Gasprom (Russia)
American Gas Association	ROSGAZIFIKATFIA (Russia)
City of Anaheim Power Utility, Southern California Edison, and City of Pasadena Water & Power	Ministry of Energy and Fuel (Armenia)

SOURCE U S Energy Association, March 1994

ate incentives and resources. Western encouragement can involve policy advice (to get pricing, regulations, and incentives correct), utility management advice (to improve understanding of cost minimization and financing), advice on specific DSM/IRP techniques, and assistance in manufacture of energy-efficient products. Regulatory agencies have played an essential role in instituting DSM in the United States, and assistance in setting up effective, cost-based regulation and pricing is likely to be critical in the former East Bloc.

Electric *Power Company Management*

The power industry is one of the few that has valued efficiency, at least in some ways. As noted below, the Soviet Union pioneered supercritical boilers and ultra-high-voltage transmission because they reduce energy losses. However, this thinking did not permeate utility operations. U.S. utilities operate with far fewer personnel and use more modem technology.

Managerial skills and operating procedures are being upgraded by an intriguing program-the Utility Partnership Program (UPP)--funded by AID at the U.S. Energy Association (USEA). In this program, U.S. utilities form partnerships with counterparts in Central and Eastern Europe. A similar program for FSU utilities—the Energy Industry Partnership Program (EIPP)—has been created more recently. Partnerships are shown in table 4-7.

The UPP and EIPP pay for visits in each direction to exchange information on engineering, finance, marketing, planning, plant operations, and other aspects of utility operation. The types of activities are described in box 4-3. The program appears to be working well. Participants report that the exchanges are fruitful.

The contacts developed have led to commercial contracts. Part of the purpose is to introduce the partners to U.S. vendors. For example, the Southern Company received a large contract from its Slovakian partner to refurbish a power-plant.

Demands on the time of the U.S. partners has grown, and they are hesitant to deepen their role because of their accountability to their stockholders and Public Utility Commission. Only travel

BOX 4–3: Eastern Europe Utility Partnership Program

The U. S.-Eastern Europe Utility Partnership Program, was implemented by AID and USEA in October 1991 to "provide a mechanism which enables the experience of U.S. electric utilities to be transferred to Eastern European electric utilities, thereby helping address institutional Issues, including free-market managerial challenges and technical, financial, economic, regulatory and environmental issues. "[1,2]

Central and Eastern European power companies are paired with an American utility and participate in a variety of activities, including executive exchanges and seminars on topics such as customer service, environmental issues, and rate regulation. An Information exchange program provides general support for the partnerships by supplying resource material, technical reports, and funds for utility officials to attend industry conferences in the United States. Industry groups such as the Edison Electric Institute, the Electric Power Research Institute, North American Electric Reliabilty Association, and American Public Power Association are often Involved in UPP activities,

The UPP has been mutually beneficial. Professionals at Central Maine Power (CMP) taught courses in accounting and customer service practices to individuals at Bulgarian NEK. CMP participants gamed valuable managerial experience and learned from the technical expertise of the Bulgarians, s Overseas contacts established through the UPP offer U.S. utilities the possibility of future business,

As the program progresses, interactions have become focused on specific problems of the East European utlilties, demanding more of the U.S. partners, A seminar on financial management, for example, provided a general perspective on the field, but not the time and expertise necessary to develop and implement a corporate financial plan, In response, more intensive training activities are to be incorporated into the UPP in 1994.

The UPP has grown in size as well as intensity Increased activity has required additional funding, Originally, the program was projected to cost $4,8 million over 3 years, A subsequent amendment to the agreement, signed in October 1993, estimated $226 million over 6 years (1992 to mid-1997).

Both sets of partners are enthusiastic in their support of the UPP, During a strategic planning session held in Budapest in November 1993, representatives showed strong interest in integrated resource planning, demand side management, and environmental issues for future topics for cooperation,

[1] Amendment to USEA Cooperate Agreement EUR-0030-A-00-1085-03

[2] A more recently established program, the Energy Industry Partnership Program (EIPP), funded through AID and administered by the USEA, arranges similar partnerships in the former Soviet Union

[3] Phone conversation with Connie Irland of Central Maine Power, Dec 28, 1993

and incidental costs (not labor) are covered by the AID grant. AID has introduced a consultancy grant program for projects that require considerable time by the U.S. partner (e.g., intensive training) to encourage continued participation. This grant program, open to all utilities, provides an alternative to UPP funds. Utilities can propose specific projects. Some utilities have created subsidiaries to participate in the consultancy grant program.[22] The first round of proposals is now under evaluation.

Reverse Technology *Transfer*

In some cases technology in the former East Bloc is superior; therefore the United States can also

22 Phone conversation with Eric Haskins, manager, Utility Partnership Program, USEA, Dec. 28, 1993.

TABLE 4-8: Technology Interchange Between Electric Power Research Institute (EPRI) and the Former Soviet Union (FSU): Plant Demonstration Projects

Topic	Brief description	EPRI interest
Supercritical Powerplants	Boiler and turbine temperature and flow conditions for low power operation.	Data on how to slide pressure through the critical point. New approach for US.
Boiler Efficiency and Emissions	New combustion air admission methods.	Efficiency and NOx improvements.
Adjustable Speed Drives(ASD)	Assessment of EPRI guides.	Validation of EPRI ASD guidelines.
Thyristor Steam Turbine Startup	Reduced temperature variation in steam turbine. First of a kind for steam turbine startup.	
Gas turbines	New water cooling scheme for high temperature blades.	Step improvement in blade cooling over current methods.
Steam turbines	Titanium blades for high back-pressure turbines.	Possible solution to higher back pressures.
Electric Generator	New design with water-cooled rotor and stator.	Elimination of hydrogen, more efficient generator, better reliability.
Superconducting Electric Generator	300-MW design already built.	Reduces R&D costs.
Modified Oxygenated Chemistry	Improved oxygen treatment for steam chemistry control.	Reduction of blade corrosion.
Coal Refinery	Liquefaction and gasification of coal.	Use of low-rank coals for gasification, smokeless fuel. Wide application in Eastern Europe, China.
Slagging Boiler Studies for Lignite	New modifications to reduce slagging.	Non-slagging boiler for high-moisture, high-ash coals.
District Heating Studies	Optimization of cogeneration turbine operation.	Modification of existing plants for district heating.
Ash Metals Extraction	Ash melting and metals extraction.	Key elements of a coal refinery.
Oxygenated Hot Water Cleaning of Boilers	New application for boiler cleaning and reduction of waste disposal.	Reduced tube failures and less chemical cleaning.
Component Life Assessment	Life extension of power plant components.	Validation and updating of EPRI life assessment tools.

SOURCE Adopted from Tony Armor, Director, Fossil Power Plants Department, EPRI, fax communication, Oct 12, 1993

profit from technological exchange. The highest voltage transmission line in the world is in Russia (1,150 kilovolts vs. a maximum of 700 kilovolts in the United States). Furthermore, Russia has far more experience with supercritical steam turbines (which are more efficient than conventional turbines because they operate at higher temperatures and pressures). U.S.-Russian cooperation in such areas has already started, in particular at the Electric Power Research Institute. Table 4-8 lists some recent fossil fuel technology interchanges with the FSU. Joint R&D cooperation could be very beneficial.

Barriers to Technology Cooperation and Sales

As in all other areas, the two major constraints to rapid increases in activity are the political situation in these countries and the limited financial resources. Other factors are also relevant, some of which are peculiar to the electric power industry.

Political Constraints

Western electric utilities, whether private or government owned, operate in a very different milieu from enterprises in the former East Bloc. There, electricity is considered to be part of the social safety net as well as a key industrial input. Prices have been determined more on the basis of what the customer could afford than the cost of the power.

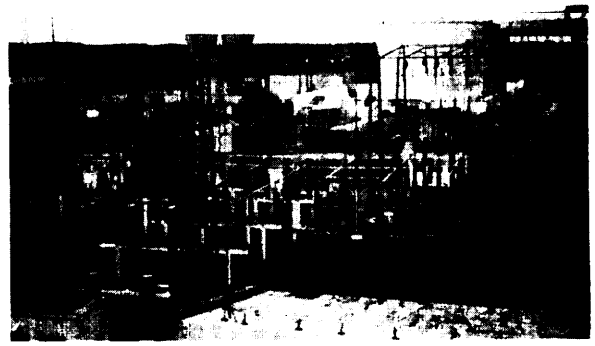
These countries are devising energy and regulatory policies but often do not have a clear concept of the role that pricing, or the utilities themselves, could play. Former regulations are no longer enforced, and agreements for power limitation are often ignored. In theory, state-owned utilities can easily implement national policies, but the practice will be difficult. The abolition of central planning could have a perverse impact on the rational allocation of power. Considerable help-both advisory and material—will be needed to rationalize energy policy and institute realistic pricing.

Financial Constraints

Technology and engineers are sufficiently good in the former East Bloc that, given unlimited financial resources, power companies could construct systems largely equivalent to those in the West. However, few of these companies have the resources to buy much from the West, and few equipment manufacturers can afford to modernize their facilities and products.

Substantial equipment and service sales are possible in this sector, but only if adequate financing is made available. Since many power systems will eventually be integrated with the Western European grid, there will be a natural tendency toward Western European equipment unless U.S. firms can offer favorable terms.

LARRY MARKEL



Holesovice Electric Substation, Prague Electric Distribution Utility.

Institutional Constraints

In some of these countries, the structure of the electrical power industry is changing. This introduces uncertainty into their planning, even though the intent is to make the utilities more responsive to market forces. In Russia, generation may be divided into 70 utilities. In some countries, generation, transmission, and distribution are being separated, a process that is difficult even in countries without economic chaos in other sectors. Utility restructuring will remove some incentives since decisionmaking will be divided between utilities that sell to end users and utilities that generate power and build powerplants. These changes will take time and considerable care to ensure that reliability of power supply is not jeopardized.

Foreign investors have expressed considerable interest in building independent powerplants. Although this would solve financial constraints and upgrade technology, investors must see political, legal, and regulatory stability before they invest.

DSM is even more uncertain. Low rates do not justify efficiency investments by customers, and low revenues do not permit utilities to invest. The structure of electricity demand is also less favorable than in the United States. Residential and commercial customers have proven more amenable to DSM than has U.S. industry. In the former East Bloc, the residential and commercial sector consumes one-third of the electricity, half the fraction in the United States and thus a smaller target. In addition, some industrial customers will close, but it is not always easy to tell which. Obviously, it is not worth improving the efficiency of plants about to close.

Russia has a complete equipment supply industry, which in some ways rivals that of the West. Therefore, it is unlikely that Russia will buy large quantities of electric power equipment from the West. Other countries are better prospects for sales.

Potential Policy Improvements

Steps that the United States could take to help modernize the electric power industry are similar to those for other sectors. High-level policy advice and encouragement to introduce market reforms and realistic pricing is essential. Enactment of legal protections and currency stabilization will be needed to encourage foreign participation. Technical assistance is likely to be important. AID programs can be strengthened and expanded. UPP and EIPP appear to be particularly attractive candidates for expansion.

On the commercial side, additional financing will be essential to assure that U.S. firms remain competitive. Eximbank loan guarantees and Overseas Private Investment Corp. insurance are vital parts of a U.S. presence there. Trade Development Agency feasibility studies are also working well and could be expanded.

RENEWABLE ENERGY TECHNOLOGIES

A vast array of technologies is used to capture and convert wind, sunlight, geothermal heat, falling water, and organic biomass into energy. Renewable energy sources can heat homes, supply electrical power and process heat, and fuel cars. Some renewable sources can be converted to feedstocks for producing chemicals. In general, renewable resources are inexhaustible and widely, but irregularly, distributed. Because of the latter, storage is very important.

The potential for renewable is enormous, but only a small amount of the resource is economically recoverable at the present time. In the United States, for example, renewable provide about 9 percent of the total energy used annually, mostly from hydroelectric power.[23]

Over the last two decades, significant advances in renewable energy technologies have been made. Many systems have reached either prototype or commercial development. Performances have improved and costs have declined. Hydropower is the most developed renewable and enjoys widespread use. Windpower is competitive or near-competitive with other sources for bulk power production. Flat-plate solar collector systems for space heating and hot water are economically viable in some parts of the world, e.g., Israel, Australia, and Cyprus. Photovoltaic systems command an increasing number of market niches, particularly for telecommunications and space, but require further development before they will be economically competitive for bulk power production. Biogas production in some locales is viewed as an important energy source and is ecologically sound, as well. Geothermal resources are enormous, but the amount that can be recovered economically is small.

Environmental concerns and increased demand for electricity have stimulated some interest in renewable resource development in former East Bloc countries. The use of renewable can reduce regional air pollution and mitigate global climate change, environmental impacts to which former East Bloc countries contribute substantially. Moreover, renewable development can reduce dependence on foreign energy supplies (and thus improve a nation's balance of payments), provide decentralized power sources for rural areas, and address nuclear safety concerns. These issues have become more prominent since the dissolution of the FSU. Each country now requires independence and control over its energy resources

[23] Robert L. San Martin, "Renewable Energy—Power for Tomorrow," *The Futurist, vol. 23, No. 3*, May-June 1989, p. 40.

and production. Renewable resources can play a vital role in realizing these goals.

Through technology transfer, the United States can help these countries develop their renewable resources. Under the terms of a recent energy agreement, the United States and Russia will cooperate on energy efficiency and renewable energy research and will exchange technology and information. The United States is a leader in developing and manufacturing most renewable energy technologies and is experienced in bringing projects on line. It has the largest installed geothermal-, hydro-, and wind-generated electricity capacity in the world. Additionally, several U.S. renewable companies are serious] y pursuing former East Bloc markets. For example, U.S. Windpower recently signed a joint venture agreement with Ukraine to develop a 500-MW wind farm in the Crimea.

This section discusses the potential for U.S. renewable technology transfer to the former East Bloc. But first, it examines the obstacles to renewable development in this region. Brief descriptions are provided of specific technologies and their applications. For further information, the reader is referred to the forthcoming OTA report *Renewing Our Energy Future.*

I Barriers to Renewable Development

As noted in chapter 2, renewable contribute only a small share of total energy production in the former East Bloc, but there is potential for growth, and interest is rising in several countries. However, there are significant obstacles to renewable development, and competition from conventional fuels will be stiff.

Past energy pricing policies discouraged the introduction of renewable energy technologies and the efficient use of energy. Conventional energy sources were priced so low that renewable could not compete. In some countries, this is still the case. Fuel prices, particularly of oil and natural gas, will continue to have an enormous influence on renewable development. As conventional energy prices rise, alternative sources will become more attractive.

The lack of political and institutional commitment to renewable development is another barrier. Over the years, a strong institutional structure developed to support the production of oil and gas, while little attention was paid to renewable. Successful U.S. experiences confirm that policies and institutions are crucial to renewable development.

Funding priorities are also an important factor. Over the last two decades, capital investment in the FSU favored oil production over other energy resources and other sectors of the economy. Moreover, foreign assistance programs also focused on large-scale conventional energy projects, particularly bulk power and oil and natural gas. Renewable projects tend to be smaller and more dispersed than conventional energy projects, thus making them less attractive for traditional aid. In addition, severe constraints on capital investment will further limit investment in renewable.

Lack of accurate data is yet another barrier. With wind energy, for example, simply measuring annual average wind speeds may not indicate the amount of power that can be generated; distribution of wind speeds over time must also be measured. Accurate data are essential to the success of a renewable project.

The lack of technically trained personnel could also bean obstacle to renewable development, as well as for the staffing of local facilities and plants. In all East Bloc countries, scientific and technical training were directed at conventional energy exploration and production, thereby exacerbating the personnel problem.

Finally, some alternative energy technologies are viewed as immature and unrel iable, presenting yet another obstacle to renewable development. Because some renewable technologies are still relatively new, long-term experience is scarce. Reliability is a major concern for countries that have neither the capital nor human resources to spend on unproven technologies. These countries are more likely to consider traditional, proven technologies.

I Potential for U.S. Renewable Technology Transfer

Wind''wer

Wind turbines convert energy of the wind to electrical energy. All former East Bloc countries have at least a few good wind sites. Several regions in Russia, Ukraine, and Kazakhstan are very favorable to wind power development, but the bulk of these are extremely remote and sparsely populated, i.e., the Far East and northern arctic coast in Russia and central Kazakhstan. Others on the northern and eastern shores of the Black Sea in Ukraine and the North Caucasus area are more accessible.[24]

There has been little wind power development in the former East Bloc. In Russia, for example, small wind turbines are used primarily for water pumping in agricultural applications, although interest in wind energy development is growing. Construction of Russia's first wind power station has begun near Novorossisk.[25] Several factors created a favorable climate for wind power development in this area, including the shortage of electricity in the Novorossisk area, termination of construction of the Rostov nuclear powerplant, and promising wind sites.

Also, prototype 100-kW (kilowatt) and 10-kW turbines are being developed at several facilities throughout Russia. Russia's aerospace industry has tremendous turbine manufacturing capability and is actively seeking Western production partners. Dutch and German companies have established joint ventures in Russia to manufacture small wind turbines.

Wind turbine R&D is being done in Ukraine, as well. The Ukrainian Institute of Electrodynamics, which has primary responsibility for renewable energy research, is working on 1.5-kW and 100-kW turbine designs. The Institute is also collaborating with a former defense factory to manufacture 250-kW turbines, several of which have been sold to the Ukrainian Ministry of Energy to construct a wind farm in the Crimea. The Ministry is also pursuing wind power joint ventures, which will convert Ukrainian factories to wind turbine and photovoltaic facilities. German, Norwegian, and U.S. firms have been contacted in this regard.[26]

In March 1993, California-based U.S. Windpower and a Ukrainian utility formed a joint venture to supply 500 MW of wind power by 1996.[27] When completed, this will be the second largest wind power facility in the world (Altamont Pass in California is the largest). Under the agreement, Ukraine is licensed to manufacture turbine parts. As payment, U.S. Windpower will receive components to service its turbines in the United States and Europe.

Poland and the Czech Republic also manufacture wind turbines for export, primarily to Denmark. Polish and Czech domestic markets cannot support wind turbine manufacturing capacity.

U.S. technology and extensive project development and management expertise could benefit wind power development in former East Bloc countries. The U.S. wind power industry is a leader in wind power technology and development. Its technologies, particularly small wind machines (under 50 kW), are the most advanced in the world, according to DOE. The industry also has tremendous site validation capabilities: our instrumentation for measuring and evaluating

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24 Eric Martinot, "Wind-Generated Electric Power in the Former Soviet Republics: Geographical Prospects," *Post-Soviet Geography*, vol. 32, No. 4, 1992, p. 229.

25 The first of si, 250-kW wind turbines has been installed, and testing is under way. Together, the turbines, which were developed and manufactured in Russia, will generate a total of 15 MW. See "Wind Power Station Construction Begins," in FBIS, *Central Eurasia*, FBIS-USR-93-112, Aug. 27, 1993, p. 84.

26 Eric Martinot, "Wind Energy in Russia and Ukraine," summer 1992 research trip excerpts, Lawrence Berkeley Laboratory, no date.

27 "Venture Plans 500 MW Wind Project in Ukraine," New *Technology Week, vol. 7, No. 14,* Apr. 5, 1993, p. 16.

wind data is the most advanced in the world.[28] Furthermore, U.S. companies have crucial experience in developing, financing, and managing large wind energy projects. U.S. Windpower, for example, is a major wind turbine supplier and wind farm developer.

In recent years, the U.S. wind power industry has suffered setbacks from changes in the tax code and opposition to wind power projects, but is now making a comback. In Europe, wind energy development has made steady progress since the 1980s. If development continues at the present pace, European wind energy development will equal California's present capacity by the year 1995. (California's 1992 installed wind power capacity is 1,690 MW.)[29] Moreover, Europe has significant manufacturing capacity with over 25 wind turbine manufacturers.[30] Because of these recent developments and proximity to former East Bloc markets, European companies are in a strong position to compete. Even so, U.S. companies have a long record of involvement in wind energy development and should be competitive.

Small U.S.-made wind turbines.

Photovoltaics

Photovoltaics (PVs), or solar cells, convert sunlight directly into electricity. Although PV energy is more expensive than conventional energy for most uses, costs continue to drop. It is expected that PV systems will produce electricity for 10 to 20 cents/kWh (kilowatt-hour) by 2000.[31]

The FSU has done extensive R&Don PVs for use in spacecraft and ground installations. PVs are used as a power source for navigation signal installations and UHF relay transmitters, and are used in cathodic protection systems for pipelines in Central Asia and Azerbaijan.[32]

Russia has begun to commercialize its PV technology. It is a large supplier of crystalline wafers to India and is trying to market its products in other countries.

U.S. and European companies are interested in marketing their PV systems in the FSU. Integrated Power Corp., for example, has had some success in Kazakhstan. It has developed a PV power system for telecommunications in that country. British Petroleum also sells PVs to the FSU to monitor oil and gas pipelines.

Engineering and designing PV systems may present technology transfer opportunities for U.S. companies. Russia has manufacturing capability but little experience in marketing and developing commercial projects. The United States has extensive experience in these areas. Joint ventures that

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28 Personal communication, Dan Acona, Department of Energy, June 8, 1993.

29 Paul Gipe, "Windpower's Promising Future," *Independent Energy*, vol. 23, No. 1, January 1993, p. 67.

30 George Stein, "Big Plan in Ukraine to Harvest the Wind," &~ *Francisco Examiner*, Business Section, &c. 11, 1992, p. B-1.

31 Forthcoming OTA report Renewing *Our Energy Future*, Ch. 5: "Renewable Energy Resources and Technologies."

32 "Alternative Power Sources in Use in the USSR," *Ambio*, vol. 19, No. 4, July 1990, p. 222.

incorporate indigenous manufacturing capacity with U.S. engineering, design, and project development expertise may make the most sense.

Solar Thermal Electricity

Solar thermal electric plants use mirrors or lenses to concentrate sunlight, heating a fluid which is then used to produce electricity. The FSU has done R&D on solar thermal systems, including work on coatings, collector manufacturing technology, plant reliability, and interseasonal storage of solar heat and solar salt ponds. However, research activities tended to focus on large centralized facilities, with few practical results.

As of 1990, there were a little over 50,000 square meters of solar collectors in the FSU, producing the heat equivalent of about 5,000 tons of fuel per year.[33] The Crimea republic in Ukraine is well suited to solar use. Solar water heating is used in major hotels in this area. The Crimea is also the location of a 5-MW experimental solar power station which began operation in 1985. The republic plans to build solar power stations with a total capacity of 50 MW in the near future.[34]

The United States has substantial experience with solar thermal systems. Today, there are 354 MW of installed solar thermal powerplant capacity in California's deserts. However, the United States has lost its leadership position to European countries. U.S. solar thermal development was seriously damaged by the bankruptcy of Luz, Inc., in 1992. Today, European companies are actively marketing their solar thermal technologies worldwide, and the Israelis are pursuing the FSU market.

Geothermal

Natural heat below the Earth's surface can be used directly for space and process heat or converted to electricity. Geothermal energy is commonly referred to as a renewable energy resource, but it can be depleted if oversubscribed. Also, geothermal energy production can cause environmental damage; i.e., when hot brines are released from wells.

Hydrothermal energy has been used in a wide variety of markets: power production, district heating, greenhouses, and therapeutic pools and spas. There are 11,300 MW of installed geothermal capacity worldwide for direct-heat applications, and 20 countries generate 5,700 MW of electricity.[35] The United States has the largest installed capacity in the world, with about 2,700 MW.[36]

Estimates of total hydrothermal water reserves in the FSU are equivalent to over 200 million tons of fuel per year. There are more than 200 wells located throughout the FSU, and extraction exceeded 20 million cubic meters in 1990.[37] Much of the geothermal heat is used in greenhouses. There is only one operational hydrothermal power station in the FSU, located in Kamchatka.

The Kamchatka area, in far Eastern Russia, shows the most promise for geothermal development. Japanese companies have shown interest in developing geothermal power stations there. Geothermal resources are also located in Central Russia, particularly in the Nizhny Novgorod and Yaroslav regions.

The FSU has continued its R&D work on hot dry rock (HDR) geothermal energy resources, but financial difficulties have slowed progress. Ac-

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[33] Ibid, pp. 221-222.

[34] "Southern Republics Draw Up Their Own Programs," *Interfax Business Report,* May 3, 1993, p. 6.

[35] Statement of the National Geothermal Association for the Hearing of the Subcommittee on Energy and the Environment of the House Committee on interior and Insular Affairs, Jan. 23, 1992.

[36] Ronald Dipippo, "Geothermal Energy: Electricity Generation and Environmental Impact," *Energy Policy,* vol. *19,* October 1991, *pp.* 798-807.

[37] "Alternative Power Sources in Use in the USSR," p. 223.

cording to one expert, HDR technology transfer would benefit both the United States and Russia. The United States has more sophisticated instrumentation, such as microseismic monitors, while the Russians have an edge in rock mechanics and thermal physics in geothermal resource development.[38]

Lithuania also has some geothermal resources, located in the western part of the country. The Lithuanian government, with help from Denmark, is exploring geothermal potential in this region. Currently, several wells are producing hot water. The Ministry of Energy indicates that geothermal energy will be used to heat resorts in the future .39

In Central Europe, Hungary is a leader in geothermal use for horticulture. About 2 million square meters of greenhouses are heated by geothermal water.[40] Poland is interested in developing its geothermal energy resources for space heating and hot water, particularly in those areas having high pollution or a long heating season. Low-energy resources are located throughout the country; the Podhale field in Southern Poland is the most developed. Several wells are producing hot water for greenhouse use, and an experimental district heating system is in the design phase.[41]

U.S. drilling and site validation technologies can help expedite the development of geothermal resources in former East Bloc countries. However, drilling and extraction costs continue to be a major constraint to greater geothermal energy development in this region.

Biomass Technology

Biomass refers to materials from biological sources that can be used directly as a fuel or converted to other forms for use as a fuel or feedstock. The principal energy use of biomass is the production of heat, via direct combustion, for use in process heating, space heating, and cogeneration systems. The use of biomass for electricity production is usually uneconomical because the dispersed production and low energy content make transportation costs high.

Biomass may be a significant energy resource in rural areas. Consumption, however, is difficult to measure because so much of it never enters the commercial market. Wood, for example, is gathered by individuals and families as the need arises.

Among former Soviet republics, Estonia appears to be taking the lead in biomass development. Estonia's large fuel wood resources, plus the escalating costs of oil and gas imports, have spurred interest in converting heating boilers from oil to wood. Several projects are now under way, using both foreign and domestic technology, and many more are planned. In 1994, the World Bank will begin a large-scale boiler conversion investment program; total converted capacity may reach 200 MW. However, questions have been raised about the sustainability of Estonia's forests.[42]

There is some interest in the FSU in utilizing organic wastes from industry and agriculture for biogas production. This interest is spurred by the need to manage waste and improve sanitary conditions primarily at large livestock complexes. However, the potential contribution of biogas to FSU's total energy supply is insignificant (about 1.5 percent) and will probably remain so in the near future.[43]

A variety of liquid fuels can be produced from biomass, including ethanol and methanol, syn-

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[38] Testimony of Professor Paul Kruger, Oversight Hearing on Hot Dry Rock (HDR) Geothermal Energy, before the House Committee on interior and Insular Affairs, Subcommittee on Energy and the Environment (Washington, DC: Jan. 23, 1992), pp. 4-5.

[39] "Minister Assesses Lithuania's Energy Options, "in Vilnius *Tiesa*, Mar. 12, 1993, p. 5, in FBIS, *Central Eurasia*, FBIS-USR-93-049, Apr. 21, 1993, p. 95.

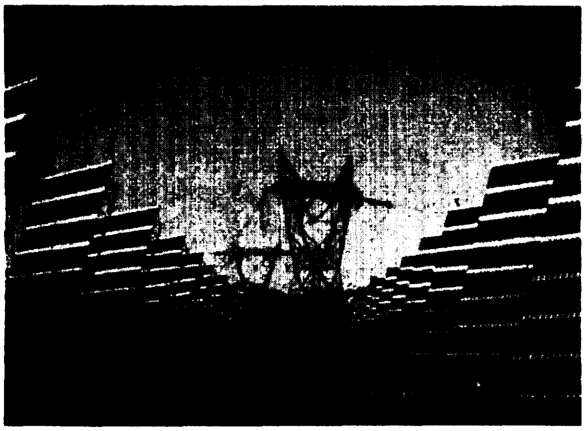
[40] World Energy Council, *Geothermal Energy: Status, Constraints and Opportunities,* Geothermal Chapter (9th Draft) April 1992, p. 17.

[41] Biyakowski Wieslaw and Dlugosz Piotr, "Geothermal Energy Utilization in Poland, State of Development," n.d.

[42] Eric Martinot, .* Renewable Energy in Former Soviet Republics: An Informal Report to OTA," unpublished document Nov. 8, 1993.

[43] " Alternative Power Sources in Use in the USSR," p. 224.

PAUL MAYCOCK



Photovoltaic array

thetic gasoline, jet, and diesel fuel. These fuels have the potential to address some environmental concerns, such as urban ozone and greenhouse gas emissions. However, there are substantial barriers to the introduction of liquid biofuels into transportation markets. These fuels cost more to produce than gasoline and lack the highly developed and massive infrastructure that already exists to support the production, distribution, and use of gasoline. The financially strapped countries of the former East Bloc do not have the substantial capital needed to build new production and distribution networks. There are far more pressing considerations, such as upgrading existing transportation infrastructure and systems and improving vehicle energy efficiency.

Hydroelectric Power

Hydroelectric facilities use the energy in flowing water to turn a turbine connected to a generator. Hydropower is considered a clean energy source that can respond quickly to utility demand. But large hydroelectric projects can be very expensive, construction times can be long, and environmental costs can be high. The development of this resource can flood large tracts of land, displacing people and leading to loss of forests and wildlife. It can also disrupt the flow of rivers.

The FSU has substantial hydroelectric capacity and expertise in developing the resource. In 1991, the FSU had 64,100 MW of hydroelectric power, which is about 19 percent of total installed capacity.[44] Russia has more than two-thirds of the FSU's installed capacity.

In Poland, hydroelectric resources are very limited and are not expected to be significant in the future. As of 1991, Poland had 1,900 MW of hydroelectric capacity, or about 6 percent of total installed capacity.[45] In the former Czechoslovakia, hydropower provides 2,900 MW of installed capacity, or about 16 percent of the total.[46]

Hydroelectric technologies are considered mature, with efficiencies greater than 90 percent. Nevertheless, several technological developments offer improvements in hydropower economics and environmental impacts. These include new ultralow-head turbines designed for use at sites with elevation differentials of less than 10 feet; cross-flow turbines that improve efficiency; and improvements in dam design, construction techniques, and materials. U.S. work on these and other hydroelectric technologies can help former East Bloc countries fully realize their hydro potential.

There is some interest in the use of small hydroplanes in areas where ample water resources exist. Microhydropower (less than 100 kW) could make a contribution in rural areas that have no access to the power grid. Microhydro electric plants are common in China and India. Although initial cap-

[44] Energy Information" Administration, Department of Energy, *Annual Energy Review 1992*, DOE/EIA-0384(92) (Washington, DC: U.S. Government Printing Office, June 1993), p. 305.

[45] Ibid.

[46] Ibid.

ital costs can be high,[47] these systems can be installed quickly and do not entail flooding large areas.

Potential for Development of Renewable "

Although there has been little renewable development in the former East Bloc, there is considerable potential. The usual obstacles to renewable development interfere, however: artificially low conventional fuel prices, capital constraints, and the lack of political and institutional commitment. These and other obstacles may prove to be insurmountable in the near term, but ongoing economic reform and price restructuring should enhance renewable development and use in the long term.

Several factors argue for renewable development in former East Bloc countries. These include the need to develop indigenous energy supplies, provide decentralized power to rural areas, and address environmental concerns. Also, the modular nature of some renewable technologies allows for shorter construction time, and they can be targeted at specific needs. Wind turbines and PV systems, for example, can be sized to fit any application.

Moreover, the availability of idle or underutilized industrial plants and defense facilities provides opportunities for renewable technologies production, especially wind turbines, PV cells, and solar collectors. Several aerospace factories in Russia and Ukraine are now manufacturing or planning to manufacture wind turbines. However, the lack of domestic markets means that production must be oriented toward exports.

Assistance from Western countries could improve the prospects for renewable development in former East Bloc countries, especially in those countries that have limited or no conventional energy resources. Technology transfer provides an important avenue for developing indigenous alternative energy resources at a more rapid pace.

U.S. firms are world leaders in developing and manufacturing renewable technologies, but other countries have expertise, as well. European renewable energy companies continue to grow and are aggressively competing with U.S. firms for global markets. U.S. renewable R&D funding is dwarfed by EU spending: the EU spends about $170 million per year on wind energy compared with $24 million per year in the United States.[48]

Even so, U.S. photovoltaic and wind technologies are among the most advanced in the world. The United States "wrote the book" on PV technology for terrestrial applications, and today, U.S. industry accounts for about one-third of total world PV production. Seventy percent of domestically manufactured PVs are shipped overseas.[49] U.S. small wind machine technology (under 50 kW) and wind site validation capabilities are the best in the world. Finally, the United States has tremendous renewable project planning, development, and management expertise. This experience is derived from having the largest installed geothermal and wind-generated electricity capacity in the world.

To compete in a significant way, U.S. firms must overcome several obstacles. The first is the cost disadvantage of some U.S. technologies relative to foreign competitors. Second, U.S. machines, such as wind turbines, must be adapted to the metric system to compete in European markets. According to DOE, this is a major disadvantage for U.S. companies, and conversion to the metric system would be a tremendous boost to U.S. industry. Third, the U.S. renewable industry, much like the energy efficiency industry, is composed primarily of small- and medium-sized firms. These companies do not have the financial

[47] Typical costs range from $1,000-$2,000/kW. For further information, see U.S. Congress, Office Of Technology Assessment, *Fueling Development: Energy Technologies for Developing Countries*, OTA-E-516 (Washington, DC: U.S. Government Printing Office, April 1992).

[48] NUTEK, *IEA Wind Energy Annual Report 1992*, (Stockholm 1993), p. 43.

[49] Jim Reynolds, International Solar Program, U.S. Department of Energy, personal commmunication, June 21, 1993.

resources to deal with the political uncertainties and financial risks associated with doing business in former East Bloc countries, risks that are intimidating even for the largest corporations.

Demonstration programs could bean effective way to penetrate former East Bloc markets and build confidence in unfamiliar technologies. Because some renewable technologies are perceived to be unreliable and very expensive, decisionmakers would see first-hand how the technology works, how to compile data, and how to develop operating experience.

Even if assistance is forthcoming, former East Bloc countries must provide a favorable climate for renewable development. The energy sector is currently undergoing restructuring, including privatizing industries and market pricing, but with varying degrees of success. Energy sector reform is a very important step to enhancing renewable development. As conventional energy prices rise and the cost of power production increases, renewable energy resources will become more attractive.

Because some of the renewable technologies are relatively new and/or commercial experiences are limited, political and institutional support will also be required. For example, wind energy development requires cooperation among equipment manufacturers, electric power producers, and land resources ministries. Without political commitment, small alternative energy projects will receive little or no financial support.

In the near term, renewable resource development will take a back seat to conventional fuels, particularly oil and gas. Russia has tremendous reserves and will continue to develop them in order to fuel its own economy and to obtain the hard currency so desperately needed. However, the desire and economic necessity to become self-sufficient will drive some countries to develop their renewable; for example, Ukraine's efforts in wind energy.