Energy-Based Environmental Technologies 5

The extent of the staggering environmental problems facing many former East Bloc countries is finally apparent. In Poland, 65 percent of rivers are unfit even for industrial use. Inversion layers over Prague result in concentrations of sulfur dioxide (SO_2) 10 times the World Health Organization's (WHO) recommended standards for peak concentrations. High levels of SO_2 have been linked to increases in respiratory disease, particularly among school children in the most polluted areas of the Czech Republic. One powerplant in Kazakhstan emits almost four times the amount of particulate released by all powerplants in the United States. The examples go on and on.[1]

Environmental damage comes from a variety of sources, including industrial processes, agriculture, and municipal waste. Insufficient or nonexistent pollution abatement equipment further contributes to environmental damage.

Energy production, transportation, and consumption play major roles in the environmental problems in former East Bloc countries. Growing domestic energy needs were met by increased fuel production rather than fuel conservation or efficiency. State subsidization of fuels and raw materials further stimulated energy consumption levels far higher than that in other industrialized countries. Exacerbating the problem, many of the fuels produced in the region were of low quality and thus more polluting. Although the countries of the region had strong environmental laws


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[1] For example, Hilary French, "Green Revolutions: Environmental Reconstruction in Eastern Europe and the Soviet Union," *Worldwatch Paper, No. 99,* November 1990; Murray Feshbach and Alfred Friendly, Jr., *Ecocide in the USSR* (New York, NY: Basic Books, 1992).

and standards (more stringent than WHO recommendations), enforcement was weak. As a result, emission abatement equipment (installed or produced) was insufficient to address pollution problems.

Although environmental activism played an important role in the overturn of Communist governments, the transition from environmental activism to action has not been easy. There are many obstacles to cleaning up the environment, many of which are imbedded in issues of economic reform. Little money is available to pay for mitigation equipment or regulatory enforcement. Also, since closing polluting facilities will exacerbate unemployment and reduce municipal revenues, many regulatory agencies have found themselves powerless to stop pollution.

Nevertheless, reducing pollution is an essential part of economic modernization. In many areas, a cleaner environment will directly increase economic well being because the benefits (e.g., improved human health, reduced corrosion of materials, and greater availability of usable water) will outweigh the costs. In addition, pollution control is a promising area for U.S. exports.

This chapter examines the possibilities for using U.S. equipment and expertise to reduce the environmental effects of energy production, transportation, and consumption in this region.[2] With the recent slowdown in economic activities, all former East Bloc countries have experienced an overall decline in pollution. However, it is extremely important that abatement equipment be in place before these economies turn around. If not, air quality problems will be magnified in the future.

REGULATORY FRAMEWORK

Given the region's severe environmental problems, many Westerners were surprised to learn that the former East Bloc countries have very stringent standards for air and water quality, legislated many years ago, and that in some countries mining reclamation laws were on the books before similar regulations in the United States. In fact, almost all ambient standards were much stricter than U.S. standards or WHO recommended standards. Lack of enforcement rendered the standards meaningless, however, Even when exercised, enforcement depended on a system of fines. Communist industries were much less responsive to financial incentives than to production quotas.

Standards themselves have also been a problem. Environmental regulations focused almost exclusively on ambient standards rather than unified source standards.[3] Specific site emission limits were generally determined by local authorities, based on modeling practices that allowed for regional air or water quality standards to be met, but there were no national targets for abatement. This complicated the design and manufacture of abatement equipment. Focusing on ambient rather than source standards is at odds with environmental regulation in Western industrialized countries, where source limits to both air and water pollution have been implemented in the past 20 years.

Every country in Central Europe and some former Soviet republics aspire to membership in the European Union (EU). As a result, they favor establishing environmental standards consistent with existing and anticipated EU standards.[4] Much work must be done, however, to bring pol-

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[2] This study does not examine the human health and environmental impacts of the nuclear fuel cycle, nuclear accidents, or problems that result from past practices; e.g, toxic waste dumps.

[3] Ambient standards generally set maximum concentrations of a targeted pollutant in a particular media (air, water, soil). Compliance requires that pollutant levels do not exceed this maximum. Source standards specify a maximum level of a pollutant that can be discharged over a given period of time from a regulated source (smokestack, well, factory) into the air or water.

[4] Margaret Bowman and David Hunter, "Environmental Reforms in Post-Communist Central Europe," *Michigan Journal of International Law*, *vol. 13, No. 4*, summer 1992, p. 970.

luters into compliance. Many countries are debating whether to phase in strict EU standards quickly or institute weaker transitional standards, to be revised after economic recovery. This debate has been strongest in the Czech Republic.

Although environmental activism played a major role in the revolutions in Central Europe and fanned dissatisfaction with centralized authority in the former Soviet Union (FSU), the environment has taken aback seat to the present economic dislocations. In Poland, for example, although environmental regulations were off to an impressive start in 1989, economic troubles in the following years took their toll on environmental law reform.[5]

Another legacy of the previous systems is the reluctance and skepticism of local officials and industry toward regulatory enforcement. Many of the old, centralized bureaucratic structures remain, especially at the local and regional levels. Decentralization may create opportunities for improved environmental decisions since local offices should have better knowledge of local environmental concerns. Unfortunately, local authorities are also more susceptible to strong local pressures not to enforce regulations that may increase local unemployment and economic hardship. Moreover, local and regional environmental agencies are often understaffed, underfunded, and underequipped.

Reliable environmental data are critical for determining the scope of environmental problems, setting priorities for pollution abatement, and understanding the impacts of new regulations, but the data for many environmental problems are questionable. Due to the lack of monitoring equipment, most data are not determined through measurement of actual emissions. Instead, analysts make calculations based on assumptions that have not been rigorously scrutinized, or that are derived from data such as the sulfur content of fuels, rated efficiencies of engines, abatement equipment, estimates of average distance driven, and mobile source emission factors.[6]

ENERGY PRODUCTION, PROCESSING, AND TRANSPORTATION

The production, processing, and transportation of fossil fuels (oil, natural gas, and coal) can have significant negative consequences for the environment. The following section examines the effect of these activities on the region's environment and the opportunities for U.S. technology and expertise to address these problems.

Oil and Natural Gas

As noted in chapter 2, most of the oil and gas activities in the region are centered in the FSU, specifically Russia, Kazakhstan, and Azerbaijan. Romania is the only non-FSU country with notable oil and gas production. All countries in the region, however, have refining capacity, pipelines, and other forms of oil product transport that can have environmental consequences.

Production

The drilling and production of oil and natural gas includes many activities with potentially harmful direct and indirect results for the environment. The main direct environmental concerns during drilling of oil and natural gas involve the proper handling of fuels and chemicals (including drilling mud) at the drilling site, which, if spilled or leaked, can contaminate groundwater and riverways.

Oil production activities pose a greater direct environmental threat than gas production. Faulty valves, well casings, and collection facilities can leak oil to the ground, forming large pools (such as at Baku) or traveling to streams and rivers. In Russia, discharges resulting from waterflooding pro-

'Ibid., p. 930.

[6] R.C. Cooper, "Environmental Problems and Pollution Abatement in Central and Eastern Europe," contractor report prepared for the Office of Technology Assessment, Aug. 6, 1993.

SPEARS AND ASSOCIATES, INC.

Typical *field* flares.

duction techniques have caused oil to enter waterways. The Ob river, which flows through the oil-producing region of Tiumen north to the Arctic Ocean, has been especially affected by all of these problems. Environmentalists have said that millions of barrels of oil in Tiumen Oblast are spilled through pipeline ruptures or lax production controls, resulting in the death of bottom fisheries.[7]

The indirect environmental impacts of oil and gas drilling and production include the consequences of construction activities and human settlements. In Russia, the climate adds additional concern. The largest oil- and gas-producing areas of Russia are in Western Siberia. Western Siberia is frozen in winter, but the spring thaw causes the land around the rivers to become waterlogged or flooded, drawing pollutants from areas contaminated by oil. As drilling and production have moved further northward, the industry has entered areas of permafrost that require stringent practices for sensitive ecosystems preservation. But no areas in the oil or gas regions of Western Siberia have been protected through the establishment of nature reserves (zapovedniki) or national parks. Given the present economic crisis and pressures to increase fuel production, it is unlikely that new areas will be protected in the immediate future.

In the major gas-producing region of Western Siberia, future production will be found beyond the Arctic Circle, at Yamburg and the Yamal Peninsula, in areas of continuous permafrost. Pipelines must be cooled and buildings must be raised off the permafrost to avoid melting the frozen soil beneath. If trees are cut away, forests that overlay permafrost can be turned into irreversible marshes.[8] While the development of the Yamal Peninsula was put on hold by the Soviet government in 1989 (the same year that travel across the bare tundra was prohibited), the Russian government has recently permitted the work to resume.[9]

Offshore oil and gas drilling also present a number of environmental concerns, most importantly, leaks or spills of oil and chemicals that can harm marine life. The major offshore producing area has been the Caspian Sea, where drilling and production has taken place since the 1920s, in the shallow waters off the coast of Azerbaijan. Minor oil spills and slicks are noted periodically off this coast,[10] but the specific reasons for these accidents are unclear. Offshore drilling and production activities have occurred to a lesser extent in the Black Sea (near Romania), the Baltic Sea, off Sakhalin Island, and the Barents Sea.

Environmental technology options

Market incentives, combined with increased regulatory enforcement, may redress some of the environmental problems presently found in oil production. For example, when oil has a real market price for the producer, increased economic efficiency will result in less oil on the ground and more in the pipeline moving to consumers. Foreign equipment does not appear to be needed for such efforts, only the adaptation of the Russian (or

[7] Mike Edwards, "Siberia: In From the Cold," *National Geographic*, vol. 177, No. 3, March 1990, p. 35.

[8] Philip R. Pryde, *Environmental Management in the Soviet Union* (Cambridge, MA: Cambridge University Press, 1991), p. 203.

[9] Matthew Sagers, "News Notes," *Post-Soviet Geography*, vol. 34, No. 6, April 1993, p. 383.

[10] Pryde, *Environmental Management in the Soviet Union*, p. 88.

Azerbaijani) and other equipment manufacturers to address market needs.

In several specific areas, such as offshore and arctic operations, Western environmental technologies and expertise are needed. While the Russians have had more experience in arctic oil and gas operations than any other country, their efforts have not focused on mitigating environmental hazards. Western technologies (such as transport vehicles or equipment that can withstand saline or arctic conditions) and field management expertise are needed to reduce the impact of operations.

U.S. opportunities to transfer technology

U.S. firms have had many years of experience in the Alaskan oil fields that would be applicable to the needs of Western Siberia. For example, in Alaska, workpads were built along pipeline ditches to protect the tundra from the wear and tear of construction, and crossings were provided for the caribou migration.[11] Also needed are vehicles that do not damage the sensitive tundra.[12] U.S. firms will compete in this area with manufacturers from other countries, particularly Canada.

U.S. firms also have a great deal of experience in offshore oil and gas operations, although the market advantage for U.S. firms is not clear. With the development of North Sea fields, some European firms have developed expertise that would readily apply to regions such as the Barents and Baltic Seas. U.S. firms would have a logistical advantage if drilling and production activities are to take place in the East Siberian Sea region, due to its proximity to Alaska. But given the great distances from markets, it is not clear whether this region will be exploited in the near future.

Processing

Refineries are generally located in market areas, with crude oil del ivered by pipeline. At oil refineries, the major air pollution concerns stem from hydrogen sulfide (H_2S), which is formed in hydroprocessing (catalytic reforming, hydrotreating, and hydrocracking) and cracking (catalytic and thermal) and from CO (released primarily during catalytic cracking) and hydrocarbon vapors. Given the relative importance of primary distillation technology in the region, refinery emissions are probably determined by the sulfur content of fuels consumed, rather than from technical processes. Waste waters from refineries, without sufficient processing, may contain oil or other byproducts of the production process. The discharge of oil products in refinery effluent to waterways has been a significant problem in Russia (where 29,000 tons entered waterways in 1989) and Uzbekistan (24,000 tons in 1989).[13] Petroleum discharge into rivers appears particularly troublesome along the Tom river (a tributary of the Ob), where petroleum product concentrations exceed standards by 8 to 10 times because of point sources at Mezhdurechinsk, Novokuznetsk, Kemerovo, and Tomsk.[14]

Gas processing, on the other hand, occurs at or near gas production sites, since the gas must be processed before entering transmission pipelines. Environmental problems resulting from natural gas processing are mainly the result of insufficient controls at sulfur-removing facilities. North Caspian Basin fields and all significant fields of Central Asia suffer from high sulfur content. The only notable environmental problems in the gas processing industry have occurred at the Astrakhan

[11] John Fowler, *Energy and the Environment*, 2d ed. (New York, NY: McGraw-Hill, 1984), p. 210.

[12] Edwards "Siberia: In From the Cold," p. 39.

[13] Goskompriroda, *Sostoianie prirodnoi sredi i prirodookhrannaia deialel'nest' v SSSR v 1989 godu* (The State of the Environment and Environmental Protection Activities in the USSR, 1989) (Moscow: Goskompriroda, 1990), p. 68.

[14] Ibid.

complex in Russia, where there have been repeated leaks of H_2S and SO_2.[15]

Environmental technology options

The most immediate problems in the oil and gas processing sectors are water purification and emission abatement. Simple effluent treatment plants for oil and suspended solids removal and neutralization are greatly needed. Those facilities with secondary refining processes would benefit from H_2S treatment, while more traditional sulfur-scrubbing units are needed at facilities burning high-sulfur residual fuel oil.

Given the archaic refinery structure that is found in most East Bloc countries, refinery upgrades are likely in the coming years. Upgrades are needed not only to produce more of the lighter fractions, such as gasoline, but also to produce unleaded fuels and to desulfurize residual fuel oil. Environmental technologies will be needed for these projects.

U.S. opportunities to transfer technology

U.S. firms are certainly experienced suppliers, manufacturers, designers, and constructors of advanced oil refineries. However, they face significant competition from other suppliers, primarily the Japanese. U.S. firms have a clearer advantage in the area of gas processing, especially for high-sulfur (sour) gases. While U.S. firms did not play a large role in the Astrakhan gas complex, they are active in the development of gas processing facilities at the Tenghiz (Kazakhstan) field.

Transportation

Accidents during transport of crude and refined oil products to market can result in severe environmental consequences. In the region, crude oil transport depended largely on pipelines, while railroads have played a major role in product transport. Inland waterways-in particular, the Volga river system—are also used for product shipments. Small tankers ply the Caspian Sea to link the oil-producing regions of Baku, Turkmenistan, Emba, and Mangyshlak, with refineries, regional markets, and the Volga river system.

Many concerns have been voiced about the reliability of both crude oil and natural gas pipelines in the region. The greatest direct environmental consequences come from leaky oil pipelines. Natural gas leaks present safety more than environmental concerns. In 1989, an explosion of escaped gas from a natural gas liquids pipeline killed hundreds of people on a passing train.[16]

There are indirect environmental impacts from pipelines. When constructed above ground (as they must be in areas of permafrost), pipelines can inhibit the migration of wildlife. For example, in the Siberian city of Norilsk, when major pipelines were built to supply natural gas, insufficient provisions were made for reindeer crossings along migratory routes. Reindeer became trapped between parallel pipelines, and whole herds were funneled into downtown Norilsk, where they became the victims of cars and poachers.[17]

Because a large share of FSU oil exports went to Central Europe through pipelines, oil tankers have played only a minor role in crude oil and petroleum product transport. Shipments of oil and petroleum product by sea accounted for only 8 percent of oil shipments for the Soviet Union as a whole.[18] Tanker transport has been used primarily for shipments to countries outside continental Europe (Cuba, the United Kingdom, the Scandinavian countries, and others). The main crude oil and petroleum product export ports have been Ventspils (Baltic Sea) and Novorossisk (Black

[15] D.J. Peterson, *Troubled Lands: The Legacy of Soviet Environmental Destruction* (Boulder, CO: Westview Press, 1993), p. 255.

[16] Pryde, *Environmental Management in the Soviet Union,* p. 98.

[17] Ibid., p. 174.

[18] Goskomstat, *Narodnoe khoziaistvo SSSR v 1990* (The National Economy of the USSR in 1990) (Moscow: Finansy I Statistika, 1991), p. 577.

Sea). Several notable tanker accidents have occurred in the Baltic Sea and the Volga River. Given the inherent risks of oil transport, it is not clear if the frequency or magnitude of these accidents is worse than industry averages elsewhere.

Environmental technology options

As noted earlier, if market incentives and regulatory enforcement were adequate, domestic equipment could address some environmental problems, such as oil pipeline leaks. But new problems and new technology needs may arise. As trading partners diversify, so might fuel transport activities. If Russian oil and product exports shift away from Central Europe, and these countries diversify their petroleum suppliers, tanker traffic could increase dramatically in the region. Increased spill protection and spill response equipment would then be needed to match the increased risks.

With extensive reserves of natural gas in Russia, and significant resources in Uzbekistan and Turkmenistan, gas exports are likely to increase. Gas pipeline construction will increase in the coming years, with extensive construction in Arctic areas if the gas fields on the Yamal Peninsula are exploited. In the long term, liquefied natural gas (LNG) tankers could provide an expanded market for Russian gas. Since LNG is flammable and heavier than air, a tanker collision would be disastrous.

U.S. opportunities to transfer technology

U.S. firms have a limited advantage in oil and gas transportation technologies. Given the economics of shipping pipe long distances and the previously established ties with West European pipeline manufacturers, U.S. firms will not be able to compete in the pipeline market. However, U.S. firms with experience in pipeline construction might be able to provide expertise and services in upcoming pipeline projects. The only other major market for U.S. suppliers is likely to be control equipment for pipeline operations, both in the field and in long-distance transport.

U.S. firms have a great deal of experience in spill response equipment and technologies. Nevertheless, given the location of ports and shipping patterns, it is not clear whether or not U.S. firms will have a market advantage because of the transboundary nature of oil spills and the European response capabilities.

Conclusions

A mix of technologies, expertise, market reforms, and regulatory enforcement is needed in the region to reduce the impacts of oil and gas operations. The highest priorities for Western equipment and expertise would be in arctic operations, oil separation equipment, refinery equipment (both water and air purification systems), and offshore operations.

One difficulty in assessing future needs for environmental equipment is the uncertainty about what impacts might arise from the disruption of historic trading relationships or the influx of Western oil exploration and service companies. Changes in export patterns could result in increased use of tankers, which might increase the likelihood of oil spills. Since it is unclear if domestically produced tankers would be involved, the most important technology transfer opportunities may lie in American experience in rapid response to oil spills. Also, the entrance of Western firms could expand the reach of the oil and gas industries to previously unexplored or produced regions, particularly in offshore areas and remote locations, resulting in unforeseen environmental problems.

| *Coal* and Shale

The initial effects of mining are land disturbances. In surface mining, huge shovels remove the soil above the coal or shale seam, causing the most visible environmental damage. In underground mining, waste is deposited above the mine, causing land degradation at the surface. The environmental impacts of both methods of mining, however, extend beyond the initial extraction process. Mining can lead to the disruption of hydrologic cycles, pollution of surface and groundwater by acidic or


ADVANCED RESOURCES INTERNATIONAL

Strip mining site outside Pees, Hungary

saline discharge, and sedimentation of rivers by the runoff from barren or sparsely vegetated sites. Even after mines are shut down, these environmental problems linger.

Surface Mining

As noted in chapter 3, surface mining is used extensively in the Czech Republic, Kazakhstan, Russia, and Estonia. In the Czech Republic alone, surface mining of lignite results in 500 million tons of mining waste each year.[19] Associated environmental problems include soil erosion, loss of vegetative cover, and water pollution (through sedimentation and acid mine drainage). The natural revegetation of mined areas is a very slow process, due to low levels of soil nutrients in the disturbed areas.

Reclamation efforts attempt to return mined areas to biological productivity. During reclama-. tion, excavated areas are refilled and regraded, then fertilized and seeded. It is sometimes necessary to create a drain with a culvert to carry the water away quickly, before it can form sulfuric acid. Successful reclamation depends on fertile soils and local climatic conditions (e.g., elevation, rainfall). The conservation of fertile soil is extremely important to reclamation efforts. Topsoil must be removed and stored as part of the mining process, and replaced after the coal (or shale) has been extracted.[20]

Starting with Poland, all of the countries in the region implemented legislation in the 1960s, 1970s, and 1980s requiring reclamation of mined areas.[21] It is difficult to judge the past success and current needs of reclamation because detailed data are not readily available. Secondary literature, however, suggests that reclamation laws are not sufficiently enforced and that reclamation efforts are much needed in the region.

Underground Mining

Mine spoils and water discharge from underground mining can result in environmental problems. Underground mining—the main form of coal extraction in Ukraine, Slovakia, and Hungary-accounts for a large share of coal mining in Russia and shale production in Estonia. Mine wastes, piled up around the mine entrances, create unfavorable conditions for revegetation: altered soil texture and structure, high or toxic concentrations of sulfates, inadequate levels of plant nutrients, and low pH levels.

Mine wastes have created significant environmental problems in Ukraine. At the Donets Basin, piles of overburden have created mounds on the surface up to 100 meters high. Ukrainian coal enterprises have almost 1,200 waste dumps (370 presently in use), occupying an area of over 5,000 hectares and containing nearly 1.4 billion cubic

[19] Stanley J. Kabala, "The Reform of Environmental Policy," *Report on Eastern Europe*, vol. 2, No. 8, Feb. 22, 1991, p. 11.

[20] Fowler, Energy *and the Environment*, p. 199.

[21] M.J. Chadwick, N.H. Highton, and N. Lindman (eds.), *Environmental Impacts of Coal Mining and Utilization* (Oxford: Pergamon Press, 1987), p. 35.

meters of barren rock.[22] Vegetating these waste piles has been difficult because the material is generally infertile.[23]

Another problem associated with underground mining is fire. In operating mines, fires result from accidents. At waste dumps, fires result from spontaneous combustion (a noted problem in Ukraine). Despite a program to reduce these fires by switching to flat dumps insulated with inert materials, spontaneous combustion has occurred at 15 of the flat waste dumps now in use.[24]

Mine Discharge

A major problem associated with underground mining is the discharge of polluted waters to ground and surface water. When water reaches the coal seams, from either producton or natural seepage, it can react with the sulfur-containing pyrites or other minerals and form very destructive pollutants, such as sulfuric acid. Mine drainage also contributes increased amounts of sediments, sulfates, iron, and salts. Acid or saline discharge can affect both surface and underground mines, depending on the mineral content of the coal seams, overburden, and groundwater. Polluted mine discharge is a particularly tenacious problem because it can occur at abandoned mines as well as surface-mined areas that have not been reclaimed for hydrologic features.

In Poland and Ukraine, most of the problems with mine drainage have occurred from underground mines and runoff from tailing piles. Water draining from underground Polish mines is largely saline which has increased the salinity of the two major rivers, the Vistula and the Ordra, rendering the water too corrosive even for industrial consumption.[25] In Ukraine, saline discharge is also a problem, caused principally by suspended substances, mineral salts, organic ingredients, and trace elements. According to Ukrainian sources, water purification systems still leave about 10 percent of intake water polluted.[26] In Russia, where the sulfur content of mined coal is lower, acid mine drainage has been less significant (with the possible exception of the high-sulfur Kiselovsk field in the Urals region).

Special measures must be taken in mining areas where acid-producing substances are present. The main techniques rely on isolating the acid-forming materials and preventing contact with oxygen, by either water or overburden. Unfortunately, both options have limitations, and if they cannot prevent acidification, then the only recourse is treatment of the mine discharge.[27] Commonly, after mining operations have stopped, the mine is sealed and water allowed to fill the mine shafts. This method works as long as there is no "breakout" of the acidic water filling the mine. Unfortunately, when a breakout occurs, it is often difficult to detect and respond to before significant damage has occurred to water bodies.[28]

Processing

As noted earlier, there is relatively little processing of energy coal in the region, and therefore the environmental consequences of coal processing has been limited. However, the introduction of additional coal cleaning capacity, although reducing pollution at the point of use, will produce significant amounts of waste that are difficult to

[22] "Ukraine: Environmental Protection Needed in Coal-Producing Regions," *Ugol Ukrainy* 1993, No. 1, as translated in *JPRS Environmental Series*, May 21, 1993.

[23] Pryde, *Environmental Management in the Soviet Union*, pp. 205-206.

[24] "Ukraine: Environmental Protection Needed in Coal-producing Regions."

[25] World Bank, *Poland Environmental Strategy*, Apr. 24, 1993, p. 3.

[26] "Ukraine: Environmental Protection Needed in Coal-Producing Regions."

[27] James M. McElfish Jr. and Ann E. Beier, *Environmental Regulation of Coal Mining* (Washington, DC: Environmental Law Institute, 1990), pp. 138-39.

[28] Ibid., p. 139.

dispose of or reclaim. In the United States, for example, coal mining is the third-ranking industrial producer of mineral waste; 90 percent of this comes from the washing of coal to remove impurities.[29]

Environmental technology options

Technical expertise more than specific equipment is needed to remediate environmental problems at coal and shale mines. Hydrologic expertise is needed to deal with mine discharge and to reduce the formation of acidic or saline discharge. Water purification systems and expertise are needed to clean up existing sites. Attention should be given to incorporating reclamation (such as grading, soil, and substrata separation and storage) into production. But reclamation of previously mined areas will likely be too difficult to attempt in the short term, unless it becomes economical to reprocess mine tailings.

U.S. opportunities to transfer technology

The United States has had significant experience dealing with problems similar to those found in the coal and shale sectors of the former East Bloc, in particular, land reclamation efforts and the reduction of acid mine discharge. The need for assistance in the reclamation of surface-mined areas appears greatest in the Czech Republic and Estonia. Problems in tailings reclamation and polluted water discharge from underground mining are greatest in Ukraine and Poland.

While the United States does not have a clear advantage in the desalinization equipment needed in Poland, there are many opportunities for firms with experience in mine hydrology.

THE ENVIRONMENTAL IMPACTS OF FUEL CONSUMPTION

When fuels are burned, minerals within are released in either particulate or gaseous forms. Thermal NO_x, hydrocarbons, CO, and carbon dioxide ($C0_2$) are also formed during the combustion process. In sufficient quantities, many of these compounds can affect human health, damage the economy (e.g., corroding structures and stunting crop growth), and cause transboundary pollution.

High energy use combined with lax enforcement of env ironmental standards resulted in widespread air quality problems in the region. Acid rain exists in all countries of Central Europe and most of the FSU. In the Czech Republic, there is evidence that soil acidity has increased significantly since the 1960s, representing one of the few examples of large-scale soil acidification caused by acid deposition.[30] This increase in soil acidity could be contributing to problems in soil toxicity, because aluminum, zinc, and beryllium are liberated from soil primarily under extremely acidic conditions.[31]

Smokestacks historically have been used to reduce pollution problems from stationary sources such as powerplants by elevating emissions above the ground where they may be more effectively dispersed. However, other environmental problems are aggravated by tall stacks. In particular, tall stacks release pollutants at a sufficient height to allow chemical transformations and precipitation as acid rain. Increased mobile-source activities—in particular, private car use-create a host of other pollution problems (such as lead emissions, CO, and hydrocarbons that react to form

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[29] Fowler, *Energy and the Environment*, p. 202.

[30] Bedrich Moldan and Jerald Schnoor, "'Czechoslovakia: Examining a Critically Ill Environment," *Environmental Science and Technology*, vol. 26, No. 1, 1992, p. 16.

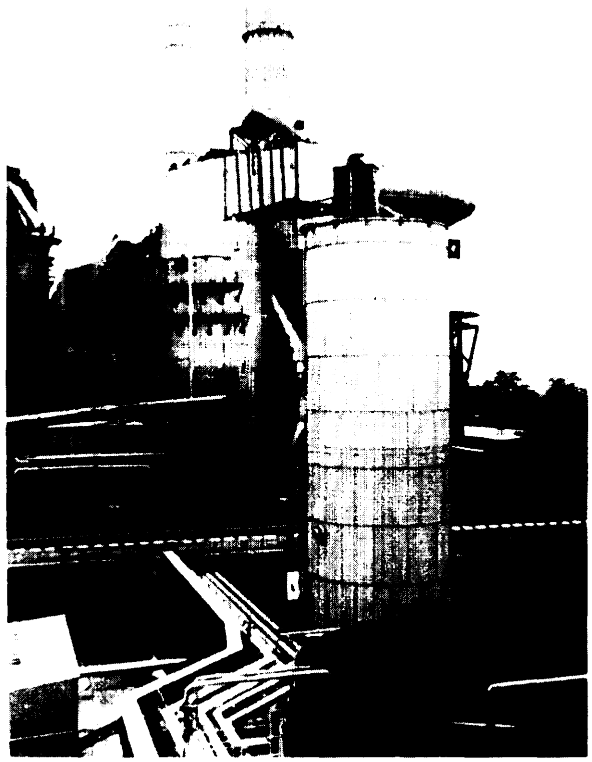
[31] Ibid.

ozone) at ground level. Therefore, in the last decade, many technologies have been developed for the control of emissions from fossil fuel use through pre-combustion fuel cleaning or processing, combustion modifications, and post-combustion cleaning of flue gases for both stationary and mobile sources. In former East Bloc countries, however, the lack of regulatory enforcement resulted in a lower level of technology (and applications) of abatement equipment than that in the West. Existing abatement equipment appears inefficient compared with Western models and is based on particulate removal, rather than gaseous components such as SO_2.

The following section examines problems arising from fuel use in former East Bloc countries. The focus is on particulate, SO_2, and NO_X because there is insufficient data about emission patterns of other pollutants (e.g., CO, hydrocarbons, lead) for a comparative analysis. The reader is cautioned that the following analysis is based on official data, which might contain errors.

Particulate

Particulate matter is composed of dust, mist, ash, smoke, and fumes. Fuel burning, industrial processes (particularly smelting), and waste incineration are the major sources of manmade particulate emissions. The smaller particles (from 0.1 to 1 micron) are mostly combustion-related, and consist of particles of tar (heavy hydrocarbons) and soot (carbon) that escape unburned in the exhaust gas.[32] In the cyclone (or wet-bottom) furnaces 'hat dominate capacity in the region, as much as 70 percent of the incombustible material in coal leaves with combustion gases as fly ash, and the remainder is collected at a bottom grate as slag, or bottom ash.[33]



AIRPOL, INC

Wet flue gas desulfurization system for the Skawina Power Plant in Krakow, Poland: completed absorber vessel with lime silo and hold tank in foreground.

The size of these particles largely determines their effects. Large particles are the most visible pollutants and can carry damaging materials, such as sulfuric acid, to the surfaces they strike. Smaller particles, however, present a greater health threat because they can evade the human respiratory system's defense mechanisms.

Regional Issues

Particulate emissions in the former East Bloc area much more significant problem than in the United States, where they have been substantially re-

32 Fowler, *Energy and the Environment*, p. 161.

33 U.S. Department of Energy, *Energy Technologies and the Environment* (Washington, DC: 1988), p. 29.

duced through the installation of abatement equipment.[34] In 1989, particulate emissions from fuel use and industrial sources[35] in Russia (7.8 million tons) were 75 percent higher than in the United States (4.5 million tons). Particulate emissions in Poland and Ukraine were less than 2.4 million tons. High levels of particulate emissions are due to the use of high-ash coal, lignite, and shale without pre-combustion cleaning and without sufficient post-combustion abatement equipment.

Table 5-1 shows the major sources and densities of regional particulate emissions measured as kilograms per capita. (Note that this measurement does not reflect health risks; instead, it is a general indicator of the intensity of emissions in the various economies.)[36]

Environmental technology options

For large sources, two very efficient (99+ percent) types of post-combustion cleaning are now commonly in use in the West: electrostatic precipitators (ESP) and baghouse filters. The decision to use ESPs or baghouse filters is largely determined by the coal type used at the boilers; low-sulfur coals of the Western United States have had resistivity problems with ESPs.

No comprehensive statistics exist on the type of particulate abatement equipment installed in former East Bloc countries. While Soviet sources have referred to the use of ESPs at large powerplants, there is little information about their effectiveness. The Polish environmental handbook provides some background information on pollution control equipment installed in the region.[37] In 1991, 88 percent of stationary particulate emission sources had some sort of particulate removal system in place, but most used cyclone technology which is much less effective than ESP and baghouse filters. Only 20 percent of all equipment was rated above 90 percent efficiency. Only half of the relatively few ESP units were rated above 95 percent efficiency, although the standard in the West is generally higher than 99 percent.[38]

A different approach to particulate emissions in this region would be cleaning coal to remove some of the ash matter before combustion (see also chapters 3 and 4). Because the coal burned in this region tends to be of high ash content, simple coal cleaning could provide a significant reduction in particulate emissions, especially for smaller fuel consumers, where post-combustion cleaning would not be feasible. In Katowice, Poland, tall powerplant and industrial stacks account for only 55 percent of particulate emissions, with the remainder coming from low stacks associated with households, district heating plants, and small industry.[39] cleaning would also reduce particulate emissions in the Czech Republic, Slovakia, and Hungary whose home heating needs are largely met by coal. Coal cleaning also provides benefits to large coal consumers by reducing the wear on ESPs, baghouse filters, and sulfur removal systems.

U.S. opportunities to transfer technology

As noted in chapter 3, U.S. firms have a significant advantage in hard-coal cleaning technologies. However, U.S. experience in cleaning lignites does not provide a good match for the needs of former East Bloc countries. Since the sul -

34 U.S. Environmental Protection Agency, *National Air Pollutant Emission Estimates 1940-1989* (Triangle park, NC: 1991).

35 Particulate emission data from mobile sources, solid waste burning, and forest fires are not available for the Central and East European countries noted here.

36 Many analysts use the measure Of pollution per dollar of GNP. Given the problems of GNP accounting and dollar conversion rates among the countries in this region, the pollution-intensity of economic output has not been calculated. It can be said, however, that given the large disparities in per capita economic output, the emission intensities of this region are much higher than the case in other European countries.

37 *Ochrona Srodowiska* 1992 (Warsaw: Glowny Urzad Statystyczny, 1992), p. 152.

38 Ibid.

39 World Bank, *Poland Environmental Strategy*, p. 4.

TABLE 5-1: Emissions of Particulates

Country	Kg/per capita	Main sources
Estonia (1989)	162	Use of locally produced shale and industrial facilities, Shale-fired powerplants 55% Cement plants 35%
Kazakhstan (1989)	122	Use of high-ash Ekibastuz coal
Czech Republic (1988)	81	Use of locally produced lignite (primarily powerplants) and industrial facilities: Powerplants 50% Industrial sector 35%
Russia (1 989)	57	Coal use, industrial sources Powerplants 50% Metallurgy 25%.
Poland (1990)	55	Industrial sector, coal use Industry 40% Residential/commercial 30% Powerplants 30%
Slovak Republic (1988)	51	Lignite use, industrial sector
Ukraine (1989)	44	Industrial processes; use of high-ash Donets coal
Hungary (1988)	40	Industrial sector, use of low-quality coal Industry 50% Powerplants 20% Residential 20%.
U.S. (1989)	24*	Industrial processes 45% Highway vehicles 22% Residential 18'%.

Other countries with reported emissions: Romania (1990) 30, Moldova (1989) 18, Belarus (1989) 17, Latvia (1989) 14, Lithuania (1989) 11

*For comparative purposes, this figure does not include emissions from incineration, waste dumps, or forest fires

SOURCES R C Cooper, "Environmental Problems and Pollution Abatement in Central and Eastern Europe, " contractor report prepared for the Office of Technology Assessment, Aug 6, 1993, pp 42, 127, and U S Environmental Protect Ion Agency, *National Air Pollutant Emission Estimates 1940-1989* (Research Triangle Park, NC March 1991)

fur content of the lignite deposits in the western regions of the United States is very low, sulfur removal has not been a major goal of U.S. technologies.

U.S. firms also have a great deal of experience in post-combustion particulate removal. While ESPs have been the main focus of particulate abatement, the exploitation of Western, low-sulfur coals in recent years has increased baghouse filter usage.

Sulfur Dioxide

Sulfur dioxide is formed when sulfur contained in the fuel combines with oxygen during the combustion process to form SO_2. It is released in the combustion gases. Certain industrial processes, such as the smelting of sulfur-containing ores, also result in SO_2 emissions. When SO_2 is carried into the upper respiratory system and the lung, it can increase airway resistance. While this may be merely troublesome for a healthy person, it can be fatal to someone already afflicted with chronic bronchitis or emphysema.

In recent years, concerns about SO_2 emissions have focused on acid rain. Acid rain is the result of an additional chemical change in the atmosphere, when some SO_2 is oxidized to form sulfuric acid (H_2SO_4). NO_x can also be oxidized to form the pollutant nitric acid (HNO_3). Aerosols containing these acids have a short residence time in the atmosphere (from two days to a week), and are then deposited on the ground through rain or snow. Acid rain can lower the pH of lakes, with consequent damage to fish and other aquatic life, and it is suspected that acid rain harms crops and forests.

Coal is generally considered the main contributor to fuel-based SO_2 emissions. However, because of the lack of desulfurization equipment in the refinery system, SO_2 emissions from residual fuel oil are greater than emissions from coal use in some regions, even on an energy-equivalent basis. Without desulfurization equipment, the sulfur contained in crude oil is concentrated in the heavier components. Because much refinery technology in the region is based on primary distillation, high shares of high-sulfur components, such as residual fuel oil, are produced, exacerbating the problems of sulfur emissions. Although low-sulfur residual fuel oil is produced in the region, most is high- or medium-sulfur grade.[40]

Regional Problems

There have been very few controls to reduce SO_2 emissions in the region. Instead, taller stacks have been used at large polluting sources to disperse sulfur emissions away from residential areas. As shown in table 5-2, the Czech Republic had the highest density of SO_2 emissions (measured per capita) in the region, due to high-sulfur lignite use. Since the energy content of this lignite is very low, large volumes must be consumed.

Although not evident from table 5-2, emissions of SO_2 fell in many countries of the region during the 1980s because of changes in the fuel balance. During the 1980s, large amounts of natural gas from the Urengoi fields started to move westward through large-diameter pipelines. Increased gas availability, coupled with a stagnation in oil production, resulted in a gas-for-oil substitution program at powerplants in the former Soviet Union. Between 1980 and 1985, natural gas consumption at powerplants in the former Soviet Union almost doubled.[41] The initial increase in gas use came from powerplants located nearest the production region of Western Siberia (the Urals and Volga regions) or along the newly constructed export line (Ukraine). By the early 1990s, powerplants in Moldova, Belarus, and Latvia had switched to gas use. Natural gas not only replaced high-sulfur residual fuel oil, but also coal and peat.[42]

According to Soviet statistics, SO_2 emissions dropped dramatically in the 1980s, from a peak of 20.2 million tons in 1983 to 16.8 million tons in 1989, a 17-percent decline.[43] However, this was due almost exclusively to a reduction in residual

[40] PlanEcon, Inc., *Petroleum Product Marketing: Eastern Europe and Former Soviet Republics* (Washington, DC: PlanEcon, Inc. and DRI/McGraw-Hill, March 1993), p. 7.

[41] A. A. Troitskii (@, *Energetika SSSR v 1986-1990 godakh* (Power Engineering in the USSR, 1986-1990) (Moscow: Energoatomizdat, 1987), p. 90.

[42] R. Caron Cooper, "Petroleum Displacement in the Soviet Economy: The Case Of Electric Power Plants," *Soviet Geography,* vol. 27, No. 6, June 1986.

[43] By comparison, during the same period, SO_2 emissions in the United States fell by only 8 percent. R. Caron Cooper, "Sulfur Dioxide Emissions in the Republics of the USSR," joint meeting of the Association for Comparative Economic Studies and the Association for Environmental and Resource Economics, Allied Social Science meetings, New Orleans (January 1992).

TABLE 5-2: Emissions of Sulfur Dioxide

Country	Kg/per capita	Main sources
Czech Republic (1988)	200	High-sulfur lignite consumption: Powerplants 66% Industrial sector 13%
Bulgaria (1985)	193	High sulfur lignite consumption
Estonia (1989)	124	Use of locally produced shale: Shale-fired powerplants 70% Other sources 30%
Hungary (1988)	115	Use of locally produced coal and residual fuel oil, industrial activities: Powerplants 40% Industry 33% Home heating 22%
Slovak Republic (1988)	112	Not available
Kazakhstan (1989)	95	Industrial processes
Poland (1990)	90	Coal consumption: Powerplants 50% Home heating 25%
Russia (1989)	71	Industrial processes, high-sulfur residual fuel oil consumption: Metallurgy 50% Powerplants 35%
Romania (1989)	67	Industrial activities, coal, and residual fuel oil
U.S. (1989)	85	Coal consumption (powerplants), industry

Other countries with reported emissions: Ukraine (1989) 60; Belarus (1989) 58; Moldova (1989) 55, Lithuania (1989) 51, Latvia 22

SOURCES R C Cooper, "Environmental Problems and Pollution Abatement in Central and Eastern Europe, '<contractor report prepared for the Office of Technology Assessment, Aug. 6, 1993, p. 39, 125; and U S. Environmental Protection Agency, *National Air Pollutant Emission Estimates 7940-7989* (Research Triangle Park, NC: March 1991)

fuel oil and high-sulfur coal use, rather than the installation of post-combustion abatement equipment.

In Central Europe, gas consumption increased slightly in the 1980s, based on imports from the Soviet Union. However, in recent years, new import pricing and the industrial downturn reduced gas use in the region. Gas was used primarily in the industrial sector, with the residential sector only recently increasing in importance. Gas has not been used extensively in powerplants, except for Hungary (35 percent of fossil-fired generation) and Romania (45 percent of fossil-fired generation).

Environmental technology options

Besides switching to low-sulfur fuels, there are many ways to reduce SO_2 emissions. Only the most common commercial practices are explored here. Sulfur can be removed from the fuel before combustion through coal cleaning and desulfurization of fuel oil. Modifications can be made in combustion, or exhaust gases can be treated after combustion.

Little has been done in the region to reduce SO_2 emissions. Only a small amount of coal is cleaned or processed, and there is little abatement equipment in place. In Poland, only 58 of the almost 1,600 SO_2-emitting sources regulated had SO_2 abatement equipment, and only six of these had sulfur removal efficiencies greater than 90 percent. Almost half the SO_2 abatement equipment had efficiencies of less than 50 percent.[44] Only three powerplants in the FSU had scrubbers, and these were experimental units.

Coal cleaning can reduce the amount of sulfur in fuel before combustion. It is also the only method, besides fuel switching, to address emissions from small boilers and individual consumers in the residential sector. Although coal cleaning technologies are advancing rapidly, commercial coal cleaning can presently remove only the pyritic sulfur components found in coal, not the organic sulfur. In Polish coal, the share of organic sulfur is high (60 percent).[45] Since conventional coal cleaning can remove 30 to 70 percent of the pyritic sulfur,[46] cleaning of Polish coal would offer only a 10 to 30 percent reduction in SO_2 emissions. While cleaning Polish coal provides a number of benefits (e.g., reducing particulate, lowering transport needs), it does not provide a significant reduction in sulfur emissions. In Ukraine, on the other hand, coal cleaning offers a larger reduction in sulfur emissions, because a large share of the sulfur is in pyritic components. Donets Basin coal has from 60 to 75 percent of sulfur in pyrites.[47] Therefore, high-efficiency conventional coal cleaning could reduce sulfur emissions by up to 50 percent. However, since the sulfur content of Donets coal is high (from 2.5 to 3.5 percent sulfur), SO_2 emissions even with coal cleaning would still be much higher than EU standards would allow.

Desulfurization of fuel oil at refineries (hydrotreating) is particularly important in this region because much of the refining capacity, especially in the FSU, is based on primary distillation, which results in high shares of heavier components, such as residual fuel oil. Residual fuel oil accounted for the largest share of fuel-based SO_2 emissions in Russia, Belarus, Moldova, and Lithuania, and a significant share of SO_2 emissions in Romania. Sulfur scrubbers can be used to reduce SO_2 emissions, but fuel oil-consuming plants are usually dual-fired, using natural gas when it is available in the summer, which reduces the economic effectiveness of installing abatement equipment.[48]

Several technologies reduce SO_2 in the combustion process. Fluidized-bed combustion (FBC) employs a circulating bed design to capture almost 95 percent of the sulfur (compared with 85 percent capture in deep-bed designs, and 60 percent in shallow-bed designs).[49] The circulating bed also has the best performance in reducing NO_x emissions. In the FSU, some FBC boilers have been installed in industry, and a 135-megawatt (MW) bubbling-bed utility version has been under development, using coal from the Kansk-Achinsk region of Siberia.[50] This project, however, does

[44] *Ochrona Srodowiska 1992*, p. 152.

[45] Robert A. Meyers, *Coal Desulfurization* (New York, NY: Marcel Dekker, 1977), p. 4.

[46] DOE, *Energy Technologies and the Environment*, p. 13.

[47] *Energeticheskoe Toplivo SSSR*, 2d ed. (Moscow: Energoatornizdat, 1991), pp. 16-17.

[48] M. A. Styrakovich and A. K. Vnukov, "Sopostavlenie ekologo-ekonomicheskoi tselesoobraznosti udleniia sery na neftepererabaty-vaiushchikh zavodakh i TETs," (Determining the Ecologic-Economic Goals for Sulfur Abatement, Refineries and Cogeneration Plants), *Teploenergetika*, No. 12, 1989, p. 39.

[49] International Energy Agency, Emission *Controls in Electricity Generation and Industry* (Paris: OECD/IEA, 1988), p. 72.

[50] Jon Cohen, "The Soviet Power Industry Opens Its Doors," *EPRI Journal*, vol. 15, No. 2, March 1990, p. 34.

not have much potential for reducing sulfur emissions, because Kansk-Achinsk coal is a low-sulfur lignite. Another combustion modification currently being explored is furnace sorbent injection. This technology injects a dry sorbent (usually lime) into the furnace, where it reacts with sulfur and forms solid particles, which can be collected by the particulate control device. While $S0_2$ removal can be up to 65 percent, this still might not be sufficient to meet regulations.[51]

Flue-gas desulfurization (FGD), a post-combustion $S0_2$ removal technology, is the most widespread method in the West. FGD systems use a sorbent to react with and scrub sulfur directly from flue gas. A 90-percent reduction or more of $S0_2$ is common with wet scrubbers. The disadvantages of wet scrubbers include space and energy requirements and relatively high retrofit costs. An additional problem is the high-volume of byproduct.[52] The choice of FGD technologies often depends on waste-disposal regulations. The spray dryer FGD is the second-most-common system in use and has been popular in Europe. This FGD process injects lime into an absorber vessel, which reacts with the sulfur, leaving dry particles of the sulfur for collection in the particulate filter system. The advantages of the spray dryer system include lower energy losses, ease of handling the byproduct, and lower capital and opera ing costs.[53]

Combined $S0_2$ and NO_x control systems are presently being developed. A combined appro ach to post-combustion cleaning would offer lower total capital and operating costs than the installation of separate equipment for control of each pollutant. The limestone-injection, multi-stage burners (LIMB) is a promising type of combustion technology designed to reduce both $S0_2$ and NO_x emissions. It also reduces particulate emission levels. It is a relatively simple system and attractive for retrofit applications. LIMB should achieve reductions of 50 to 60 percent in $S0_2$ and 50 percent in NO_x emissions. However, these levels of reduction might not be enough to meet standards.[54] Advanced FGD systems, which potentially reduce both $S0_2$ and NO_x to compliance levels are under long-term development.[55]

FGD systems could play a role in reducing SOL emissions in some former East Bloc countries. If regulatory priorities mirror those of the West, standards will be strictest and the need for FGD greatest at large fuel-consuming units such as powerplants. The facilities best suited to the use of FGDs or similar sulfur-abatement equipment are the coal-fired powerplants in Poland, the Czech Republic, Ukraine, and Russia, and possibly the shale-fired plants in Estonia. Post-combustion removal of sulfur would probably not make sense in Slovakia or Bulgaria (powerplants are small), Hungary (coal consumption has been displaced by gas and nuclear power), and Belarus or Moldova (large powerplants have been converted to gas, and $S0_2$ emissions are from residual fuel oil at smaller facilities). In Ukraine, a new coal-fired powerplant (a 300-MW unit at Dobrotvor, on the border with Poland) received a $50-million investment grant from the German Environmental Ministry for the installation of FGD and particulate control technologies.[56] In Poland, a Dutch firm will build two smokestack scrubbers for the

5 I Jason Makansi, "Controlling SO_2 Emissions," *Power, vol. 137, No.* 3, May *1993,* p. 50.

52 Ibid.

53 Ibid.

54 1 bid., pp. *67-68.*

55 1 bid., p. 68.

56 "Germany to Help Provide Financing to Clean Coal-Powered Plant in Ukraine," *International Environment Reporter, vol. 15, No. 19,* Sept. *23, 1992.*

Belchatow Powerplant, and provide engineering for two others.[57] The Czech government has called for the installation of FGD equipment at the country's largest and most modem powerplant, Prunerov II, and funding has been received for this project from the World Bank, the EU, and the German government.[58]

U.S. opportunities to transfer technology

Technologies for sulfur abatement extensively used and manufactured by U.S. firms have some advantages in the region. FGD systems in the United States can handle coals with much higher sulfur contents than their overseas counterparts.[59] This could be a significant advantage in countries with high-sulfur coal such as the Czech Republic and Ukraine. The United States also holds an edge in FBC, having the largest share of installed capacity (among International Energy Agency members) of circulating-bed plants.[60] However, Europe has greater experience in spray dryers.[61]

Nitrogen Oxides

NO_x is a mixture of nitric oxide (NO) and $N0_2$. When combustion occurs at high temperatures—regardless of the fuel used—some nitrogen contained in the air is oxidized to NO and $N0_2$ (thermal NO_x). Nitrogen contained in some fuels, such as coal, is also oxidized during the combustion process (fuel NO_x). At stationary sources, the quantity of NO_x emissions is determined by the temperature of combustion and the amount of excess air in the furnace unit. For large, pulverized-coal boilers, the highest rate of NO_x emissions occurs at cyclone furnaces, followed by wall-freed units and tangential-fired boilers.[62] Cyclone furnaces are common throughout the former East Bloc. For example, Ukraine alone has 85 of these units.[63] The health effects of long-term NO_x exposure are still unknown, but emissions of NO_x are linked to acid precipitation and ozone formation.

The major sources of NO_x emissions include cars and trucks, powerplants, and the industrial sector (from fuel use rather than industrial processes). With the advent of catalytic converters on cars, NO_x emissions have decreased in many countries, even where vehicular ownership increased. For example, in the United States, NO_x emissions from the transport sector as a whole fell from 9.8 million metric tons in 1980 to 7.9 million tons in 1989.64 In the former East Bloc, most NO_x emissions come from industry, although most large cities experience high NO_x levels due to the use of cars without catalytic converters. Moreover, the future of NO_x emissions in the region is presently unclear. In many countries, the low level of private car transport has kept NO_x emissions at artificially low levels. Increases in car ownership may significantly increase NO_x emissions.

Regional Problems

One of the difficulties in assessing NO_x emissions in former East Bloc countries is that the emission statistics for thermal NO_x are almost impossible

57 "Dutch Firm to Build Scrubbers for a Polish Power Plant," *International Environment Reporter, vol.* 15, *NO. 8,* Apr. 22, 1992, p. z@.

58 Stanley J. Kabala, "EC Helps Czechoslovakia Pay Debt to the Environment," RFE/RL Research Report, vol. 1, No. 20, May 15, 1992, P. 55; "Czech Government Accepts German Grant to Install ScrubberSat Coal Plants in North," *International Environment Reporter, vol. 15, No. 24, Dec. 2, 1992;* "World Bank Approves Loan to Cut Power Plant Pollution," *International Environment Reporter, vol. 15, No. 12,* June 17, 1992, p. 425.

59 Makansi, "Controlling $S0_2$ Emissions," p. 28.

60 IEA, *Emission Controls in Electricity Generation and Industry,* p. 73.

61 Makansi, "Controlling S02," p. 46.

62 IEA, *Emission Controls in Electricity Generation and Industry, p. 65.*

63 "US, Ukraine, and Russia to Produce New 'Reburn' Technology," *Environmental Watch, East Europe, Russia & Eurasia,* vol.1, No. *4,* November 1992, pp. 6-7.

64 EPA, *National Air Pollutant Emission Estimates 1940-1989, p.* 21.

TABLE 5–3: Emissions of Nitrogen Oxides (NO_x)

Country	Kg/per capita	Main sources
Czech Republic (1988)	83	Stationary sources 75% Mobile sources 25%
Romania (1990)	39	Not available
Poland (1990)	36	Stationary sources 67% (half from powerplants) Mobile sources 33%
Slovak Republic (1988)	**37**	Stationary sources 80% Mobile sources 2570
Bulgaria (1985)	**34**	Not available
Estonia (1989)	**31**	Stationary sources 55% Mobile sources 45%.
Hungary (1988)	**24**	Stationary sources 55% Mobile sources 45%
U.S (1989)	80	Stationary sources 60% Mobile sources 401%0

Other countries with reported emm.ions. Kazakhstan (1989) 22;[a] Ukraine (1 989) 21, Lithuania (1 989) 21, Russia (1989) 19;[a] Moldova (1989) 19; Belarus (1989) 10;[a] Latvia (1989) 5

[a]Mobile-source data not included.

SOURCES R C Cooper, "Environmental Problems and Pollution Abatement in Central and Eastern Europe, " contractor report prepared for the Office of Technology Assessment, Aug 6, 1993, p. 39, 125, and U S Environmental Protect Ion Agency, *National Air Pollutant Emission Estimates 1940-1989* (Research Triangle Park, NC: March 1991)

to verify. Furthermore, for many former Soviet republics, no data on mobile-source emissions by specific pollutant have been reported.

To calculate mobile-source NO_x emissions, a large data base containing information on gasoline consumption, engine efficiency, operating conditions, miles driven, emissions, and other factors for many categories of transport modes is needed. However, most of this data have not been tracked, recorded, or reported.

Therefore, the emission figures in table 5-3 must be approached with some caution. Although the Czech Republic again tops the list of polluters, the density of NO_x emissions in the Czech Republic was very similar to that of the United States. However, stationary sources play a much more important role in NO_x emission in the Czech Republic than they do in the United States.

Environmental technology options

Combustion modifications were the first methods employed to reduce NO_x emissions in the West. Originally used to reduce mobile-source emissions, they are now used almost exclusively on stationary sources. The success of combustion modification methods depends on the type of furnace and burner. In general, wall- and tangentially fired units are easier to retrofit for low-NO_x burners than are cyclone furnaces. In the cyclone units common to the FSU, fuel reburning is thought to be the only option to reducing NO_x emissions during combustion.[65]

[65]Ibid.

For post-combustion NO_x removal, selective catalytic reduction (SCR) has been the primary commercialized technology. While SCR technology is much more efficient than combustion modification in removing NO_x (as high as 90 percent removal, compared with approximately 50 percent for combustion modification), SCR systems have high operating and capital costs compared with combustion modification.

A second, recently commercialized technique for removing NO_x from flue gases is selective, noncatalytic reduction (SNCR). This system has lower costs and lower NO_x removal efficiencies (about 50 percent) than SCR.[66] Also, SCNR is extremely sensitive, and additional NO_x can form if temperatures are too high. Another problem preventing widespread use of SNCR is that some NO is converted to N_20, a greenhouse gas.

Advanced generation technologies, such as high-efficiency gas turbines, also emit NO_x. Injection of steam from the exhaust boiler into the gas turbine burner can be used to control NOx emissions from the basic gas turbine. Conventional NO_x control techniques, such as combustion control, SCR, or SNCR can also be employed.

U.S. opportunities to transfer technology

The primary advantage of U.S. firms in reducing NO_x emissions at stationary sources is reburn technology, which can reduce NO_x emissions by up to 50 percent. Reburning is an in-furnace technique for reducing NO_x by creating a reducing zone downstream from the primary combustor. The injection of natural gas into the reducing zone with insufficient oxygen bums the fuel completely. A demonstration project to retrofit a powerplant boiler at the Ladyzhin PowerPlant (located in Ukraine, 150 kilometers southeast of Kiev) with U.S. reburn technology was sponsored by the U.S. Environmental Protection Agency, working with ABB Combustion Engineering (Windsor, Connecticut). While retrofitting was very labor-intensive, this factor was not a deterrent in Ukraine, where wages for skilled workers are very low. Reburn technology was also the cheapest method for retrofitting cyclone boilers.[67]

In post-combustion NO_x removal, however, the United States is at a disadvantage. While SCR has been commonly used in gas-turbine cogeneration and combined-cycle systems in the United States, the first full-scale utility applications (one coal-fired, one oil/gas-fired powerplant) are just starting up. Meanwhile, tens of thousands of megawatts of fossil-fired boilers are operating with SCR in Japan and Europe.[68]

| Other Pollution Problems

Hundreds of other pollution problems are noted during fuel combustion. Principal among them are hydrocarbon, carbon monoxide, and lead emissions and photochemical smog formation. Motor vehicle traffic is a major source of these problems.

There are relatively few trucks in the FSU compared with the United States,[69] but the potential for expanding truck transport in the former East Bloc is substantial. Under almost any scenario of economic development, trucks will play a much greater role in freight transport, particularly if regions, industries, and consumers have more autonomy in the production and purchase of goods.

The pattern of passenger transport in the region varies from other industrial countries, as well. Passenger transport has been dominated by collective carriers (buses and trains), although private vehicles have started to make inroads. By

[66] IEA, *Emission Controls in Electricity Generation and Industry*, p. 67.

[67] Ibid.

[68] Makansi, "Controlling SO_2 Emissions," p. 22.

[69] While Statistics are unclear, it appears that in the late 1980s there were 5.4 million trucks in the Soviet Union, compared with 40 million in the United States. See Vavilov, "Vce krugi chada," *Energetika, ekonomika, tekhnika, ekologiia*, No. 10, 1989.

Western standards, there are very few private cars in the FSU.[70] In Central Europe, car ownership levels are higher, but vary significantly.[71] There is tremendous potential for motor vehicle usage to increase rapidly if market conditions permit.

As noted earlier, data on emissions from mobile sources are insufficient to perform a detailed analysis at this point. Even given the scant data, it appears that emissions are quite high, despite the low level of truck transport and private car ownership. For example, in 1987 for the Soviet Union as a whole, hydrocarbon emissions from mobile sources were at 90 percent of U.S. levels for mobile sources. Carbon monoxide was at 65 percent, and NO_x was at 25 percent,[72] even though the U.S. had almost eight times the number of cars and three times the amount of freight haulage (measured as ton-kilometers) by trucks.

Emissions control equipment on cars manufactured in the region has been minimal. Very few vehicles manufactured in the FSU were equipped with catalytic converters, owing in part to shortages of platinum and palladium and the low production levels of unleaded gasoline.

Environmental technology options

Most domestic auto industries, in joint ventures with Western firms, are shifting to production of cars with catalytic converters. But due to financial constraints and the lack of unleaded gasoline, it is not clear how rapidly these new vehicles will penetrate the market. The problem of the highly polluting existing car fleet will remain for many years because cars are typically held and operated for much longer periods of time in former East Bloc countries than in the West. Therefore, an important engine emission control system under development for retrofit to four-stroke engines is the lean combustion system. This system uses a microprocessor with a lean-mixture sensor, and works to ensure the leanest fuel mixture under varying engine loads. This system not only reduces emissions, but it also increases overall fuel efficiency. Recentl y, a Maryland firm won a patent for its lean-bum design, which can be retrofitted to pre-1980 cars and trucks.[73] While emission reductions with lean-bum technology are not as large as with catalytic converters, lean bum technology could play an important role in reducing automotive emissions in the region.

U.S. opportunities to transfer technology

Opportunities to transfer U.S. mobile source emissions abatement technologies are limited in former East Bloc countries. U.S. firms face stiff competition from European and Japanese firms that have significant manufacturing capacity and technical expertise. Also, vehicle emissions are not likely to be a pressing concern in former East Bloc countries because of the present low level of car ownership. Moreover, it is likely that emissions control technologies, such as catalytic converters, will be tied in with the automobile manufacturing process.

OUTLOOK FOR U.S. TECHNOLOGY TRANSFER

U.S. abatement equipment manufacturers are well positioned to meet some regional needs (see table 5-4). Specifically, U.S. suppliers could supply the

[70] In 1990, for the Soviet Union as a whole, there were only 50cars per 1,000 people, compared with over 250 in Japan, 440 in the FRG, and nearly 600 (including personal light trucks) in the United States. See Goskomstat, *Transport i sviaz'* (Moscow: Informatsionno-izdatel 'skii Tsentr Goskomstata, 1991).

[71] Car ownership levels have been highest in the former Czechoslovakia(219 cars per 1,000 people), followed by Hungary (202), and Poland (155),

[72] E. Iu Bezuglaia, G.P. Rastorgueveva, I.V. Smironova, *Chem dysit promyshlennyi gorod* (How Do Industrial Cities Breathe) (Leningrad: Girdrometeoizdat, 1991), p. 219.

[73] Warren Brown, ". Carburetor Device May He]p Mexico Clean Up Its Air," *Washington Post*, Washington Business Section, June 28, 1993, p. 9.

TABLE 5-4: Summary of Potential U.S. Equipment and Expertise Needs, by Energy Complex

Country	Environmental equipment or expertise needed
All countries	Monitoring equipment, air and water purification systems for refineries, low-sulfur residual fuel oil production, unleaded gasoline production, low NO_x combustion modifications, lean-burn, mobile-source reductions.
Russia	Offshore drilling expertise, arctic operations and equipment reclamation of mined areas, ESPs or baghouse filters.
Ukraine	Coal reclamation, acid mine drainage abatement, coal cleaning, FGD for powerplants (when operated on coal year-round), ESPs or baghouse filters for particulate removal.
Kazakhstan	Coal reclamation, ESPs or baghouse filters for particulate removal.
The Baltics	Reclamation of shale areas (Estonia), abatement equipment to reduce particulate and sulfur dioxide emissions from shale combustion.
Poland	Control of saline discharge from mines, reclamation of tailing piles, coal cleaning, FGD at large power plants, ESPs or baghouse filters for particulate removal.
Czech Republic	Reclamation of surface mined areas, coal cleaning, FGD at large powerplants, ESPs or baghouse filters for particulate removal.
Slovak Republic	Coal cleaning.
Hungary	Coal cleaning.

SOURCE: R.C Cooper, "Environmental Problems and Pollution Abatement in Central and Eastern Europe," contractor report prepared for the Office of Technology Assessment, Nov. 9, 1993.

needs for FGD units, electrostatic precipitators, baghouse filters, reburn technology for low-NO_x combustion, lean-bum technology for mobile sources, desulfurization equipment for refineries, and coal cleaning and improved mining techniques. U.S. firms have had a significant amount of experience in a range of activities that are needed to produce fuels with less environmental damage and to mitigate the damage that has already occurred. For instance, the sensitive tundra ecosystem in Russia could benefit from some of the lessons learned in Alaska. U.S. mining firms also have more experience dealing with acid mine drainage than does any other country in the world, as well as extensive experience in land reclamation.

However, unlike energy supply investments, most environmental improvements are diffilcult to finance because they produce no direct revenue stream. FGD systems might be of interest to avoid future fines, but much of the electricity in the former East Bloc is still sold at low rates, leaving the power company without means to invest. Thus government export financing may be necessary. However, the transboundary effects of some pollutants ($S0_2$ and NO_x, in particular) mean that Western European countries are more impacted by pollution coming from the region than the United States is. Western Europe thus has additional incentive to offer financial and technical support to address these issues.

In addition, U.S. regulatory standards and the phase-in periods for the Clean Air Act have put U.S. firms that supply pollution abatement equipment at a competitive disadvantage in the region. The EU standards to which many countries in the region aspire are, in general, stricter than U.S. standards, giving European (and Japanese) manufacturers of abatement equipment a market advantage. Because of differences in regulatory framework, European and Japanese firms have much more experience in retrofit designs and equipment for powerplant abatement equipment than do U.S. firms. For example, while U.S. low-NO_x combustion modifications provide a low-cost means of reducing NO_x emissions, the reductions are not enough to meet upcoming EU standards. Differences in regulatory regimes have resulted in higher prices for some U.S. domestic equipment as compared with other countries. For example, the allowance for some operational downtime of control systems due to failure, as in Germany and Japan, lowers FGD system costs in comparison with the United States, where no period of nonattainment is allowed, and systems must be built with additional redundancies.[74]

Environmental technology transfer is also plagued by a number of problems in former East Bloc countries. These include the lack of experience in regulatory enforcement, the uncertain results of economic reform, the costs of environmental technologies, and the number of other pressing environmental problems not directly related to energy.

Lack of regulatory enforcement will delay environmental reform. Enforcement is being postponed in part by the need first to develop new environmental laws and regulations.[75] But the enforcement problem also stems from overlapping and uncertain authorities among ministries, as well as competition between republic-level and local authorities.[76]

The uncertain path of regulatory reforms reduces the incentives to install abatement equipment. Even in the Czech Republic, where regulatory reform has been greatest, there is little incentive. For example, under the new environmental law in the Czech Republic, annual pollution fees for a 1,000-MW powerplant will rise steadily from 80 million to 200 million korunas ($2.4 million to $6 million), but the installation of abatement equipment would cost 12 billion korunas ($360 million) .77 In this case, the fee for pollution is smaller than interest on a loan to install a scrubber and particulate removal device.

Abatement will be very expensive throughout the region. Although labor and material costs might be lower, the capital requirements for abatement control emission, particularly for air purification, are high. For example, the costs of FGD alone for a 1,000-MW coal-fired powerplant (in the United States) would be $170 million. Adding particulate removal equipment would bring this figure to over $300 million.[78] Assistance would be needed not only for capital investments, but also for operations and maintenance ($60 million for the annual operation and maintenance of the above-noted FGD system), because electricity rates are presently too low to generate sufficient revenue to support abatement programs.

Another issue is how to plan environmental protection for an economy in transition. In addition to the immediate difficulties of financing and currency convertibility, these countries must design environmental regulation for a mix of economic activities that have no historic basis in the region. While NO_x and hydrocarbon emissions are not a significant concern at this point, ownership levels of private cars can increase quite rapidly, which could present new abatement requirements for both mobile and stationary sources. Further, a large share of the technology transfer needs identified in chapter 3 to stimulate fuel production have environmental impacts of their own. New types of drilling muds might re-

[74] IEA, *Emission Controls in Electricity Generation and Industry,* p. 125.

[75] Bowman and Hunter, "Environmental Reforms in Post-Communist Central Europe," p. 972.

[76] Ibid., pp. 972-73.

77.* Genera] Environmental Law Adopted b, Federal Parliament, *International Environment Reporter,* Jan. 15, 1992, p. 8.

[78] IEA, *Emission Con fro/s in Electricity Generation and Industry,* p. 111.

quire different containment linings; increased remote sensing and exploration could damage pristine regions; increased drilling and production from offshore sites could result in increased spills; and coal cleaning wastes need reclamation and proper disposal systems.

The pace of economic reform is also an important aspect of pollution planning. For example, coal production from the Donets basin has long been subsidized by the Soviet, and now Ukrainian, government. The Donets basin produces a high energy value coal (although it is also high in sulfur and ash) and is located near the sources of demand. However, mines must now penetrate deeper, to less economical portions of the basin. Production costs and incremental capital requirements are very high, and production has been falling. The Ukrainian government will need to decide whether to invest billions of dollars in sulfur scrubbers for powerplants that currently use Donets coal, or to shut mines and purchase natural gas from Russia or Turkmenistan. Until subsidies are removed throughout the economy (resulting in large energy savings) and some sort of safety net is established to mitigate labor dislocations, the signals for environmental technology will be adverse.

Finally, it is unclear whether the pollution from fuel production, processing, transportation, and consumption is the most pressing environmental problem in some countries in the region. For example, Belarus and Ukraine still have to face the long-term consequences of the Chernobyl accident. Toxic and hazardous waste disposal has resulted in extremely dangerous environmental conditions. Many areas do not have safe drinking water. Also, in the FSU, since fuel production, particularly of oil and gas, usually occurs away from population centers, it is difficult to correlate the impact of fuel production on human health. Instead, it is the health of surrounding ecosystems that is at risk, but the economies of the region might not be able to afford such protection in the short term.

CONCLUSIONS

At present, economic, scientific, and regulatory uncertainties make specific recommendations for U.S. involvement in the transfer of environmental technology and expertise to the energy sector difficult. Serious consideration should be given to projects that will play a significant role in protecting human health, which means thinking primarily about pollution at the ground level (low stacks and mobile sources). The Environmental Action Programme (EAP),[79] a product of the collaborative efforts of Western governments and multilateral organizations, has recommended that health and productivity costs be used as guiding priorities for environmental policy formulation and for investment in environmental cleanup.

Perhaps the best way to reduce the impacts of fuel production, processing, and transportation, is to plan environmental protection as part of the transition to a market economy. Environmental mitigation needs to be encompassed in all new Western activities in the region, from coal cleaning operations to offshore drilling activities.

Finally, it is important to remember that environmental problems cannot be addressed without considering the wider context of the economies in transition. Environmental problems are linked to a host of issues that must be addressed in the near future: investment and industrial policy, energy policy, subsidies, unemployment, and privatization. Examining environmental problems in isolation from economic and social policies will result in misguided and ineffective programs.

[79] The Environmental Action Programme for Central and Eastern Europe is based on the principles and priorities outlined at the Ministerial Conference "Environment for Europe," which took place in Lucerne, Switzerland, in April 1993. The report outlines a broad strategy for environmental reform in the region and is based on studies funded jointly by the governments of the Netherlands, Switzerland, Denmark, the United States, Germany, Italy, the United Kingdom, the European Union Commission, OECD, and the World Bank.