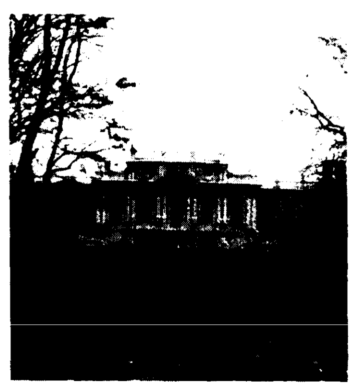
Fossil Fuel Technologies 3

The energy sector was a cornerstone of the East Bloc system. Cheap and abundant fossil fuel resources underpinned industrialization strategies, and fossil fuel exports to the West provided the substantial hard-currency earnings needed to import capital equipment, food, and consumer goods.[1] With the dissolution of the Soviet Union and the restructuring of East Bloc trade ties, the region has now differentiated into two groups-countries that are substantial net exporters of energy (e.g., Russia and Kazakhstan) and those (e.g., Ukraine, Hungary, and the Czech and Slovak Republics) that are dependent, often heavily, on imports for their energy supplies.

Supply problems in the resource-rich countries—the focus of this chapter-concern the revival of flagging production through renovation of existing facilities and the efficient exploitation of new resources. This involves the acquisition of improved technologies, major efforts to mobilize capital resources, changes in sector organization and management, radical revisions of the policies and regulations governing energy development, and immediate attention to the environmental damage associated with energy use.

The pressing need to revitalize the energy sector of these countries could offer good opportunities for U.S. energy companies, which are world leaders in most branches of oil, gas, and coal technology, with extensive experience in working abroad. How-


ALAN T. CRANE

Marinsky Palace, Kiev, Ukraine.

1 For the energy-exporting countries of the region-notably Russia—revenues from oil and gas provide 80 percent of convertible currency earnings. U.S. International Trade Commission, *Trade and Investment Patterns in the Crude Petroleum and Natural Gas Sectors of the Energy-Producing States of the Former Soviet Union,* investigation No. 332-338, Publication 2656 (Washington, DC: June 1993), pp 2-8.

ADVANCED RESOURCES INTERNATIONAL

Wet/ *site quarters for drilling crew in Kazakhstan.*

ever, only a small faction of the full potential will be realized unless political and economic barriers to energy technology transfer are removed.

OIL AND NATURAL GAS

Rehabilitation of the oil and gas industry is crucial to the economic recovery of the former Soviet Union (FSU) countries. The FSU oil and gas sector has major strengths that could stand it in good stead as it seeks to revitalize. These include a rich resource base, long experience as a major energy producer, and technically skilled personnel. At the same time, the industry is presently facing critical problems—poor technology; lack of capital, largely related to inadequate economic incentives and inappropriate legal and institutional frameworks; economic instability and political uncertainty; and a shortage of management skills. The solution of these problems will require wide ranging energy sector reform. A start has been made, but there is still a long way to go.

Western technology and resources have the potential for making an important contribution to the solution of these problems. However, the FSU is unlikely to attract western private sector capital on the scale needed unless stronger assurances and incentives governing foreign investment are forthcoming. Major problems for the foreign investor, particularly in Russia, are the lack of a legal framework governing oil and gas investment, a cumbersome decision- making process, and the current tax regime that is, compared with competing provinces, high, poorly structured, and unpredictable.

| Oil and Gas Industry Problems

Signs of trouble in the oil sector appeared in the 1980s when recorded production,[2] which had been expanding rapidly, peaked at about 12 million barrels per day (MMbbl/d) and subsequently fell sharply, by almost 40 percent. Virtually all of this decline took place within Russia, by far the largest producer among the FSU countries. Hence the emphasis in this sector on revitalization of the Russian industry.

The decline in oil production is attributable largely to the maturing of two super-giant fields in Western Siberia and, despite immense development expenditures until the mid- 1980s, lack of adequate exploration. Resources were funneled into increasing production rather than developing an adequate portfolio of new projects to take up the slack as older fields matured.

The impacts of economic crisis and political dislocation were superimposed on this longer term stagnation. Shortages of capital and foreign exchange prevented replacement and repair of existing equipment. Insurrection in Azerbaijan (which provides almost 40 percent of the equipment needed by the oil and gas sector)[3] disrupted deliveries of essential oil field equipment to Western Siberia. Further delays have been caused by intermittent stoppages of railroads, highways, and Caspian Sea transportation. The changing, often confrontational, relationship between central, re-

recorded production data do not take into account underreporting production or capacity, or deliberately holding back Production in anticipation of future price increases. These factors could moderate the extent of the decline.

[3] A. Konolplyanik, Former Deputy Minister, Russian Federation Ministry of Fuel and Energy, in "Russia Struggling to Revive Production, Rebuild Oil Industry," *Oil and Gas Journal, vol. 91, No. 31,* Aug. 2, 1993, p. 44.

gional, and local authorities discouraged orderly development. Strikes and the introduction of short working weeks because of lack of cash to pay salaries have held back production.[4]

On the demand side, the sharp contraction of the economy, and the rapidly declining number of customers able and willing to pay fuel bills has reduced oil consumption. Refineries, for example, are not being full y paid for their deliveries, which leads them to reduce crude oil orders from producers, or not pay for them.[5] Strict export quotas limit foreign sales, already suffering from the breakdown in the traditional East Bloc oil trade and the disruption of the oil transmission system.[6]

Gas has avoided the sharp production decline experienced by the oil sector. FSU production rose sharply in the 1980s before leveling off toward the end of the decade and subsequently declining moderately (by about 5 percent).' The failure of the gas sector to continue expanding after 1989 is associated with many of the factors causing the decline in oil output—poor technology, the fall in investment, declining domestic demand, and export disruptions,

Given the problems facing the gas industry, it may be surprising that production has not declined more. One reason is that the investment needs are much less than for the oil industry. Reserves are still plentiful, easier to access, and therefore cheaper to develop. The gas sector infrastructure is relatively new, and the industry requires less sophisticated technology to maintain current levels of production.[8] Another reason could be institutional. Though an organization the size of Gazprom (a joint stock company owned by the Russian government) may not be compatible with longer term plans to liberalize and decentralize the industry, its sector-wide, integrated structure may have been able to provide greater stability during the recent turbulent years.

Opportunities for Technological Upgrades

Poor technology is considered to have played a major role in the decline of the oil and gas industry in recent years. It is widely agreed that oil and gas technology used in the FSU is far behind the technology currently being used by the international oil and gas industry and that it must be upgraded if production is to recover and new fields are to be explored and developed. As the following survey shows, opportunities for technological upgrade are present in all stages of the oil and gas industry-exploration, drilling, production, transportation, refining, and offshore activities. The large number of efficiency-enhancing, cost-saving innovations in the international oil industry in recent years has largely bypassed the FSU industry.

Exploration

The exploration stage identifies promising areas for subsequent drilling. Because drilling is expen-

[4] Financial Times, *East European Energy Report,* Issue 30, March 1994, p. 27.

[5] Igor.K Lavrovsky, "A Case Study of Joint Ventures in the Oil Sector of Russia," OTA contractor report (September 1993), p. 4.

[6] The Druzhba (Friendship) pipeline, for example, built to deliver crude oil to the former COMECON and the FSU republics of Lithuania and Latvia, was divided at the time of the dissolution of the USSR into nine enterprises belonging to five independent states—Russia, Belarus, Ukraine, Latvia, and Lithuania-each introducing its own hard-currency transit tariff. The governments of the 15 new states also took control over the sections of railroad (major carriers of petroleum products) situated in their territories.

[7] The decline in 1992 production was attributed almost entirely to a sharp fall in Turkmenistan production, largely due to the loss of markets in the other republics. Matthew J. Sagers, "The Energy Industries of the Former USSR: A Mid-Year Survey," *Post Soviet Geography, vol. 34,* No. *6,* June 1993, p. 384.

[8] Sagers "The Energy Industries of the Former USSR," p. 377; and U.S. International Trade Commission, *Trade and Investment Patterns,* pp. 22-30

Truck-mounted drilling rig used for oil well drilling at Langepas, Western Siberia.

sive, accounting for 15 to 40 percent of offshore development costs and up to 80 percent of land development costs, careful exploration is essential for minimizing project costs.[9]

The first stage in the exploration process is the identification of promising oil regions by measuring changes (by aircraft, satellite, and ground observations) in magnetic fields and variation in the Earth's gravity. Once promising regions have been established, seismic surveys are performed to identify exploratory drilling sites within the region. These surveys provide detailed maps of underground structures through information derived from artificially generated shock waves. The detail of the maps depends on whether the seismic survey is two or three dimensional. A two-dimensional (2-D) seismic survey (based on observations along single lines) maps vertical slices of the subsurface. A three-dimensional (3-D) survey, based on grid pattern observations yields more accurate and detailed information of underlying structures. Both systems are currently used by the international oil industry. The advantage of 2-D technology is its lower cost, but 3-D technology is increasingly used because it permits more efficient field development. Both types, but especially 3-D, require advanced computer capability to process and interpret the large amounts of information produced.

Russian seismic technologies have not benefited from recent innovations. Equipment is bulky, difficult to transport, and low quality, yielding information that is inadequate for the complexity of the structures. The quality and availability of minicomputers to produce a rough picture of the area, large computers to further refine the information, and the necessary software, is limited. In the past, the abundant, easily accessible, and low-cost reserves may not have required sophisticated seismic technology. But future development is likely to take place in more costly, technically difficult environments, such as permafrost, that require advanced exploration technologies.

Drilling

Once promising reservoirs have been identified, drilling for exploration and subsequent production takes place. Drilling involves a number of components. The drill bit performs the boring action at the rock face. It is powered by either a turbo or rotary action motor, and connected to the surface rigs, hoists, and derricks by drill pipe. The borehole itself is lined with cement to anchor the casing and stop corrosion and leakage. Chemically designed mud is used for lubrication. The debris in the mud as it returns to the surface provides valuable information on the geology of the drilling area. Blowout preventers at the surface prevent sudden explosive escapes of gas or liquids caused by high pressure. Computers to monitor progress and interpret the information obtained from the drilling operation are an essential part of the drilling process.

Major innovations in Western technologies over recent years have vastly improved drilling precision and lowered drilling costs. A wide range of advanced drill bits has been developed to match specific site conditions. The quality of drill pipe, cement, and chemical muds has been improved

[9] Shell Briefing Service, *Producing Oil and Gas* (London: Group Public Affairs, Shell International Petroleum Company, Ltd., 1989), p. 2.

and refined. Reductions in the size of the drilling hole (slim-hole drilling) has yielded cost savings of 25 to 40 percent over conventional drilling because they permit reductions in rig size, casing, drilling muds, and cement. Slim-hole drilling also results in less waste mud and debris than conventional drilling.[10] Automated drilling rigs reduce manual labor requirements and are therefore inherently safer. Measurement while drilling (MWD), where measurement instruments are incorporated into the drill string (or pipe) above the bit, transmit information to the surface while the drill is in operation. MWD permits continuous drilling, which reduces costs, and provides more information than conventional wire line surveying (where drilling must be stopped while measurements are taken). New technologies allow for controllable directional drilling, particularly useful for tight, low permeability reservoirs and for improving production potential.

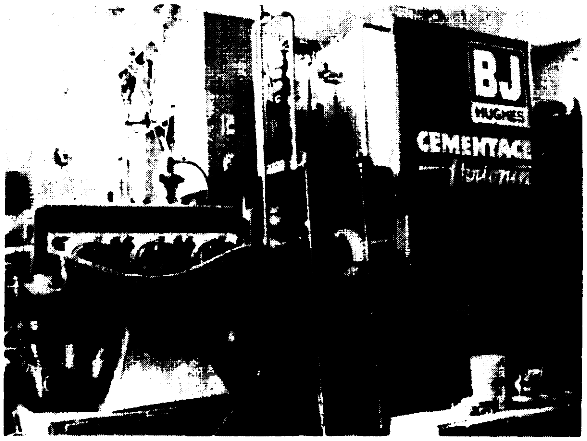
The Russian industry has limited access to these innovations. Drill bits and muds are of poor quality. Drill pipe has low tensile strength and is prone to corrosion. Defective connections do not withstand the range of temperatures, torque, and bending experienced in Russian conditions. Unresponsive fishing tools, used to retrieve broken equipment downhole, lead to excessive downtime in drilling operations. Worker safety is threatened by lack of blow out preventers, including ancillary equipment such as effective rubber seals, and remote control devices. The Russian industry has lagged in MWD, slim hole, and accurate directional drilling techniques. There is inadequate use of computers to optimize drilling programs and equipment maintenance schedules. The reasons for this lag in technological development is not primarily a lack of technical knowledge, but rather the incentive system, which in the past put priority on achieving short-term volumetric goals and emphasized quantity rather than quality.

The development of drilling technologies in Russia has differed from those used in most of the rest of the world. There are two main types of drilling technologies, rotary and turbo. The rotary system, used by most of the international oil industry, is powered from the surface, whereas the turbo drill, widely used in the FSU, is situated down hole, close to the bit. The widespread use of turbo drilling in the FSU was largely due to the Soviet inability to provide the high-quality steel drill pipe necessary to withstand the torque of rotary drilling, especially at greater depths. Turbo drilling thus allowed the Russian industry to dig farther and deeper than would otherwise have been possible with rotary drills. However, turbo drilling cannot be used in conditions of high stress, and requires frequent maintenance, thus adding to drilling time. It also requires high pressure pumps, not currently available domestically in sufficient supply. Though adequate for the past, this technology may not be suitable for future developments in more difficult geological environments.

Turbo drills are, however, essential for directional drilling because they allow the bit to take a predetermined direction. The concept behind Positive Displacement Motors—a highly successful directional drilling technology widely used by the international oil industry—apparently originated in Russia but was developed and commercialized largely outside (by Drilex Services of Scotland and the United States). A comment of John Forest, president of Drilex Services, illustrates both the strength and weakness of Russian petroleum technology, "The design idea was brilliant, the industrial engineering poor, and the materials totally unacceptable."]

[10] Shell Briefing Service, *Research and Development in the Oil Industry, No. 4* (London: 1991) p. 4

[11] J. Karpeisky-Ryan, "Energy and Environmental Technology Transfer from the Former Soviet Union to the United States," OTA contractor report, November 1993.



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U.S. manufactured pumping equipment, Ostrava, Czech Republic.

Production

The production process consists of drawing the underground deposit to the surface. Efficient production requires careful reservoir modeling and management. Oil and gas flow from a reservoir at varying rates, depending on natural reservoir pressures. Well stimulation technologies, such as hydrofracture stimulation, can enhance the natural drive. This technology involves cracking the rock by forcing fluid into the well at high pressures and rates, thus increasing the permeability of the formation. The cracks are propped open with material such as gravel, to keep the channels to the well open. This technology could be of growing importance to the Russian industry in the future because an increasing share of recoverable oil reserves is located in reservoir rocks with low permeability.[12] The domestic industry cannot provide the necessary equipment. The only manufacturer of hydrofracturing technology "Krasnyi Molot" (Red Hammer) enterprise in the Republic of Chechnya, has virtually stopped production. Domestic capability of acidizing, another form of well stimulation is also limited.

At some point during production, primary recovery mechanisms, depending on natural pressures, become insufficient and must be supplemented by secondary and tertiary recovery technologies. Secondary recovery involves direct displacement of oil by water flooding (the most usual method) or gas injection. Tertiary recovery consists of treating reservoir rock with chemicals or heat and is not often used, especially at current low oil prices. In all recovery techniques, artificial lifi-reinfecting oil or gas into the oil flow-enhances drive.

Water flooding, the injection of water into a well to supplement the natural pressures, is a widely used recovery technology throughout the world. In Russia, however, water flooding is both excessive and implemented in an arbitrary manner, regardless of the individual characteristics of the oil field. Wells are drilled and water injected according to prescribed rules based on hectare of field area. Russian oil field technologists believe that early water flooding increases ultimate recovery rates. If arbitrarily used, however, water flooding runs the risk of breaking through the oil bearing formations and damaging the producing well, thereby reducing total output over the life of the field.

In addition, excessive water flooding entails enormous costs and raises major environmental water disposal problems. The water cut in the Russian industry—the percent of water in total well output—is high (75 percent) and rising. This means that enormous amounts of fluid have to be pumped from the wells, using either sucker rods (situated on the surface and working like a plunger) or the higher precision electric submersible pumps situated at reservoir depth. Russian domestically manufactured electric submersible pumps are, however, of poor quality and prone to frequent breakdown.

As a result of poor reservoir management and production practices, a substantial number of wells in Russia are now idle. Almost 28,000 wells in the Russian Federation are officially listed as

[12] According to Russian experts, hydrofracturing should be introduced at Yuganskneftegaz, Nizhnevartovskneftegaz, Tomskneft, Surgutneftegaz, Varyeganneftegaz, Noyabrskneftegaz, Kondpetroleum, and Permneft associations.

idle, but potentially productive following repair (in addition to 26,000 classed as abandoned or awaiting abandonment). However, a much smaller number of these wells (between 5,000 and 8,000) are attractive candidates for rehabilitation, especially at present world oil prices, largely because of demage to the oil fields by poor management.

Offshore Operations

Offshore operations differ from onshore mainly in the need for platforms for drilling equipment. Here again, there have been many innovations in recent years. In deeper waters, rigid platforms attached to the seafloor have been replaced by lighter platforms, floating on the surface and held in place by cables fastened into the sea floor. Simplified deck or "top sides" reduce costs and complexity of operations. Temporary drilling rigs, packaged rigs, or semi-submersible tenders can reduce capital costs by up to 25 percent and operating costs by up to 40 percent.[14] Greater automation is reducing costs and environmental damage while improving safety.

This area of technology is of particular interest for the FSU where promising areas of future development have been identified in offshore Arctic, Baltic, Black, Caspian, and Okhotsk Seas. Russia has relatively little capability in this area—most Russian production has taken place onshore—and has in the past depended on technology directly purchased from the West or reproduced from Western designs. Because of the high technology content, offshore projects may be particularly suited to joint ventures with foreign partners.

Pipelines

Crude oil and gas are usually carried in pipelines. Both oil and gas pipelines are equipped with devices—pumps in oil pipelines, and compressors in gas pipelines—to maintain pressure and flow.

Due to the size of the country and the distance between producing areas and markets, the FSU has a vast network of oil and gas pipelines. Future development of remote resources of oil and gas, and rerouting of lines in accordance with new political alignments following the dissolution of the Soviet Union, imply that considerable additions will be needed to the pipeline network, requiring large quantities of large-diameter pipe for gas transmission.

The pipeline infrastructure already faces major problems of technical performance. Domestically made pipe is defective in wall thickness, insulation, resistance to corrosion, and general workmanship. Welding procedures are not adequately controlled; diagnostic and inspection technologies are poorly designed. Problems of pipeline quality are particularly acute in the Central Asian gas system, where a combination of poor anticorrosion treatment and the high electrochemical activity of the soil results in accelerated deterioration. Leaks, especially in gas pipelines, are frequent and difficult to detect, leading to catastrophic explosions.[15] pipelines can be under repair up to 20 percent of the time.

Essential pipeline components such as excavating and pipe laying equipment and modem pipeline inspection and monitoring equipment are in short supply, especially since the dissolution of the FSU, and variety is limited. The FSU frequently relied on imported supplies of large-diameter pipe, mainly from Germany and Japan. Pipeline management, including maintenance and leak detection, is hindered by the lack of modem computer diagnostics.

Quality and performance of compressors are acute problems. These machines, fueled by gas

[13] Troika Energy Services, for the U.S. Department of Energy, reported in "Restoring Idle Russian Oil Capacity" *Oil and Gas Journal*, May 17, 1993, vol. 91, No. 20, pp. 30-31.

[14] @he]] Briefing Service, *Producing Oil and Gas*, p. 3.

[15] The worst was an explosion of a liquified petroleum gas pipeline in June 1989 that killed 575 and injured 623 passengers on two trains that were in a station a few yards from the pipeline.

from the pipeline itself, push the gas through the pipeline. A system of well placed, efficient compressors can substantially increase pipeline capacity. Since domestically manufactured compressors were of poor quality, the Soviet Union imported Western compressors, one of the few areas where the Soviet Union relied on imports. However, much of this capacity is now outdated or worn-out. For example, the pipeline from Orenburg to the western border of the FSU, built in 1976-1978 with Cooper-Bessemer and Italian Nuovo Pignone compressors, now loses 25 percent of transported gas through compressor consumption and corroded pipes. The latest export pipeline, built from Yamburg to the western border in 1987-1988, loses "only" 14 percent of the gas, despite being longer and having much bigger compressor capacity.

Gazprom is attempting to remedy compressor problems by developing domestic compressor manufacturing capacity, based on Russian aero derivative turbines, at factories in Perm and Yekaterinburg. Gazprom also plans to boost efficiency through the manufacture of recuperators. Recuperators, not widely used in Russia, can raise pipeline efficiencies from 20 percent up to 33 percent. But Gazprom still needs to import Western compressors. In 1992, the company signed a $1.46 billion contract to purchase compressors from Nuovo Pignone. The United States lost the Russian compressor market to Europe in the late 1970s and early 1980s, when an embargo was introduced. However, this loss is not final, and U.S. firms are well placed to increase sales in the FSU since the majority of imported compressors (typically 25-, 16-, and 1O-MW capacity) are of General Electric design.

Refining

Refineries transform crude oil into products (such as gasoline, diesel, kerosene, and residual fuel oil) for use by the final consumer. Virtually all areas of the former East Bloc have some refining. But here again, this sector's activity encounters major difficulties, in part due to lagging capital investment, even in the days when upstream oil and gas were being highly favored.[16] Since the dissolution of the FSU, the regional refinery situation has become increasingly complex. Deliveries of crude oil from Russia to some of the other republics have fallen sharply: deliveries to Ukraine and Belarus, for example, are running at one-half previous levels.[17]

Refinery technology is chronically outdated throughout the region. Much of the refinery capacity was built in the 1960s. It is estimated that between 60 and 80 percent of refinery fixed assets are worn out.[18] In addition, existing equipment not well used and losses are exceptionally high.[19] Product quality is low.

A basic problem is that current FSU refinery technology (which maximizes heavy fuel oil output) does not match current and likely future demands for petroleum products (lighter products such as gasoline and kerosene). Secondary refining technologies (such as hydrocracking and catalytic cracking) that permit a wider range of product output and a larger share of light products in the total account for a much smaller share of refinery capacity in the Former East bloc compared with North America (see table 3-1). Consequently, heavy products, such as residual fuel oil, account for 36 percent of total output of refined petroleum products in the FSU, compared with 6

[16] In the early 1980s, when capital budgets for oil and gas rose by over 100 percent, budgets for refineries rose by only 34 percent.

[17] Mikhail Korchemkin, "Oil and Natural Gas Systems of the Former Soviet Union, OTA contractor report, October 1993, p. 28

[18] Konolplyanik, "Russia Struggling to Revive," p. 44.

[19] According to Russian estimates, the same amount of refined products could be produced out of three-quarters Of the current input Of crude if refineries were reconstructed.

TABLE 3-1: Share of Selected Upgrading Technology in Total Refinery Capacity (percent of total distillation capacity[a])

	Former East Bloc	Us.
Vacuum distillation	27	44
Catalytic reforming	3	24
Catalytic hydrorefining	9	12
Catalytic cracking	5	34
Catalytic hydrocracking	negligible	8

[a]Figures reflect maximum percentage of crude that may be converted by each refining method

SOURCE "Worldwide Refining Report, " *Oil and Gas Journal, VOI* 91, No 51, Dec 20, 1993, pp 37 and 49

percent in the United States. The more valuable lighter products such as gasoline, 46 percent of petroleum product output in the United States, represent less than 20 percent in the FSU.[20]

In the Soviet Union, the strategy used to meet the rising demand for light products was expansion of output rather than technology: that is, increasing refinery throughput to the point of adequate production of light products. This strategy had several drawbacks. Even when the crude was available in sufficient quantities, there was an oversupply of heavy products, notably residual fuel, that was passed on to power stations (which would have preferred to use natural gas) or to the export market, frequently at unremunerative prices. When production fell, crude was no longer available in sufficient quantity, and acute shortages of light products, especially gasoline and jet fuel, developed.

Critical Technologies

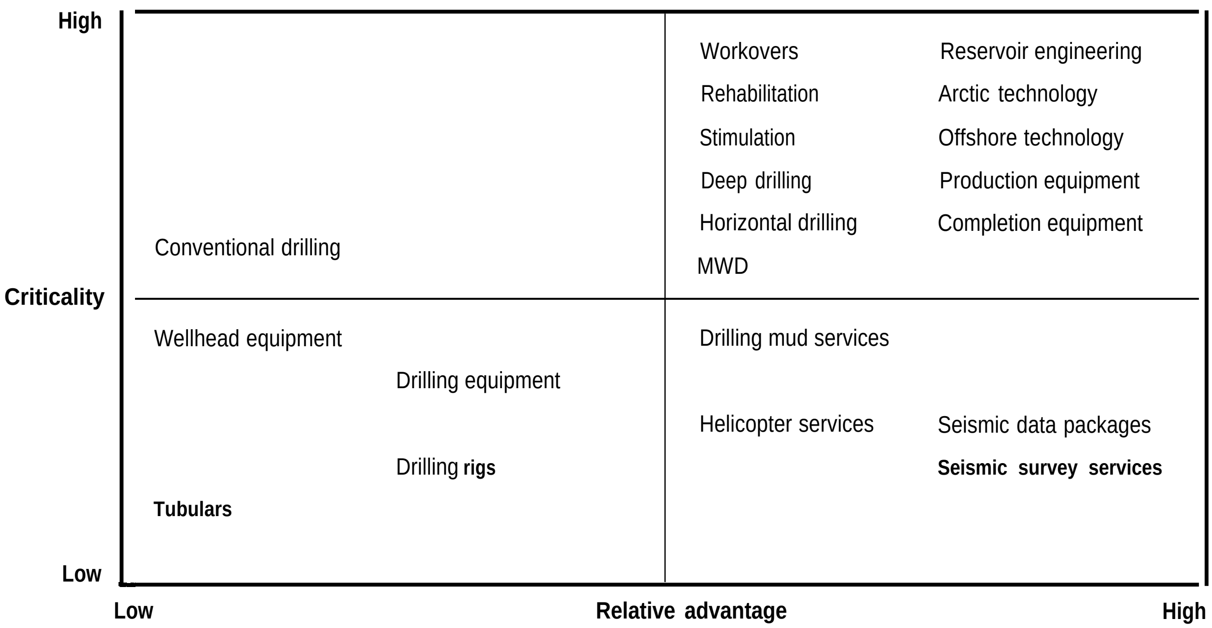
OTA's survey of the state of technology in the oil and gas sector yields a list of technologies that could substantially increase FSU oil and gas output over both the short and long term. Those countries, such as Turkmenistan, Kazakhstan, and Uzbekistan, that do not have domestic equipment supply industries, will rely largely on imported technology, especially in the near future. As their oil and gas sectors develop, however, they may wish to initiate domestic production of some items of equipment. For those countries with substantial supply equipment capacity, such as Russia and Azerbaijan, the situation is different. They are likely to be more selective in their choice of imported technology, taking only those technologies that cannot be provided by the domestic industry. Taking this into account, the technologies identified here fulfill two criteria—they are critical to FSU oil and gas sector rehabilitation and development, and they have a relative advantage overdomestic Russian technologies (see figure 3-1).

Technologies are needed both to rehabilitate existing idle wells and to explore undeveloped resources. Technologies that could rejuvenate idle wells at relatively low cost include advanced drill bits, fishing and downhole tools, sucker rods, and submersible electric pumps. Because of their durability, advanced drill bits could speed the drilling process and reduce downtime. Improved fishing tools would have the same effect. Water flooding on the scale practiced in Russian fields necessitates more efficient electric submersible pumps to lift large amounts of fluids. Improved gas lift equipment is also needed for wells using gas injection as a secondary recovery technique. These items are all produced in the FSU, but the need appears to be for a higher quality and larger range of model and size than are immediately available.

Also, existing wells can benefit from well stimulation technologies, such as fracture stimulation, which enhances the natural reservoir drive by increasing the average permeability of the formation and therefore increases recovery rates. This technology is likely to be of continuing impor-

[20] Energy Information Administration, U.S. Department of Energy, *International Energy Annual 1992* (Washington, DC: U.S. Government Printing Office) p. 42.

FIGURE 3-1: Opportunity Segments in the Oil and Gas Industry



SOURCE: Etienne H Deffarges et al., "E and P. Opportunities for Service Firms Abound in the C I S ," *Oil and Gas Journal*, VOl 90, No 38, p. 61

tance as an increasing share of new oil and gas reserves are found in less permeable structures. Local availability of this technology is limited but it is currently being provided by foreign firms.

Additional technologies will be highly beneficial to the longer term exploitation of oil and gas reserves. Many of these are not currently available in the FSU. Advanced seismic technologies such as 3-D systems, by providing more detailed information than alternative technologies, shorten the exploration process, enable improved reservoir development, and minimize expensive drilling. These considerations are particularly important in developing resources in remote or hostile environments. The FSU could also benefit greatly from new drilling technology. MWD improves the precision of the drilling process and reduces drilling time—again, important factors in exploitation of new resources. This technology is apparently not available from local industry. Improvements in deep drilling and horizontal drilling technologies will increase the resource base and improve recovery rates.

As much of the most attractive new petroleum potential in the FSU is offshore, the FSU could benefit from the major improvements in offshore technologies that have taken place in recent years. There is little experience with these technologies because much FSU production takes place on shore or in relatively shallow water.

Moving downstream, oil and gas transmission systems will require compact, efficient compressors and higher quality pipe. The local industry could benefit from recent advances in anticorrosion and seamless pipe, and in compressor design. These technologies are likely to be increasingly important as the pipeline network is expanded and penetrates further into hostile environments. Refinery upgrading, including residual fuel oil conversion capacity, will be required to improve system efficiency and meet current and expected demand for petroleum products. These technologies are good candidates for technology transfer since they are now standard, mature, and predictable in operation. Moreover, the FSU is accustomed to importing refinery technology.

Information technology underpins many of these technical improvements, making possible the greater precision, speed, and efficiency that has been the hallmark of technological development in this and other industries over the past 20 years. Advanced computers process geophysical data quickly and provide high-quality interpretation, thus reducing the risk, time, and cost of exploratory drilling. Computer diagnostic equipment can improve safety and reduce losses in both pipeline and refinery operations. Although computers are produced in the FSU, they do not have the range of Western models and lack the software.

However, as with all technologies, effective deployment depends on incentives. Until economic and institutional incentives are in place to ensure that technology is correctly and efficiently used, even the best technology will not be used efficiently. The reform of the FSU energy sector is critical to technology upgrading.

I Energy Sector Reform

The rehabilitation and development of the FSU oil and gas industry will require massive investments. One estimate suggests that to achieve Russian oil production levels of about 7 MMbbl/d) through the year 2000 will require external financing of about $3 billion annually, and double that amount in domestic (ruble) financing. Increasing production to the 1990 level of about 10 MMbbl/d would require a doubling in external financing, as well as substantial increases in domestic financing.[21] In addition, substantial capital investments will be needed in gas development, oil and gas transmission systems, and refinery upgrading. An added complication is that these sums must be mobilized from unaccustomed sources-domestic producers rather than the central government, and external sources including the international oil companies. The scale of this effort implies major reforms to the energy sector.

The shortfall in domestic capital investment, previously provided by the central government, was presumably to be met from the surplus revenues of the new operating entities, particularly the production associations. This strategy depended, however, on changes in pricing policies and investment laws that would provide the necessary incentives.

While changes have been made, they have so far been inadequate to revive domestic investment. On the contrary, industry resources available for investment have, if anything, been reduced by changes in pricing policies introduced since the breakup of the Soviet Union. Prices of virtually all of the materials and equipment purchased by the oil and gas sector were freed from government control in 1992, and rose sharply. Prices of all energy products, however, were exempted from decontrol. They have been raised several times by decree, but the rise in nominal prices has been offset to a considerable extent by high rates of inflation and the depreciation of the ruble. Oil prices in Russia and other parts of the FSU are still under one half the level of comparable world prices, and gas prices are even lower. Since the oil and gas industry's costs rose faster than its revenues, the funds available for capital investment were therefore compressed. In addition, taxes increased in number and complexity.

Finally, there are reports that the foreign exchange holdings of several production associations, which had been earmarked for imported equipment, were frozen in government accounts, or held in the foreign commerce bank, which subsequently went bankrupt. All these factors have made it difficult for the production associations to

[21] Y. Bobylev and A. Chernyavsky, "The Impact of the Oil Industry Crisis on Russia's Economy," *FBIS Report, Central Eurasia, FBI S-USR-93-006-l,* July 151993, quoted in the Atlantic Council, *Energy Policies for Russia and Ukraine,* Policy Paper (Washington, DC: November 1993), table 6.

take up the slack in capital investment from the central government.

It is difficult to overestimate the importance of price reform in the oil and gas sector. Raising oil and gas prices not only creates the resources available to the production associations for investment, but also makes the sector attractive to other domestic investors. Economic oil and gas pricing as part of a broader program of macro economic reform could encourage the return of the substantial amounts of capital presently being held outside Russia.[22] (The importance of capital repatriation in economic recovery has been amply demonstrated in Latin America in recent years.) Higher energy prices would also encourage efficient energy use and therefore confer an important environmental benefit. Foreign exchange earnings would be augmented by increased exports.

However, raising energy prices, especially to residential consumers, can cause considerable hardship. The question for the future is how to reduce the still substantial gap between domestic and international prices currently being maintained by a system of export taxes and quotas. The attainment of international parity by gradual reductions in controls and taxes may take unacceptably long. This could be the moment to consider new approaches to price reform. One approach would be to combine higher prices with increased efficiency in energy use so that total energy bills do not rise, or at least increase by less than the rise in prices.

Though correct energy pricing is a necessary condition for energy sector reform, it is frequently not sufficient because institutional and market imperfections can weaken or negate the signals being provided by higher prices. For example, many consumers in the FSU, particularly the large, energy-intensive, industries, and the regional importing countries, do not pay their oil and gas bills, so the specified price is an administrative fiction that does not provide incentives to producers. Effective energy pricing will require additional supporting actions.

Many of these can be achieved by moving toward a market system, through restructuring the industry, and by setting up the necessary legal and institutional framework. Some progress has already been made in industry restructure. The Ministry of Gas Production was transformed into the giant, government-owned joint stock company, Gazprom, in 1988. Beginning in 1992, a series of decrees converted oil sector enterprises, formerly under the jurisdiction of the energy ministries into joint stock companies as a first step toward corporatization and eventual privatization. The oil industry is to be divided into three integrated holding companies, all of world-class size (Yukos, Surgutneftegaz, and Lukoil), each of which includes exploration, production, refining, and distribution activities similar to the large vertically integrated, international oil companies. At a lower level in the organizational structure are a number of production associations, some of which would rank among the world's largest oil companies on the basis of their annual oil production. In all cases, the state retains a controlling interest, but there are plans for some private investment.[23]

This new structure, though introducing elements of corporatization and privatization, still bears some common characteristics with the old including the prominent position of large units with considerable monopoly power, which are frequently staffed by top officials of the old regime—the so called "oil generals." On balance, centralized political control of the industry has

[22] The Institute of International Finance has estimated the current scale of capital flight from Russia to be at least $1 billion a month, although this will include foreign currency legally deposited by Russian companies into Russian banks that place it overseas.

[23] For further description of the structure of the oil and gas industry in the Former Soviet Union see U.S. International Trade Commission, *Trade and Investment Patterns*, pp. 2-1 and 2-2; and Anthony Reinsch, Igor Lavrovsky, and Jennifer Considine, Canadian Energy Research Institute, *Oil in the Former Soviet Union*, Study #48 (Calgary, Alberta: October 1992), pp. 22-30.

been considerably weakened. However, the last word on the centralization/decentralization struggle has not yet been said, and it may be many years before a stable reorganization of the industry is achieved.

There has been less progress on the other institutional underpinnings of the market economy. The countries of the FSU lack a body of commercial law that spells out the rights and responsibilities of commercial enterprises and their accountability to their shareholders, whether government or private. Bankruptcy legislation is ineffective. Private property rights and contracts are still insufficiently protected. The land title system is unclear, and the decisionmaking process is clouded by a multiplicity of authorities all of whom have effective veto power.

The privatization of the energy sector is also hampered by unfamiliarity with basic Western business practices and concepts such as profit, the time value of money, depreciation, risk, quality control, contracts, and liability. Management skills are weak, and there is little experience in project evaluation. However, Russians appear to be well aware of these limitations and are eager to acquire management skills.

I The Role of Foreign Investment

Anticipating the difficulty of raising adequate capital resources, especially foreign exchange, from domestic institutions during a transitional restructuring period, there was considerable interest in attracting external financing from both the international public and private sector.

The public sector responded promptly (see ch. 7). The Group of 7 (G-7)[24] put oil and gas at the top of its assistance agenda for the FSU. As part of this effort, the United States is developing bilateral programs in the U.S. Agency for International Development (AID), the U.S. Department of Energy (DOE), and the U.S. Environmental Protection Agency (EPA) programs; the Export-Import Bank of the United States (Eximbank) Framework Agreement, and expanded investment guarantees from the Overseas Private Investment Corp. (OPIC). Other G7 members are also providing bilateral support. The Japanese Eximbank, for example, is negotiating a $1.5-billion export credit for oil and gas equipment. The European Energy Charter, which provides a government-sponsored framework for energy investors in the region, is nearing completion. In addition, the multilateral development banks (MDBs)—the World Bank, the International Finance Corp. (IFC), and the European Bank for Reconstruction and Development (EBRD)—have made major new loans to FSU countries. These loans have the potential for leveraging much larger sums through cofinancing with the private sector.

It is assumed, however, that the bulk of the external financing of FSU oil and gas will come from the private sector, notably in the form of foreign direct investment. This is a particularly attractive form of investment (compared with portfolio, licensing, and even MDB lending) as it provides not only capital, but also management and technology. Most public sector commitments are explicitly designed to supplement and encourage rather than supplant private capital, though some observers (see ch. 8) consider that these programs have failed to achieve this aim. Moreover, the international oil companies have large development budgets that dwarf the resources available from public sector institutions. They are reported to foresee spending $30 billion to explore and produce oil in Russia over the next decade, but only if conditions are favorable.

Recognizing the need for foreign direct investment and its accompanying technology transfer, the Russian government introduced major changes to rules governing foreign investment. Previously, foreign investment was discouraged, if not forbidden, and technology imports were kept to a minimum. The first change was made in

[24] The Group of 7 is the term applied to the group of large industrial economies (United States, Canada, Japan, France, Germany, United Kingdom, and Italy) that meet regularly to consider the state of the global economy.

1987, when the Soviet Union authorized joint ventures and allowed foreign companies to own up to 49 percent of the equity. Later changes permitted foreign companies to take majority ownership and control. This liberalization was reinforced by Russia's membership in the International Monetary Fund, which promised additional financial assistance and the creation of a ruble stabilization fund. Legislation specific to oil and gas ventures is, however, still lacking.

In response to these initial changes, the international oil industry showed a high level of interest in the FSU. A recent compilation of projects with foreign participants listed over 100, including all branches of the sector, all of the oil and gas producing republics, and different sizes of companies of many nationalities.[25] Over one-half had U.S. joint venture partners. Two-thirds of the projects are in Russia itself, mainly in the oil sector, but many of the Russian projects are small in scope and investment.[26] planned investments in Kazakhstan on the other hand, if they materialize, could amount to many billions of dollars.[27] (Box 3-1 describes the main forms of investment to date.)

Despite the large number of projects, progress on the ground has been modest to date. Agreement had been reached on only one-third of the projects, mainly contracts to bring idle wells back into production.[28] Joint ventures currently produce about 4 percent of Russian oil production, accounting for 15 percent of Russia's hard currency crude exports. This combination of a high level of interest from the international oil company, and their relatively small commitments, reflects the balance between the attractions and problems attached to foreign investment in the FSU (see appendix 3-1 to this chapter on Dresser Industries' experience with joint ventures).

Attractions to Foreign Investors

On paper, the attractions of foreign investment in FSU countries are strong. As Jonathan Stem puts it:

> It is hard to think of a previous situation where such an immense and potentially promising set of oil and gas provinces, denied to foreign investors for many decades has been suddenly opened up.[29]

The FSU countries have immense resources offering a wide range of opportunities at low geological risk. Inefficient production practices in existing fields initially held out the promise for quick and easy projects—the deployment of improved production techniques in a short timeframe and a consequent quick return on investment. Early optimism regarding the rehabilitation of idle wells has since been dampened, though opportunities still exist. In addition, there are projects involving the exploration and development of new fields. Russia, Kazakhstan, and Azerbaijan offer the unique opportunity of a new area with known and proven oil reserves, thus minimizing the geological risk of opening up promising but unknown areas, like those in countries of Africa, or the Antarctic. Turkmenistan and Uzbekistan are amply endowed with gas reserves. Though many of these new areas will be in hostile climates, U.S. and other oil companies can adapt, given their long experience in a wide variety of countries and climatic conditions.

FSU countries offer other advantages to the foreign investor. Most republics have a trained work force at all levels of expertise, from scientists to oilfield workers. Though many of the sites are remote, they generally have abetter infrastructure of roads, air service, trains, and telephones, than that in many of the other countries competing for oil

[25] U.S. International Trade Commission, *Trade and Investment Patterns,* appendix E.

[26] Jonathan P. Stern, *Oil and Gas in the Former Soviet Union* (London: Royal institute of International Affairs, 1993), pp. 30, 31.

[27] 1 bid., p. 30.

[28] 1 bid., p. 31.

[29] 1 bid., p. 53.

BOX 3-1: Main Forms of Investment in the FSU Oil Industry to Date

Joint Ventures

Until now, joint ventures between foreign firms and local partners have been the main form of foreign investment in the FSU Industry, The advantages for the host country partners (typically, production associations) are seen to be the halting of production declines, an increase in convertible currency revenues, and the acquisition of technical and management skills. Foreign investors in joint ventures gain access to local information and expertise and assistance in dealing with FSU bureaucracies.

The major joint venture activities are fields with technical problems, well stimulation (including hydraulic fracturing), drilling of horizontal wells, idle well reactivation, oil spill cleaning, and separation of liquid hydrocarbons. Well stimulation and reactivation of idle wells is the leading activity, as the service contract for idle well reactivation (a Russian decree—1 Or of January 1992-entitles Western companies to receive contractors' margins of up to 25 percent of the total cost of the workover) is the best developed instrument in legal terms, In April 1993, 12 production associations had signed 34 contracts with foreign partners to repair 7,407 wells with estimated production potential of 1.7 MMbbl/d. The Western companies, mainly small to medwm-sized, receive about 15 percent of this volume as payment. They are to ship an estimated $800 million of equipment, mainly service rigs and auxiliary equipment. The host production association pays for much of the down hole equipment, pipes, materials, and chemicals. The production associations receive about **40** percent of the export price for 011, with the rest retained by central and local fiscal authorities. A new decree envisages the transition to a system of payments in kind. There is less interest in natural gas because investment is needed primarily for rehabilitation of existing infrastructure rather than in-increased production

Production Sharing Agreement

At present, there is no legislation governing production sharing agreements, and each agreement is settled on a case-by-case basis. Russia's first agreement was approved in early 1993 between Elf Neftegas (a subsidiary of the French company Elf Aquitaine) and Interneft, a Russian company. This agreement calls for Elf to bear the full financial risks for exploring a tract in Volograd and Saratov estimated to contain 100 to 500 million tons of crude. Elf is committed to revest $500 million over a 9-year period. Elf will be repaid in petroleum in terms of specific formulae designed to protect Elf against changes in legislation, particularly taxation Elf has also **signed** a similar agreement with Kazakhstan.

Equity-Sharing Agreements

These will depend on the effectiveness of the privatization programs. Russia plans to privatize 60 percent of state property in the near future. The state will retain a controlling share in privatized petroleum companies whose dividends will be plowed back into the companies for investment in production facilities and the provision of social services. Foreign investors may acquire up to 15 percent of the shares auctioned. Kazakhstan and Azerbaijan also allow foreign equity participation.

Tenders and Auctions

Several international tenders and auctions have been held in Russia, largely covering the Sakhalin province, for exploration and development rights. **A** notable example is a consortium of Marathon, McDermott, Mitsui, Shell, and Mitsubishi to undertake an $80-million feasibility study to explore and develop a tract offshore Sakhalin. At the conclusion of the feasibility study, the consortium will negotiate a final agreement on development rights, though the original agreement did not guarantee the consortium development rights.

SOURCE U S International Trade Commission, Trade and Investment Patterns in the Crude Petroleum and Natural Gas Sectors of the Energy Producing States of the Former Soviet Union, Investigation No 332-338 Publication 2656 (Washington, DC June 1993), pp 3-8 to 3-10, and Igor K Lavrovsky, "Case Study of Joint Ventures in the 011 Sector of Russia, " OTA contractor report, (August 1993) company investment. Finally, these opportunities are becoming available at a time of U.S. spare capacity, which reduces the opportunity cost of going abroad. However, the FSU republics are not the only investment opportunities in the world. The oil companies will weigh the overall environment for investment in FSU countries with possibilities in other parts of the world.

Obstacles to Foreign Investment

On the other hand, there area number of obstacles to foreign investment. These include a high level of political uncertainty, lack of a legal and regulatory framework, a poor economic environment, and different perceptions of the role of foreign investment.

Political Uncertainty

Political uncertainty, especially as it affects the sanctity of contracts, is of prime concern to prospective investors. The history of the international oil industry has shown that perceptions of political uncertainty are not consistently associated with any one type of political regime. Gulf Oil (now part of Chevron) continued production in Angola throughout its civil war, and many foreign oil companies continue to be interested in Azerbaijan, despite a recent unilateral cancellation of all previous agreements with foreign companies. The perception of stability is important however, and may explain the particular interest in Khazakhstan, despite major logistical problems in oil transport. In Russia itself, where production potential may from many points of view be more attractive, there is considerable uncertainty over the political environment.[30] Programs such as OPIC and the Multilateral Investment Guarantee Agency (see ch. 7), which offer—at a cost—insurance against political risk, help reduce exposure.

Lack of Legal and Regulatory Framework

In addition to general political uncertainty, there are more specific aspects of particular concern to foreign investors in the oil and gas sector. There is as yet no legal and regulatory framework governing oil and gas leasing, exploration, and development, and current draft laws do not resolve many of the issues that foreign oil companies cite as limiting their greater participation. Nor is there legislation defining the rights and responsibilities of the foreign investor. Each project must negotiate its own terms, a long and complex business. For example, it took Chevron over 3 years to negotiate its agreement with Kazakhstan. There is also concern over the consistent application of laws and decrees. According to Exxon:

> "Laws and decrees are promulgated, discounted, ignored, exceptions are promised, granted and revoked. There are also great voids where no Russian legislation exists at all."

Issues of owning and disposing of private property, intellectual property, due process in cases of expropriation, and environmental liability have not been addressed.

Unclear rights of ownership

In Russia, as in many other countries, oil and gas resources are owned by the government. This, in itself, is not a serious obstacle to investors. However, in Russia it is not clear how to obtain rights to develop these resources, especially as surface property rights lie within the jurisdiction of the regional and local governments. Ownership rights are hotly contested between the central federation, local governments, and the production associations, causing uncertainty among potential for-

30A recent ranking of countries by country risk (a weighted average of 11 factors, including indebtedness, current account position, and political stability) in *The Economist,* Aug.21, 1993, p. 84, ranked Russia as the second most risky country in the world, a few points behind Iraq, and both just under 100, the highest number on the index.

TABLE 3-2: The Current Russian Tax Regime

Export tax: Levied at the rate of 30 ECUs per ton ($5.15/bbl) on crude oil sold abroad.

VAT: Twenty percent of the cost of all inputs (domestic and imported) at the time of purchase, but refunded in full after 24 months if production stream is for export.

Profits tax: Levied at 32-percent rate on taxable income, but with straight-lme depreciation of most capital expenditures, expensing of certain outlays (but not interest), full loss carry-forward provisions, and deduction for reinvested earnings (limit 50 percent of taxable income).

Production royalties: Combined state and federal assessment equal to 16 percent of the gross value (world price) of production,

Currency exchange: Fifty percent of hard currency receipts from exports to be exchanged for rubles at market rates. We presume that the unstable value and inconvertible status of the rubles acquired via such transactions constitutes an implicIt tax of 25 percent on the value of currency so exchanged,

Social reserve fund: A levy equal to 37.5 percent of total wages, collected for the purpose of rebuilding social Infrastructure.

Repatriation tax: In the case of U.S. Investors, 5 percent of remitted dividends, Could be higher or lower for legal residents of other jurisdictions,

SOURCE James L Smith, Department of Economics, "Poor Economic Prospects Face Investors in the Russian 011 Industry" (Houston, TX University of Houston, April 1993), p 2

eign investors about the legality of agreements and contracts. Some U.S. companies sign contracts with all three levels of government. Even within each level of government, there is an absence of established lines of decisionmaking. Some recent improvement is reported. Relationships between the center and the provinces, a serious problem in the past, appear to be stabilizing, with regional authorities receiving more freedom in equipment procurement and searching for investment sources.

Poor economic environment

The economic environment is crucial for foreign investors, who need to be assured of their ability to make profits and their freedom to remit them. Foreign investors, whose earnings are derived from oil exports rather than from sales to the much lower priced domestic market do not suffer directly from oil and gas price controls as do their Russian counterparts. However, foreign investors are subject to a multiplicity of taxes (see table 3-2), which taken together are seen by U.S. investors to represent an unrealistic and unstable tax regime.

Taxes are high compared with competing provinces, such as the North Sea, and based on revenues rather than profitability, a great disadvantage when costs vary greatly between areas.[31] Under this tax regime, oil produced in Russia would have to sell for nearly twice the price of oil produced in the United States or Australia for a project to be economically viable.[32] This punitive tax situation exists not so much by design, but because many of the jurisdictions that have the authority to impose taxes fail to realize the cumulative impact of their tax decisions.

Taxes are also subject to change. An export tax of $6 per barrel was imposed in 1992 to bridge the great differences between domestic and export prices. The tax virtually eliminated the profit of one U.S. venture. Although some companies managed to be grandfathered into the export tax exemption, negotiating the exemptions took valuable time and energy and often tied up tax payments until a decision was reached.

One of the attractions of investment in oil and gas, over other branches of industry in the FSU is

[31] In most Countries, the investors are first allowed to recover their costs from the initial revenue streams of the project. Higher tax rates are imposed only after costs have been recovered. In Russia, under the present regime, high taxes are imposed before cost recovery.

[32] James L. Smith, Department Of Economics, "Poor Economic Prospects Face Investors in the Russian Oil industry" (Houston, TX: University of Houston, August 1993).

the ready ability to earn the hard currencies necessary to cover the cost of imported equipment and to remit profits.[33] For this purpose, it is necessary to have clear title to the oil (which is sometimes in doubt) and the freedom to export it. However, the freedom of foreign investors to export oil is subject to changing regulations. In 1991, central control over oil exports was loosened, and joint ventures were given the right to export a share of their production. In December 1992, however, controls over oil and gas exports were reinstated because of suspected illegal sales. In 1993, the 80 licensed exporters were cut to 30, and further cuts are contemplated. In the same year, Decree715 (of July 23) specified that joint ventures involved in incremental production projects would not own the additional crude they produce but would instead work on a contractual basis for cash.

These measures have increased central government control over Russian oil exports, including those of joint ventures. However the situation is still fluid and may change again especially as increased central control over exports is strongly opposed by many of the regional and local associations. In theory, joint ventures should be able to export oil under any combination of centralized/decentralized governance; but in practice, constant changes in administrative systems can be time consuming, costly, and destabilizing for the foreign investor. A further cause for concern is the possible unwillingness of third parties to allow transit of oil and gas across their territories.

Different perceptions of foreign investment

One obstacle becoming more apparent as experience with joint ventures and other foreign investments grows is the difference in perception about technology transfer and foreign investment between the Russian hosts and the foreign investors. Views are not consistent among participants on either side. In Russia, for example, the oil sector shows more interest than the gas sector in foreign investment. Within the oil production associations, views also differ over the merits of foreign investment. And views vary among countries of the FSU. Kazakhstan and Turkmenistan, with little indigenous technical capability, encourage foreign investment. Russia, which has considerable technical capability, is more ambivalent.

U.S. companies, too, have different perceptions. Several oppose public sector programs, such as those implemented by the World Bank and the EBRD, on the grounds that they supplant rather than supplement the private sector, and thus discourage Russia from making necessary reforms, including granting access to Russian hydrocarbon resources. Other companies, and suppliers of oil equipment, on the other hand, support such programs on the ground that they help share the risk of doing business with FSU countries.

Despite all the differences, some generalizations can be made. To the Western eye, the need for up-to-date technologies throughout the oil and gas industry is obvious and represents a large export market. In influential parts of the FSU government and industry, however, there is a deep-seated opposition to the involvement of foreign capital in the oil and gas sector. This suspicion toward international oil companies is a common phenomenon in many countries of the world but is particularly acute in Russia, a pioneer in the oil industry and, for much of its history, the world's largest oil producer.

Part of the opposition is based on Russia's disappointment with foreign oil company performance so far. They regard the international oil companies primarily as bankers and have been disappointed at the sums actually forthcoming. They feel that much foreign investment to date has mainly benefited Western companies.

[33] In 1992, the ruble was made internally convertible and convertible for current account transactions. But the shortage of foreign currency has limited the practical operation of full internal and current account convertibility, and foreign investors in the oil sector seek to obtain foreign currency through oil exports for payment for their services and investment.

More fundamentally, influential elements of both the Russian government and Russian industry do not consider Western technology to be a key element in petroleum industry rehabilitation, but rather, as in the past, a supplement or temporary substitute for domestic technology. The new producing regions, like Turkistan, Kazakhstan, and Uzbekistan that do not have a domestic equipment supply industry, may be eager, or have no alternative than to encourage foreign investment if they wish to develop their petroleum resources. Russia, however, is likely to want to preserve its domestic equipment supply industry, especially because the development of oil and gas technology is considered a fruitful area for defense industry conversion.

U.S. Regulations Governing Private Sector Participation

For many years, U.S. trade and investment with the Soviet Union was prohibited or very strongly controlled. The major legal obstacles (the Byrd Amendment to the Trade Act of 1974, and the Stevenson Amendment to the Export-Import Bank Act of 1945, both restricting U.S. Export-Import Bank operations in the FSU) were repealed by Joint Resolution of Congress on April 1, 1992. Since then, U.S. firms have been able to export equipment freely. However, industry considers that restrictions remaining in the National Security Controls Act could constrain use of some recently available technologies, particularly seismic or computer equipment.[34]

New bilateral tax and investment treaties (eliminating double taxation on interest and royalties and defining the conditions of international investment) have also been concluded with Russia and several other republics. An exception to these new initiatives to encourage foreign direct investment in the FSU is the case of Azerbaijan, where U.S. aid is specifically prohibited except for nuclear weapons disarmament until Azerbaijan ceases uses of force against Armenia and Nagorno-Karabakh.[35] As a result, the International Trade Commission reports that the government of Azerbaijan has delayed signing a contract with a U.S. firm for the development of an Azeri petroleum field, while negotiations continue with non-U.S. companies interested in the same project.[36]

Though much of the legal legacy of the Cold War has been dismantled, U.S. industry still feels at a competitive disadvantage with oil and gas companies of other nations. (In addition to oil companies based in Western Europe and Japan, companies from the Middle East and Latin America are also active in the FSU.) This competitive disadvantage is based on 3 factors. First, U.S. companies lack the long experience of other Organisation for Economic Cooperation and Development (OECD) countries in conducting business with the FSU. Contacts and knowledge of trading conditions were not readily available to the industry in the early days, adding to the frustrations, costs, and complexity of early initiatives. As time goes by, and U.S. efforts to disseminate information about Russian trading conditions improve, this initial disadvantage will be overcome, but in the important early days it could have disadvantaged U.S. firms.

Second, there is widespread belief among U.S. companies and policymakers that other governments provide much greater financial and diplomatic support to their national companies, many of which are nationalized companies, than does the United States. This issue has been a long standing bone of contention between the United States and its competitor allies in the OECD.

Third, U.S. business practices may differ in important respects from those of other countries. U.S. companies, for example, maybe held by public opinion in this country to higher standards of environmental practice than are the companies of

[34] U.S. International Trade Commission, *Trade and Investment Patterns*, pp. 4-1 and 4-2.

[35] Section 907 of title IX of the Freedom Support Act of 1992.

[36] U.S. International Trade Commission, *Trade and Investment Patterns*, p. 4-3.

other countries. Also, U.S. companies, which are forbidden by U.S. law to engage in bribery, must compete with companies domiciled in other countries that lack similar legislation. This factor could be of particular importance during the inevitable disruptions occurring during the transition from a state-owned to a market economy.

| Conclusions

The rehabilitation of the FSU oil and gas industry through U.S. investment and technology offers a mixed prospect. On the one hand, these countries offer exciting and rich new possibilities for oil and gas development and a well educated work force. U.S. participation in the oil and gas sector could provide benefits to both partners. It could contribute to the establishment of political and economic stability in the FSU and provide a major area of growth for the U.S. industry.

On the other hand, there are several obstacles to these mutually beneficial outcomes. Some of the more important have been outlined here. They include a severe lack of investment funds (largely related to political uncertainty, insufficient economic incentives, and inadequate legal and institutional frameworks); economic instability, including the disruption of the previously important energy trade that took place before the dissolution of the Soviet Union; a shortage of management and some technical skills and information; and the frequently differing agendas of the host country, foreign investors, and aid donors. The U.S. industry may be disadvantaged by its unfamiliarity with this particular market and a tradition of less aggressive government backing.

These are formidable barriers. Some progress has been made in the past few years, but much remains to be done to help the energy sector of the FSU attract domestic as well as foreign capital. Despite a distinct cooling of the early euphoria, the FSU energy industry is still regarded in the West as the single most promising area of joint business activity, and some companies have been able to achieve considerable success in their Russian undertakings. Another good augury for the future is the greater spirit of realism in Western companies about the amounts of money, time, and effort needed to succeed. On the Russian side, the perception of whether foreign investment is needed is still a key issue. Eventually, the continuing shortage of capital investment and technology may make the foreign investment option more attractive—many other countries have changed their views about foreign investment as the need arose.

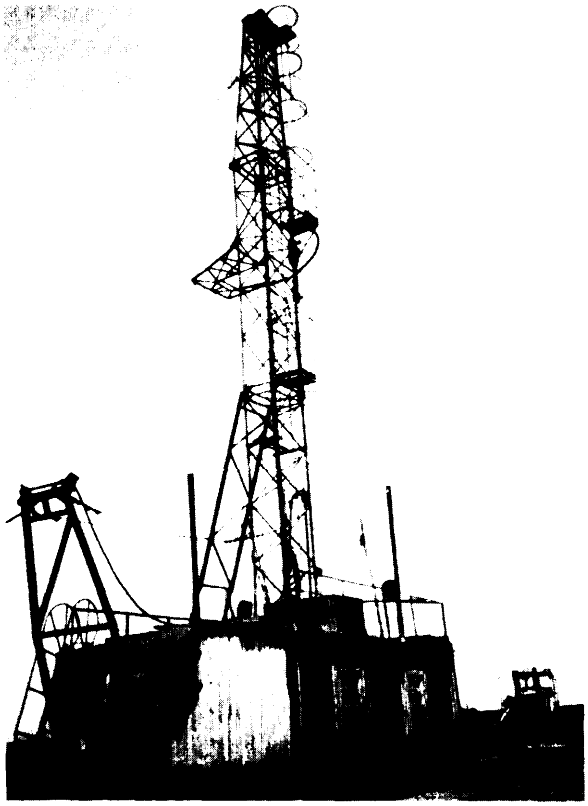
But the actual path of development has been slow, lagging early expectations. The experience of the past few years suggests that there is no quick fix for either side. Overall, the picture is mixed, showing some improvement of late, but suggesting that the rehabilitation of the oil and gas sector will take more time and care than originally thought.

COAL MINING AND BENEFICIATION

Coal is an abundant, widely distributed resource in Russia, Ukraine, Kazakhstan, and Poland. Coal deposits vary in geologic composition and quality. For example, the geologic characteristics and location of some of Russia's coal deposits—very deep or thin, and located in areas far from consumers—make it difficult and expensive to mine. Deposits also range from high-quality hard coal to lignite. In the former East Bloc, most coal is mined underground using a variety of mechanized equipment. Railroads are the dominant means of transportation to markets.

Prior to World War II, coal was the dominant fuel in the Soviet Union, as it was elsewhere in the world. In 1940, coal supplied 75 percent of Soviet energy needs.[37] Since then, oil and natural gas use has increased significantly, and today, coal ac-

[37] U.S. Congress, Office of Technology Assessment, *Technology and Soviet Energy Availability*, OTA-ISC-153 (Washington, DC: U.S. Government Printing Office, November 1981), p. 82.



Coal coring exploration rig, Kuznetz Basin, Kazakhstan,

counts for only 14 percent of energy use in Russia.[38] Coal, however, is still widely used in the Far East and Siberia for industry and as a household fuel in rural areas. Poland also relies on coal for a large percentage of its energy needs. This reliance is unlikely to diminish before the end of the century.

The coal industry in the FSU is a multifaceted enterprise. In Russia, for example, the coal industry consists of more than 1,500 associations, enterprises, and structural units. The industry not only mines coal but is responsible for mine construction, mineshaft equipment production, and geological surveys. The industry also provides housing (some 35 million square meters), health care, children's schools, and other facilities for its employees.[39] This situation is similar to the coal company town that existed in the United States 70 years ago. Today, the coal industry is trying to divest itself of some of these community/social activities, which have proven to be a tremendous burden on resources.

In the FSU, the coal industry is in crisis. Production has been steadily declining since 1988, and that will likely continue for the near future. Moreover, production costs are escalating rapidly, and transportation costs are high when compared with that for natural gas. Continued government management and control, environmental concerns, and labor unrest cloud the industry's future. Reasons for the decline in output are outlined in this section, followed by a discussion of the potential for U.S. mining and beneficiation technology transfer to former East Bloc countries. Reclamation technologies are examined in chapter 5.

I Declining Coal Production

In former East Bloc countries, coal production's downward slide is directly linked to the lack of capital investment in new coal mines and in upgrading old, established ones. In recent decades, government strategy dictated that the coal industry take a backseat to oil and gas development. Thus, over the past 15 years, no new mines have been opened in Russia. Moreover, over one-half of the operating mines are at least 30 years old and in poor working condition; few of these mines have been upgraded.[40] In Ukraine, no new mine

[38] "Rosugol" Malyshev: Coal Industry Privatization 'Problematic,'" June 16, 1993, in *FBIS Report, Central Eurasia,* July 23, 1993, p. 90.

[39] Yuriy Malyshev, "Coal: Uphill or Downhill?," *FBIS Report, Central Eurasia;* and "Rosugol's' Malyshev Analyzes Deep Crisis of Coal Industry," FBIS-USR-93-079, June 25, 1993, p. 52.

[40] Yuriy Malyshev, *FBIS Report, Central Eurasia,* June 25, 1993, p. 53.

construction has occurred in the last 10 years, according to the Minister of Geology.[41]

Equipment shortages have also contributed to the decline. The failure to produce suitable equipment and spare parts in the required quantities has been a longstanding problem in the FSU. Critical equipment is idled because spare parts are not available, and some equipment simply does not exist; e.g., methane gas detectors and other safety equipment.[42] More recently, the dissolution of the FSU has further aggravated the situation. Economic ties between various sectors in former republics have been disrupted. For example, Ukraine produced about 60 percent of the underground excavation equipment, as well as the face cleaning machinery, mine rescue equipment, and electric locomotives; Kazakhstan provided the copper for the electric locomotives.

The uneven quality of equipment also contributed to the decline. Some mines have to make do with old, decrepit machinery, while others command better, more sophisticated equipment. Improper maintenance and repair, and the lack of spare parts, make a bad situation even worse.

Furthermore, the thickest coal seams closest to the surface are now depleted, and miners must work thinner seams at greater depths, making extraction slower, more difficult, and more expensive. This is particularly true in Ukraine. In Russia, new mines located in the east are considerable distances from population centers. Moreover, several of the Siberian basins have lower quality coal, which is uneconomical to transport. Cold climes further limit extraction and transportation.

Labor unrest adds to the problem. Wretched working and living conditions and low salaries have led to miners' strikes. For example, many miners work without safety equipment, such as hand-held methane detectors. Methane gas explosions are the number one cause of death in underground mines. Also, medical facilities are inadequate, and consumer goods are scarce, particularly in remote areas in Siberia and the Arctic.

Finally, the mutual financial indebtedness among related industries has resulted in production decline. At the heart of this situation is the coal industry's indebtedness to the railroads. Recently imposed higher shipping rates and fines for late payments have further strained relations. As a result, coal is being stockpiled in storage areas, where it is subject to degradation and spontaneous combustion.

Coal Mining Technologies

About 50 percent of coal output in the FSU is mined underground, a decline of 13 percent since 1980.[43] This decline reflects the former Soviet government's view that surface mining must expand to ensure the coal industry's success. Of course, there are differences between countries as well as regions. Underground mining is still the predominant coal extraction method in Ukraine.

Underground mining is more complex than surface mining. Instead of scraping away the overburden (overlying soil and rocks), miners must work underground, connected to the outside world by shafts and passageways sometimes thousands of feet long. Roof support, ventilation, drainage, and lighting are some of the factors that complicate underground mining.

Equipment used in underground mining ranges from relatively simple to highly automated machinery. The oldest method, hand labor, is still used occasionally in small mines.

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41 U.S. General Accounting Office, Report to the Chairman, Subcommittee on European Affairs, Committee on Foreign Relations, United States Senate, *Ukraine Energy-Conditions Affecting U.S. Trade and Investment*, GAO\GGD-92-129 (Washington, DC: U.S. Government Printing Office, August 1992), p. 7.

42 Dolores Kern, "Melting the Ice," *Coal Voice*, vol. 16, No. 3 (May/June 1993), p. 14.

43 Richard Levine, U.S. Bureau Of Mines, personal communication, Sept. 13, 1993; and the Office Of Technology Assessment, *Technology and Soviet Energy Availability*, p. 82.

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Coal mine entrance in Upper Silesian Basin, Poland.

Longwall mining is the principal underground mining technique used in the FSU and throughout Europe. In the FSU, longwall mining accounts for about 85 percent of total underground output.[44] It involves the creation of interconnected corridors that are 300 to 600 feet apart. The long wall of the interconnection is mined in slices, using a rotating cutter that moves back and forth across a coal face. As the machinery moves, it cuts the coal, which falls onto a conveyor belt. The roof is held up by steel jacks while the cutter makes a pass across the face. The roof jacks are advanced with the shearer to make a new pass. The roof collapses in the mined-out area behind the jacks. Almost all of the coal can be extracted by this process.[45]

In recent years, open pit mining in the FSU has become more important, increasing from 35 percent of coal output in 1980[46] to 50 percent in 1992. Surface mining is used extensively in the Czech Republic and Estonia (see table 3-3). Surface mining equipment includes bulldozers, draglines, excavators, and large-capacity trucks.

I Potential for U.S. Mining Technology Transfer

The FSU designs and manufactures coal mining equipment. Although adequate, FSU equipment is heavier and somewhat less sophisticated than that of the United States and other western countries. Shortages of equipment, such as draglines and large-capacity excavators have been met in the past by Central Europe, particularly Poland and the former East Germany. Western imports provided only a small share.

Germany and Britain are leaders in longwall mining research and development. Because of this expertise and their proximity to former East Bloc markets, German and British companies are in a strong position to transfer technology. Germany is now actively marketing its equipment in former East Bloc countries.

The preferred method of underground mining in the United States (down to 700 meters) is the room and pillar with roof bolting system. Thus, opportunities for U.S. export and technology transfer of underground mining equipment largely hinge on a change in mining techniques, i.e., from single-entry longwall mining to roof bolting techniques. Changes in mining techniques are unlikely to occur in the near future. Moreover, geologic differences render much U.S. equipment unsuitable for the narrow seams of many FSU mines. Modifications must be made to U.S. equipment prior to export, a major market disadvantage.

However, the United States is a leader in surface mining technology and equipment. Examples of equipment that might increase productivity are large-capacity draglines and excavators. While these technologies are not unique to the United States, U.S. companies do produce equipment that typically have larger capacities than

44 Central Intelligence Agency, *USSR Energy At/as* (Washington, DC: U.S. Government Printing Office, January 1985), p. 32.

45 For an indepth discussion of mining processes, see U.S. Congress, Office Of Technology Assessment, *Direct Use of Coal—Prospects and Problems oj'Production and Combustion, OTA-E-86* (Washington, DC: U.S. Government Printing Office, April 1979).

46 OTA, *Technology and Soviet Energy Availability, p. 82.*

TABLE 3-3: The Role of Surface Mining

Country	Surface mined (percent)
Russia	**55**
Ukraine	*4*
Kazakhstan	70
Estonia (shale)	50
Poland	70
Czech Republic	75
Hungary	32
Slovak Republic	0

SOURCES Przemysl (Warsaw 1992), p 20, Iparstatisztikai Evkonyv (Budapest 1989), p 301, Statistiska Rosenka (Prague 1992), p 388; Okhrana okrushaiushchei sredy i ratsional'noe ispol'zovanie prirodnykh resursov (Moscow Goskomstat, 1991), pp 202-203.

their Western European and Japanese counterparts.

To date, the U.S. coal industry presence in the FSU has been part of a much larger humanitarian effort, Partners in Economic Reform (PIER). With U.S. government funding and coal industry and labor support, PIER administers the Coal Project, which provides technical assistance and training in health, safety, efficiency, and productivity throughout the coal regions of Russia, Ukraine, and Kazakhstan. Technical assistance includes demonstrations of U.S. mining technology and equipment, as well as management, engineering, and safety techniques. The Coal Project also funds the purchase of safety equipment, such as methane detectors, for FSU miners. The Coal Project has liaison offices in Moscow, Kiev, and Almaty and regional training centers in the Donbass, Kuzbass, Karanganda, and Vorkuta mining regions.

Coal Beneficiation

Coal beneficiation (cleaning) is done at the mine prior to transport. Cleaning improves the quality of coal so that it can be used more cleanly and efficiently and offers significant savings in transport fees. Coal cleaning also reduces handling and storage, and maintenance costs for pulverizers because of lower volume. Furthermore, pre-combustion cleaning can result in environmental benefits; e.g., cleaning removes ash and some of the sulfur[47] found in coal, thus reducing particulate and sulfur dioxide, which are emitted during combustion.

It is important to note that the benefits of coal cleaning will vary among East Bloc countries and will largely depend on the characteristics of the coal. For example, in Ukraine, where coal is high in pyritic sulfur, cleaning will offer significant reductions (up to 50 percent) in sulfur emissions. In Poland, the primary benefits are reduced transport costs and particulate emissions, especially in urban areas where a large percentage of households use high-ash coal for heat. (See chapter 5 for a discussion of the environmental benefits and potential impacts of coal beneficiation.)

There has been little cleaning of coal in former East Bloc countries. For example, during the 1970s and 1980s, only about 15 percent of coal was cleaned in the FSU, mostly for coking coal. Coking coal typically receives cleaning because of the technical requirements of metallurgical operations. Polish coal is cleaned for the export market.

Potential for US. Technology Transfer

The United States has extensive experience with coal beneficiation. About one-third of U.S. steam coal (over 200 million tons) is cleaned to remove ash and sulfur impurities and to increase heat value.[48] This experience and technological expertise could both benefit the coal industry and mitigate the air quality impacts of coal combustion in several countries.

But before U.S. and other Western companies invest in coal cleaning projects, coal data must be collected and evaluated to determine appropriate

[47] Two types of sulfur are found in coal: pyritic and organic. Traditional coal cleaning methods can only remove the heavier, pyritic sulfur.

[48] Thomas C. Elliott, "Coal Handling and Preparation," *Power*, January 1992, p. 17.

cleaning techniques and to ascertain the level of newly generated wastes resulting from beneficiation. In most cases, such data are not available and must be assembled by U.S. companies interested in doing business in former East Bloc countries, a major financial undertaking for small- and medium-sized firms and a significant obstacle.

Although few U.S. firms are involved in coal cleaning technology transfer to this region, Custom Coals is actively pursuing opportunities in Poland. The U.S. company is planning to build three facilities near Krakow, Poland. These plants will have the capacity to clean 10 million tons of coal annually for powerplant use. Appendix 3-2 details Custom Coals' experience in Poland and provides some perceptions of federal government efforts to assist U.S. businesses.

Conclusions

The coal industry in former East Bloc countries continues to experience serious problems including declining output of mines near population centers, few additions to mine capacity, declining coal quality, and labor unrest. The low priority given the coal industry in the past has contributed significantly to present-day instability. For example, capital investment decisions in the 1970s and 1980s favored oil and gas development and starved the coal industry. Moreover, government strategy to mine the thickest seams closest to the surface quickly depleted high-quality, economical coal. What is left is coal of poorer quality that is located far from consumers. Production costs are rising rapidly, and transportation costs are high, when compared with those for natural gas.

The shortage of capital also hindered the development and production of coal mining technologies. The use of old, inefficient technologies is commonplace. In addition, equipment manufacturers historically have been reluctant to develop and produce new technologies. Fear of jeopardizing output plans and risking related bonuses are at the root of this fear. Moreover, the reliability of equipment has been a longstanding problem. Infrequent repair and maintenance, the lack of spare parts, and the use of equipment that is unsuitable for the conditions aggravate the situation. Equipment failure results in work stoppages, and poorly maintained equipment results in an increased rate of accidents and injuries in the labor force.

Some restructuring of the coal industry has begun in Russia, Poland, Hungary, and the Czech Republic. Recently, Russia announced the closure of 41 underground mines and one open pit mine by 2000. These mines produce about 3 percent of total output but account for 26 percent of all coal industry accidents.[49] Also, a new entity, Rosugol, was created in 1993 to administer the coal industry. However, principal responsibility still resides with the 28 coal associations that oversee production and transport. In other countries, restructuring is further along. Hungary, for example, has closed several mines, raised coal prices, and reduced subsidies. In Poland, the Hard Coal Agency, a state-owned, joint stock company, was formed to encourage privatization and to close inefficient mines. Also, prices have been raised, subsidies have been reduced, and some mines have become independent entities. However, the coal industry in former East Bloc countries is still far from being a competitive structure of private producers, distributors, and traders. Legal and regulatory issues are two of the many concerns that must be addressed before a truly competitive industry emerges.[50]

Associated environmental problems further cloud the outlook for the industry. The widespread burning of low-quality lignite is largely responsible for the alarming degradation of the environment in the region. Cleaning up the pollution will require many years of effort and large infusions of capital. The Polish government, for example, esti-

49 Radio Free Europe/Radio Liberty Daily Report, "Forty-Two Mines to be Closed," Oct. 29, 1993.

50 Energy Sector Management Programme, *Poland—Energy Sector Restructuring Program, vol. 2: The Hard Coal Subsector*, Report No. 153/93 (Washington, DC: World Bank, January 1993).

mates that $260 billion will be needed to attain European Union environmental standards and reach sustainable economic development.[51] Hence, technological advances in clean coal burning and pollution control equipment will not only provide environmental benefits but also may help stabilize coal output and use.

Modem coal mining technology offers short-term improvements in productivity, efficiency, and environmental impacts. It also buys time while the transition is made to a market economy. However, Western assistance alone will not reverse the coal industry's downward slide informer East Bloc countries. Efforts must be made by Central European and FSU governments to solve the variety of problems now facing the industry. To stabilize output and reverse the decline, capital must be invested in mine development and modernization. Manufacturers must be able to produce the required equipment and get it to the miners. Western imports and joint ventures in production facilities could provide some relief in this regard. The industry's social/community activities, such as health care, housing, wages, taxes, and pensions, must also be addressed.

In the final analysis, however, the long-term survival of the coal industry will depend on how well governments make the transition to a market economy. Economic reform is the key.

The U.S. coal industry has not thus far actively pursued technology transfer to former East Bloc markets, as compared with the oil industry. The characteristics of the region's industry and related environmental impacts, labor, and transportation problems have not been conducive to foreign investment. Furthermore, mining techniques and geologic characteristics of coal deposits differ from those found in the United States. Because mining is generally done at deeper levels and on thinner seams, U.S. companies would have to modify their equipment for export to former East Bloc countries, a major market disadvantage. As reforms take hold, and the coal industry stabilizes, there may be more interest in coal mining technology transfer to that region. One near-term possibility for U.S. companies might be to focus on opportunities for U.S. technologies and expertise after the coal is extracted, such as coal beneficiation. The United States is a leader in coal cleaning technologies and project development and management. This expertise could provide significant energy efficiency and air quality benefits. However, the lack of accurate coal data will present a challenge to Western companies interested in technology transfer. Accurate data are essential to the success of coal beneficiation projects.

In sum, there are many opportunities to rejuvenate the coal industry in former East Bloc countries and make it financially healthy. Whether U.S. companies jump in will depend on the region's and coal industry's success in making the transition to a market economy and addressing the myriad of problems it now faces.

COALBED METHANE

Methane gas is often associated with coal. Generally, the amount of methane stored in a coal deposit is related to the quality and depth of a coal deposit. Higher quality and deeper coal seams have greater capacity to hold methane.

Large amounts of methane can be released during the mining process. For example, coal mining operations in Poland release about 4.8 trillion cubic feet (Tcf) annually, most of which is vented to the atmosphere.[52] Unutilized methane is a potent greenhouse gas and a safety hazard. Methane is estimated to be about 25 times more effective in

[51] Stanley J. Kabala, "The Environmental Morass in Eastern Europe," *Current History*, vol. 90, No. 558, November 1991, p. 388.

[52] U.S. Environmental Protection Agency, *Assessment of the Potential Economic Development and Utilization of Coalbed Methane in Poland*, EPA/400/1-91/032 (Washington, DC: U.S. Government Printing Office, August 1991), p. ii.

TABLE 3–4: Methane Degasification Emissions, Selected Countries

Country	Total recovered (bcf)	Total used (bcf)	Total vented (bcf)
FSU	43.4	9.8	33.6
Czechoslovakia	4.9	4,4	0.5
Poland	10,0	7.0	3.0

SOURCE Charles M Boyer, II, and Jonathan R Kelafant, and Dina Kruger, "Diverse Projects Worldwide Include Mine, Unmmed Coals," *Oil and Gas Journal*, VOl 90, No 50, Dec 14, 1992, p 40

trapping heat than carbon dioxide (CO_2) on a weight basis,[53]

Methane gas explosions are the number one cause of death in underground mines in the FSU. In the past, miners took canaries down into the mine with them as a warning that methane was present. Gas detection equipment and mine ventilation systems are now used.

The methane can be captured and used instead of being released. Coalbed methane is essentially identical to natural gas and can be transported by pipeline to households and industries. Extracting and using coalbed methane improves mine safety and provides environmental benefits. Its use could thus reduce pollution in the heavily industrialized areas of southwestern Poland, where adverse health effects have been associated with high levels of sulfur dioxide emissions. There is great potential for methane recovery and use in Poland, Russia, Ukraine, and Kazakhstan. They are among the major coal bed methane resource countries in the world.

I Coalbed Methane Technologies

In gassy coal seams, ventilation systems are inadequate, and degasification technologies must be used. These technologies can recover methane before, during, and after mining, and can be used inside the mine or from the surface. Degasification systems have become more important in light of growing concerns about greenhouse gas emissions. Methane degasification emissions for several areas are highlighted in table 3-4.

The four principal methods of degasification are surface pre-mining drainage, in-mine drainage, surface gob recovery, and cross-measure boreholes. Several factors, including the characteristics of the coal deposit, mining methods employed, and surface conditions, determine which degasification technology is used.

Surface pre-mining drainage uses vertical wells that are drilled from the surface to recover the methane before mining activities commence. Drilling can occur from 2 to 15 years prior to mining. This method is used exclusively in the United States, but can be used in other countries as well.[54] Poland has expressed interest in surface pre-mining drainage.

In-mine drainage is preferable in areas where surface mining is impractical because of land use patterns and where immediate drainage is required. Boreholes are drilled into the coal seam where they can be connected to the mine's piping system, which transports the gas out of the mine.[55]

Surface gob recovery is used after a coal seam is mined. Wells are drilled to within a few feet of the top of the coal seam. As mining is completed underneath, gas is produced from the fractures

[53] U S Congress, Office ~) f Technology Assessment, *Changing by Degrees: Steps to Reduce Greenhouse Gases*, OTA-O-482 (Washington, *DC:* U.S. Government Printing Office, February 1992), p. 59.

[54] Charles M. Boyer, II, Jonathan R. Kelafant, and Dina Kruger, "Diverse Projects Worldwide Include Mines, Unmined Coals," *Oil and Gas Journal*, vol. *90*, No. 50, Dec. 14, 1992, p. 39.

[55] Ibid.

created by the caved-in areas. Surface gob recovery often produces large quantities of methane. However, the gas is not pipeline quality because it has been contaminated by mine air.[56]

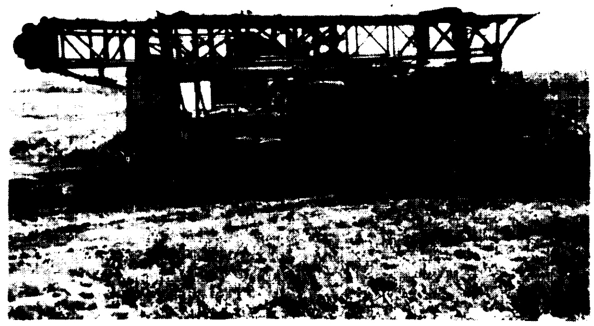
In many countries, including the FSU, Central Europe, and the United States, cross-measure boreholes are the principal recovery method. Boreholes are drilled at an angle into the strata above or below the coal seam being mined. Like other in-mine recovery systems, the boreholes are connected to the mine's piping system.[57]

Potential for U.S. Methane Technology Transfer

The desire to reduce greenhouse gas emissions and become energy self-sufficient has spurred interest in developing coalbed methane resources worldwide. Poland, for example, is actively seeking Western assistance to explore and develop its resources.

The United States has done extensive research on coalbed methane exploration and development technologies. This research paved the way for successful U.S. projects, such as that in the San Juan Basin in Colorado and New Mexico and the Warrior Basin in Alabama. With a vast resource base (400 Tcf) and production experience (over 1 billion cubic feet per day), the United States is a recognized leader in coalbed methane development.[58] U.S. technologies and project management expertise can help expedite coalbed methane development in former East Bloc countries.

Recently, two U.S. companies, Amoco and McCormick Energy, have been awarded contracts to extract coalbed methane in the Upper Silesian coal fields in southern Poland. Most of the methane will be compressed and transported by pipeline. It is expected that the recovered methane will replace about 7 percent of Polish gas consumption, or 1 percent of the country's total energy demand.[59]



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Truck mounted drilling rig typically used for coal and coalbed methane explorations in the former Soviet Union,

U.S. and European companies are also pursuing coalbed methane exploration and production projects in the Czech Republic, Hungary, Romania, and Bulgaria. Additionally, the EPA is actively promoting expanded coalbed methane recovery and use in several countries, including Poland, Russia, Ukraine, and the Czech Republic. Thus far, EPA has funded resource assessments and established a coalbed methane information center in Katowice, Poland. EPA also has established a U.S./Poland working group to encourage projects to reduce methane emissions from mines.

While interest in commercial coalbed methane projects is growing, several factors have dampened Western enthusiasm for market development in former East Bloc countries. The lack of appropriate regulations and the legal uncertainties that relate to ownership and granting concessions have hindered development. Also, the poor condi-

[56] Ibid.

[57] Ibid.

[58] Jonathan R. Kelafant, Scott H. Stevens, and Charles M. Boyer, II, "Vast Resource Potential Exists in Many Countries," *Oil and Gas Journal*, vol. 90, No. 44, Nov. 2, 1992, p. 80.

[59] "Flaring Coal," *The Economist*, vol. 328, No. 7820, July 17, 1993, p. 65.

tion of many coal mines and the continuation of subsidized energy pricing have further reduced the economic attractiveness of coalbed methane projects.

Available and accurate geologic data, a fully integrated natural gas pipeline system, and tax incentives are also needed. Most of these conditions do not exist in former East Bloc countries, making coalbed methane development riskier. These countries must address these legal, financial, and political issues to attract Western investment and fully realize their coalbed methane resource potential.

APPENDIX 3-1: EXPERIENCE WITH JOINT VENTURES-DRESSER INDUSTRIES

Background

Dresser Industries is a full-spectrum oil and gas production equipment manufacturer that has been selling oil- and gas-related equipment to the Soviet Union since 1936. Dresser began doing business with Moscow when Soviet Russia was rapidly expanding its petroleum production capabilities to fuel the huge spurt of economic growth that took place under the state-sponsored industrialization program of the 1930s. Dresser has remained in Russia ever since, selling a full spectrum of highly engineered upstream and downstream oil- and gas-related equipment. Dresser's business intensified in the early 1970s, and the company established an officially accredited office in Moscow in 1979. With almost six decades of experience in the Soviet market, Dresser is one of the most experienced American exporters to the FSU.

Present Activities

The company is currently working on two large projects in the FSU. In St. Petersburg, Russia, Dresser is in the process of setting up a joint venture with the Kirovskii Zavod, a former military enterprise, for the manufacture of oil and gas pipeline turbine compressor sets. This will be the company's first manufacturing operation in Russia. In Uzbekistan, Dresser has signed a $200-million agreement to build a gas injection condensate recovery project.

Doing Business in the FSU

Dresser officials who have worked recently in Moscow note that many of the skills that the company learned in the Soviet era are still vital for doing business in the FSU. Of particular importance are the company's wide range of contacts within the FSU oil and gas industry and the understanding that doing business in the FSU requires a long-term commitment and perspective. Moreover, since Dresser's activities have been almost exclusively commercial in nature and have not involved resource extraction, the company has not been greatly hampered by the legal and ownership uncertainties that have affected oil and gas exploration ventures since the breakup of the Soviet Union.

But there have been substantial changes in the way business is done and in the types of problems Dresser has encountered since the Soviet Union split apart. Whereas before 1991 the company dealt almost exclusively with ministries and foreign trade organizations, it now sells directly to end-user organizations such as enterprises, production associations, and refineries. This can be a double-edged sword. Although it is easier to deal with end-users than third parties, Russian enterprise directors have had little experience negotiating major purchases with foreign contractors. Managers are often unfamiliar with Western price norms, warranty standards, and other trade-related matters previously handled by professional negotiators in Moscow. As a result, the customarily long Soviet-era negotiation process is often further attenuated in the FSU.

Moreover, the Soviet Union was such a reliable creditor that Dresser never needed to require a letter of credit. Now, the need to obtain financial guarantees from enterprises in the post-Soviet states can create confusion and misunderstanding. Post-Soviet enterprise managers are unfamiliar with Western financial requirements and have been slow to appreciate the need for confirmed letters of credit and other guarantees. Dresser thinks that a U.S. government sponsored training program to teach basic business management and marketing skills to FSU energy sector managers could improve understanding of the mechanics of market economies and foreign trade. But the need for such training is so great that company officials wonder whether any foreseeable American training program could have a significant impact.

U.S. Government Role

According to Dresser, recent U.S. government activity in the commercial sector has had a positive impact on energy-sector exports to the FSU. The relaxation of COCOM has been of particular help to the company, allowing it to sell its high-technology nuclear logging equipment and other computer-driven systems to markets from which they were previously prohibited. The company also notes that the U.S. government has shown greater interest in promoting American exports over the past four or five years. This includes not only greater coordination between agencies such as DOE and Commerce, but also encompasses changes in other aspects of U.S. government policy. For example, the easing of visa restrictions for Russians to visit the United States may not have been seen as a commerce-enhancing step, but it greatly eased Russian frustration at what was perceived to be unequal treatment: Dresser officials could visit the Soviet Union, but Soviet citizens could not come to the United States. Dresser notes that the easing of these restrictions and the placing of former Soviet citizens on a more equal footing with Americans in the business process has eased relations with Dresser's Russian partners and made it easier to do business.

Nevertheless, company officials maintain that without substantial United States government assistance in the area of finance, Dresser and other equipment supply companies will be unable to expand their export activities to the FSU. They say that given the acute need for FSU countries to raise hard currency, the U.S. government should give greatest priority to promoting investment in those FSU sectors, such as oil and gas production, that will provide the quickest and most lucrative hard-currency exports. But given the region's economic and political instability, Western banks will not lend money on an unsecured basis. Western resource extraction ventures such as Chevron can afford to risk investing their own money because the potential rewards are so great. But in the equipment export sector, where the returns are much smaller, Western firms such as Dresser cannot risk investing hundreds of millions of dollars of their shareholders' money in the turbulent conditions of the FSU. Accordingly, Dresser advocates a large expansion of Eximbank guarantees (at the standard 85 percent rate) for energy sector investment projects. In his view, Eximbank guarantees (coordinated with similar guarantees by other Western nations) will prove much more effective and will promote investment much more quickly than other efforts currently under consideration, including the European Energy Charter and attempts to set up escrow accounts or funnel investment funds through multilateral organizations such as the World Bank.

APPENDIX 3-2: CASE STUDY: CUSTOM COALS CORP.

Custom Coals Corp. is an Arizona corporation headquartered in Pennsylvania and founded to market a recently developed technology to reduce the pre-combustion sulfur content of coal. According to the company, its cleaning process removes sulfur more economically than flue gas desulfurization (scrubbers), the most widely used post-combustion process. Company data show that in many cases the Custom Coals process, which employs physicial benefication and limestone and hydrated sorbent additives, reduces sulfur emissions at half the cost of scrubbers. The company's products are designed for electric utilities and for the district and home heating markets.

The company recently won a $76-million contract under the U.S. Department of Energy's Clean Coal Technology Program to construct and operate a demonstration coal cleaning plant in Somerset County, Pennsylvania. After this project goes on line, Clean Coals plans to develop 9 to 10 full-scale plants in the United States.

The Project

In addition to U.S. markets, Custom Coals is seeking to sell its technology overseas in countries that depend heavily on coal but lack effective and cost-efficient pollution-control technologies. At the present time, the company's most active project is in Poland, though it is also working in China and Mexico. Poland is a particularly attractive prospect because of its huge coal reserves, its dependence on coal for power generation and heating, and the need to curtail the emissions of sulfur that have contributed to the country's nearly catastrophic levels of pollution.

Ideally and in the long term, the best way for Poland to reduce toxic emissions is to convert its powerplants to gas-fired operations. But conversion to gas would demand a great deal of capital, which the country cannot afford. Coal cleaning provides a good short-to medium-term solution to Poland's problem. It demands much less capital investment and results in significant pollution reduction. Custom Coals estimates that its clean coal product will contain 75 percent less particulate and heavy metals and 50 percent less sulfur than raw Polish coal. In addition, the coal cleaning technology will offer Poland the ability to clean its high-sulfur coals and export the product to Western Europe.

The company has proposed an initial project involving three coal cleaning plants, which would process about 10 million tons of Polish coal annually for sale on the domestic and export market. It sees the potential for 25 plants, to process around 100 million tons (75 percent of Polish annual coal production). The company has already spent one year working on the project, in consultation with government officials, as well as the managers of coal mines, power generation plants and the electric grid. The company is presently studying the technical characteristics of Polish coal; evaluating project sites, supplies, builders, and operators; and developing a detailed project for submission to international lending agencies. It hopes to have a financeable project ready for presentation to the World Bank and the EBRD by the second quarter of 1994, with groundbreaking set for the fourth quarter of that year.

Doing Business in Poland

Custom Coals reports a warm reception from Polish government and enterprise officials because it actually proposes to build a project. Poles have told Custom Coals officials that they feel "studied to death" by fly-in, fly-out Western consultants who spend a great deal of money identifying problems but do very little about solving them.

However, business negotiations have not been problem free. The Poles' lack of background in free market economics and lack of knowledge about the rates of return needed to attract investment capital has impaired their ability to evaluate potential business deals. Polish managers have difficulty judging whether they are receiving reasonable terms, in the context of the international economy, and they worry about being taken advantage of by more knowledgeable Western business people. The lack of a consistent and reliable system of cost accounting often makes it difficult for Custom Coals to generate the types of data needed to satisfy financial requirements. And the many unusual attached costs borne by Polish enterprises (everything from bowling alleys to day care centers) have to be taken into account in computing total project cost.

Nevertheless, Custom Coals has had few major problems setting up its business. This is in large part because the company has been able to find professional service providers who are fluent in U.S.-Poland business issues, the technical questions of coal production, and the English 1anguage. Beyond management training for future senior Polish managers of Custom Coals projects, the company does not foresee a need for substantial investment in training.

Custom Coals' German competitors have been active in the same market. German companies enjoy an advantage over Custom Coals because their domestic operations are subsidized by the German government. However, the German firms rely on conventional pollution-control technologies, not the advanced, pre-combustion technologies developed by Custom Coals. The German companies are also seeking direct financing or sovereign financial guarantees from the Polish government to underwrite their proposed projects. Custom Coals is structuring its project proposals so that the Polish government will not have to provide financing, making their proposal potentially much more attractive from the Polish point of view.

International Lending Agencies and the U.S. Government

Since commercial banks are still extremely reluctant to lend to projects in Central Europe, the success of Custom Coals' Polish project depends on funding from multilateral lending agencies such as the World Bank and EBRD. Custom Coals officials have been solicitous of advice from representatives of both institutions and have remained in continuous contact with them as they develop their funding proposal. World Bank officials are particularly enthusiastic about coal cleaning as a more cost-effective answer to Poland's pollution problems than the installation of highly expensive scrubbers. Custom Coals is optimistic about prospects for long-term project financing from these institutions.

Custom Coals' experience with U.S. agencies has been more mixed. The company applied for and received a $375,000 matching grant from the AID to conduct feasibility studies for its Polish project. But the application process was extremely slow. AID took 7 months to review the project before approving it in May 1993, and another 7 months to disburse the funds.

In the company's view, the World Bank and EBRD are fulfilling their missions as multilateral lenders financing development projects. The company is therefore less concerned about project funding than with financing the feasibility studies and other initial costs involved in putting together a project proposal. The company notes that these initial costs can be quite high—around $2 million to $3 million simply to put together a project financing proposal suitable for submission to a multilateral lender. For a large corporation, this is not a big expense, but for a relatively small business like Custom Coals, these development costs constitute a considerable sum. The company's AID grant is designed to meet part of these costs, but the AID application process is too slow.

The company would therefore like to see a new and more timely way of providing development assistance for U.S. firms, especially for small companies, in the form either of loans or grants. (Custom Coals would gladly take a commercial loan to cover these costs if it could obtain one for its Polish project.) The company points to the DOE Clean Coals Technology Program as a model. The DOE program provides startup monies on a timely basis, requires company matching funds (which eliminates spurious projects), and requires repayment to replenish the revolving fund. Unfortunately, these DOE funds cannot be used for projects abroad. The company thinks that something like this would be ideal for projects in Central Europe.

The International Perspective

Custom Coals notes one larger philosophical issue. The company sees coal cleaning not as a national issue, but as a global one. American firms and the U.S. government have spent large sums of money developing domestic technologies for coal cleaning and for the reduction of sulfur dioxide and particulate emissions. Domestically, where all powerplants and industry are already meeting previously established standards for pollution control, recent investments in coal cleaning technology will yield significant, but relatively marginal improvements in pollution control. But applying these technologies elsewhere, where the basic technologies in use are far below the U.S. standard or where no pollution-control technology exists, could yield much larger results in terms of reducing worldwide sulfur emissions. In essence, $2 billion spent worldwide would have a much greater impact on reducing pollution levels than the same money spent in the United States.

Overseas projects thus offer a much greater environmental ‘*bang” for the investment buck. Accordingly, the company advocates a shift in U.S. government focus and a more global approach to coal cleaning as a way of obtaining greater results from technologies already developed at home.