United States
Environmental Protection
Agency

Air and Radiation
(6202J)

EPA 430-K-94-003
April 1994

REDUCING METHANE EMISSIONS FROM COAL MINES IN RUSSIA AND UKRAINE:

THE POTENTIAL FOR COALBED METHANE DEVELOPMENT

REDUCING METHANE EMISSIONS FROM COAL MINES IN RUSSIA AND UKRAINE:

THE POTENTIAL FOR COALBED METHANE DEVELOPMENT

APRIL 1994

GLOBAL CHANGE DIVISION
U.S. ENVIRONMENTAL PROTECTION AGENCY

Acknowledgments

This report was prepared jointly by the U.S. Environmental Protection Agency and Raven Ridge Resources, a subcontractor to ICF Incorporated, under Contract # 68-D2-0178. The contributing author from EPA was Dina Kruger. Contributing authors from Raven Ridge Resources were James S. Marshall, Raymond C. Pilcher, and Carol J. Bibler. Important contributions to this report were provided by the staffs of the Skochinsky Mining Institute in Moscow, Russia and the Ukrainian Gas Institute in Kiev, Ukraine, and many other Russian and Ukrainian experts.

SUMMARY

INTRODUCTION

This report presents an assessment of the coalbed methane resources of the Donetsk, L'vov-Volyn, and Kuznetsk basins in Russia and Ukraine. The study was commissioned by the U.S. Environmental Protection Agency, as part of its efforts to identify cost-effective opportunities to reduce methane emissions to the atmosphere. The study evaluates the potential for coalbed methane development and utilization, and its impact on the environmental and energy needs of these regions, as well as the two republics.

This study emphasizes recovery of coalbed methane in mining areas because the methane emitted to the atmosphere as a result of mining operations represents the loss of a valuable energy resource, and because it is a greenhouse gas affecting the global climate.

KEY FINDINGS

- **Coalbed methane is an abundant domestic natural gas resource with excellent potential for increased development and utilization in Russia and Ukraine. Coal mining operations vent significant amounts of methane to the atmosphere.**

  -- Preliminary estimates suggest that coalbed methane resources associated with the principal mining reserves of coal within mines of the three regions studied are between 627 billion and 1.1 trillion cubic meters. Additional methane resources are contained in other coal reserves in the mining areas and in areas beyond the boundaries of the mines, bringing the total estimated methane resource contained in coal seams of the three coal basins studied to perhaps as much as 7.8 trillion cubic meters. Still further methane resources are contained in the partings and strata surrounding the coal seams.

  -- Large volumes of coalbed methane are liberated during coal mining operations each year, representing a serious waste of energy. Coal mining operations within the Commonwealth of Independent States (CIS) emit an estimated 7.2 to 10.7 billion cubic meters of methane to the atmosphere annually. Ukraine accounts for 49 percent and Russia for 35 percent of this total; the remaining 16 percent is emitted by other republics. Only about 2 percent of the total methane liberated by coal mines in the CIS is utilized.

- **There appear to be many opportunities for mines in Russia and Ukraine to develop profitable projects to expand the recovery and use of coalbed methane.**

  -- Using demonstrated technologies, such as pre-mining degasification and enhanced gob well recovery, it appears likely that Russian and Ukrainian coal mines could recover and use 50 percent or more of the methane currently being liberated by mining.

  -- Additional recovery could be achieved by employing an integrated approach to methane recovery, including drainage prior to, during, and after mining, and, where feasible utilizing low methane concentration ventilation air as combustion air in power stations. If such an approach were used within the active mines, 80 to 90 percent of the methane that would be liberated and otherwise lost by mining operations could be recovered and available for use.

  -- There is significant potential for increased methane utilization, moreover, even without expanding methane recovery. Currently, coal mines release approximately 78 percent (more than 618 million cubic meters) of the medium quality methane they recover with their existing degasification programs. Introduction of methods to improve gas quality and use medium quality fuel in turbines or for other purposes could reduce these emissions.

- **Ukraine and Russia confront difficult economic and environmental challenges related to the transformation of the traditional state-subsidized energy industry to a more competitive industry. Any new source of domestic energy could reduce economic burdens.**

  -- Natural gas will play an important role in the future of the energy economy of the CIS as natural gas is significantly less expensive to produce than coal, on an energy-equivalent basis, and is a much cleaner burning fuel.

  -- Coalbed methane is an attractive gas resource in both Russia and Ukraine because it is plentiful and is located in coal producing areas that have traditionally been intensely industrialized and highly polluted.

- **The development of coalbed methane could make important contributions to the energy economy of both Russia and Ukraine as well as benefiting the local and global environment.**

  -- Russia and Ukraine will likely continue reducing their dependency on low-quality hard coal, brown coal and lignite, and coke-oven gas in order to reduce the environmental problems use of these fuels creates. These trends will improve environmental quality and will create opportunities for additional use of natural gas by the republics. Coalbed methane development could assist these republics in achieving their environmental goals and increase domestic production of clean burning energy.

  -- Aggressive coalbed methane development and utilization would also decrease methane emissions dramatically, which has important implications for the global climate. Methane is a potent greenhouse gas that contributes to tropospheric ozone formation and may contribute to stratospheric ozone depletion. Coal mines in the CIS emit significant quantities of coalbed methane; the CIS is the second largest emitter of methane from this source.

-- Coalbed methane extracted during mining will be most valuable when used locally in situations where high compression, enrichment, drying, or long distance transmission is not required. Given the heavy industrialization of Russia and Ukraine's major coal mining regions, there are numerous end-users available in the vicinity of many mines.

-- Coalbed methane could be used to generate both steam and electricity, displacing the use of low-quality hard coal and lignite. Coalbed methane can also be transported by pipelines directly to end-users, replacing coke-oven gas, or, in the case of Ukraine, natural gas currently being imported from Russia. Displacement of hard coal, lignite and brown coal, or coke-oven gas with coalbed methane would improve local air quality.

-- Increased mine productivity and safety would result from increased methane drainage, improving the economic viability of hard coal mines of Russia and Ukraine.

RECOMMENDATIONS

- **The potential for coalbed methane to help Russia and Ukraine achieve their economic, environmental, and energy goals should be comprehensively assessed and, where appropriate, development of the resource should be strongly encouraged.**

  -- The most feasible technologies for expanding methane recovery at coal mines in Russia and Ukraine should be evaluated on a site-specific basis. The relationships between expanded methane recovery and mine safety and economics should be considered in such studies. In addition, the role that coalbed methane development could play in the reorganization of the coal industry should be examined.

  -- Where feasible, programs to increase the production of coalbed methane in conjunction with mining should be implemented.

  -- Special attention should be given to reducing the venting of medium- and high-quality methane currently being produced by mine degasification systems in Russia and Ukraine. Such methane represents a ready source of clean fuel that could be utilized with additional investments.

  -- As methane recovery expands at coal mines in Russia and Ukraine, a wide range of utilization options, including power generation, direct uses, gas enrichment and pipeline injection, should be evaluated and those that are most efficient, economically attractive and environmentally beneficial should be emphasized. Opportunities to store coalbed methane in abandoned coal mines should be examined.

  -- The economic and environmental impacts of coalbed methane should be assessed, including evaluation of the local economic impacts (such as job creation), land needs, and any water disposal requirements.

- **Rapid development of coalbed methane will require participation by the Russian and Ukrainian governments, international development agencies, foreign governments, and private industry.**

  -- Potential markets for methane produced by active coal mines should be assessed and the investments required to bring this gas to market should be determined.

  -- Implementation of some specific programs could greatly assist in the development of coalbed methane projects in Russia and Ukraine, including:

    - Establishing appropriate policies to encourage the recovery and use of methane from coal mines at the national and local level. To the extent that foreign investment could help expedite the development of the resource, attention could be given to the development of policies that encourage such investment.

- Undertaking feasibility assessments of methane recovery and use projects at specific sites in Russia and Ukraine, with a goal of identifying projects that could subsequently be developed either as demonstration projects or as commercial ventures.

- Disseminating coalbed methane information to the coal mining regions of Russia and Ukraine through the establishment of one or more Coalbed Methane Recovery Technology Centers. These centers would facilitate information exchange by publishing a journal, arranging meetings and technical seminars, conducting outreach, and undertaking research and policy studies.

- Developing training programs for government and industry personnel to raise awareness of the coalbed methane resource and the available technologies for its recovery and utilization.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF BOXES

CHAPTER 1

COALBED METHANE IN THE ENERGY ECONOMY OF THE CIS, WITH EMPHASIS ON RUSSIA AND UKRAINE

1.1 INTRODUCTION

The former Soviet Union, now called the Commonwealth of Independent States (CIS)[1], is the third largest producer of coal in the world behind China and the United States. In 1990, an estimated 7.2 to 10.7 billion cubic meters[2] (4.8 to 7.2 teragrams) of methane were emitted to the atmosphere from coal mining operations in the CIS, which represented about 20 percent of world coal mine methane emissions (USEPA, 1993a). Between 80 and 90 percent of these emissions were liberated by underground mining operations, which are primarily located in the republics of Ukraine, Russia and Kazakhstan.

Methane emissions represent the loss of a valuable energy resource and have a detrimental effect on the earth's atmosphere. Methane is a potent greenhouse gas, second in significance only to carbon dioxide. In addition, it tends to increase tropospheric ozone and smog formation, and may also contribute to stratospheric ozone depletion (Kruger, 1991). Methane released by coal mines and other activities is generally a wasted resource, opening the possibility for low cost, potentially profitable, emission reduction opportunities. Because methane is the primary constituent of natural gas, it can be recovered before or during coal mining operations and used as fuel for power generation or direct industrial and residential energy needs.

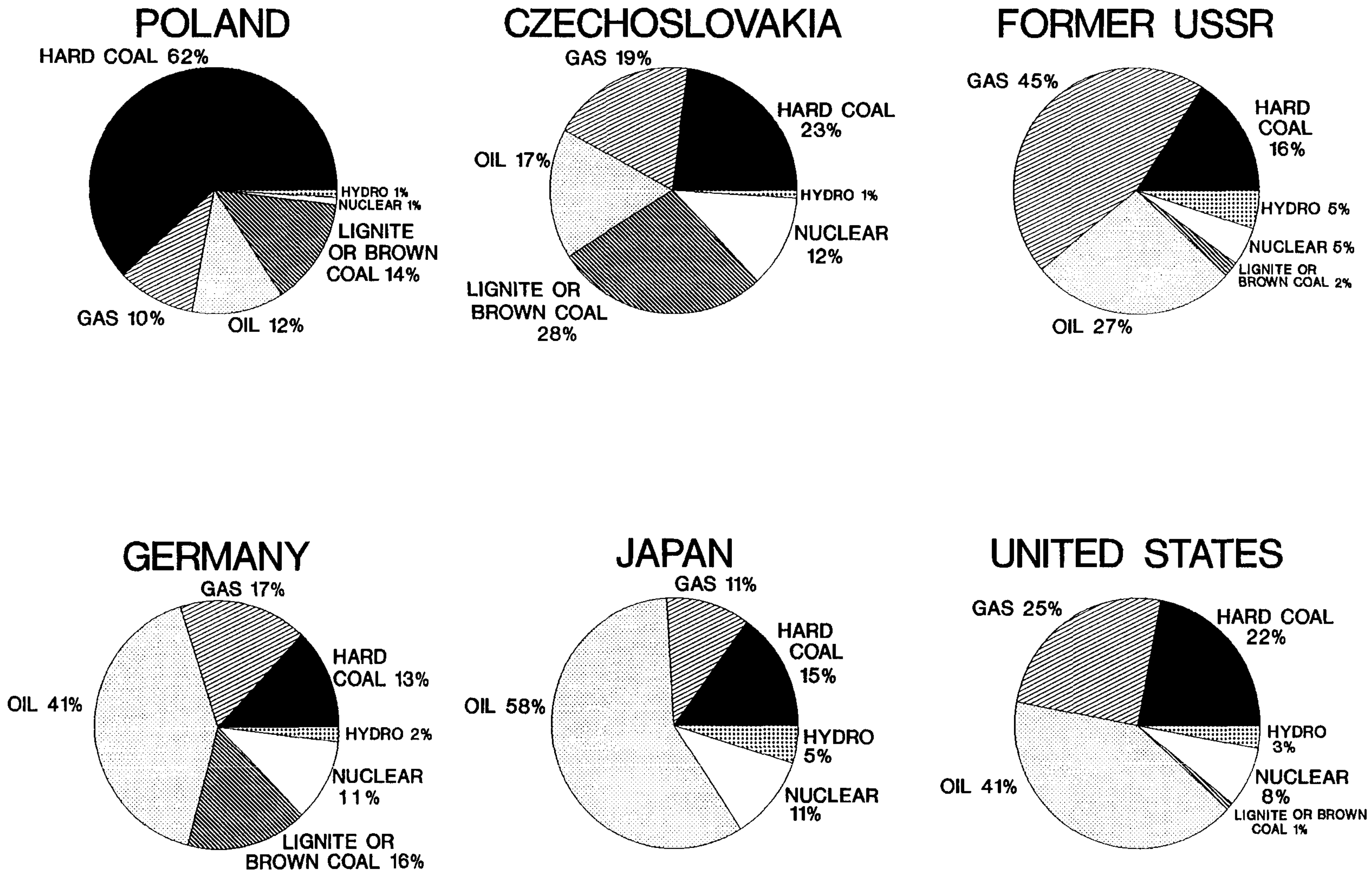
Within the CIS, the republics of Russia and Ukraine account for 56 and 24 percent of the total hard coal production (U.S. DOE EIA, 1992a), and 35 and 49 percent of the estimated methane emissions, respectively (Zabourdyaev, 1992). Because of inefficient energy use, declining resources of hard coal, and severe environmental problems resulting from extended mining and burning of coal, Russian and Ukrainian officials want to reduce their republics' dependency on low grade coal and utilize more natural gas. Increased use of natural gas would clearly help these republics meet their environmental goals because natural gas emits less sulfur dioxide, nitrous oxide, particulates and carbon dioxide than coal when it is burned.

---

[1]The CIS was founded on December 21, 1991, and the USSR ceased to exist on January 1, 1992 (U.S. DOE EIA, 1992b). The CIS includes Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan. It does not include Latvia, Lithuania, Estonia, and Georgia, which were part of the USSR.

[2] The International System of Units (SI) and its symbols (abbreviations) are used throughout this report.

FIGURE 1. FUEL MIX OF SELECTED COUNTRIES, 1992



Source: U.S. DOE EIA, 1994; UNECE, 1992

Methane contained in coal seams constitutes a new source of gas which has only in recent years been recognized as an important energy resource. The drainage and use of methane from minable coal seams could also increase mine safety and productivity, which is of particular importance because methane is explosive in low concentrations in air and has been responsible for many mining accidents in the CIS and throughout the world.

For all of these reasons, this report focuses on the potential for the republics of Russia and Ukraine to expand the recovery of methane from the coal seams of the Donetsk, L'vov-Volyn, and Kuznetsk coal basins. It examines the potential role of coalbed methane in the energy sectors of the Russian and Ukrainian economies, estimates the magnitude of the coalbed methane resource in these coal basins, outlines some promising project types, and identifies some necessary actions to encourage development of the resource.

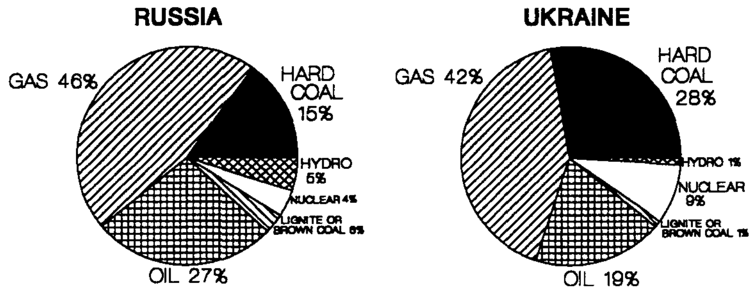
1.2 THE ENERGY SECTOR IN THE CIS

1.2.1 OVERVIEW

Energy Consumption and Production

Natural gas dominates the fuel mix of the CIS. It comprised 45 percent of the energy consumed in 1992 (Figure 1), followed by oil at 27 percent and coal at 18 percent. Hard coal accounted for 88 percent of the coal consumed in 1992, and lignite (including brown coal) 12 percent. It is interesting to note that the country included in Figure 1 whose fuel mix is most similar to that of the former USSR is the United States.

FIGURE 2: FUEL MIX OF RUSSIA AND UKRAINE, 1992



Source: U.S. DOE EIA, 1994; PlanEcon, 1993a

As shown in Figure 2, the fuel mix for the republics of Russia and Ukraine are quite similar to the overall fuel mix of the CIS, which is to be expected because these republics are the Commonwealth's largest economic units. In Russia, natural gas accounted for 46 percent of total energy consumption in 1992, with oil accounting for 27 percent (U.S. DOE EIA, 1994). Coal comprised only 18 percent of the fuel mix; hard coal accounted for about 83 percent of the total energy derived from coal, and the remainder was from lignite. Likewise, in Ukraine natural gas dominated the fuel mix in 1992, accounting for 42 percent of total energy consumption. Oil represented 19 percent, and coal accounted for 29 percent, with hard coal accounting for more than 98 percent of all energy derived from coal (PlanEcon, 1993a).

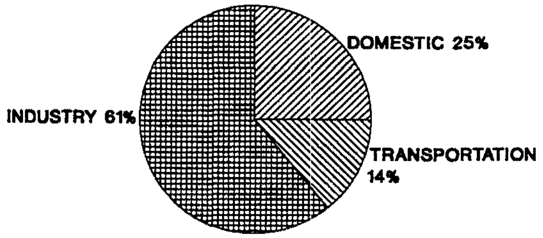
Although natural gas dominates the fuel mix of both Russia and Ukraine, the two republics differ greatly in natural gas production. Russia produced 640 billion cubic meters in 1992, more than 30 percent of which was exported to other republics and European countries. Ukraine, in contrast, produced only 21 billion cubic meters of natural gas in 1991, which satisfied less than 19 percent of its natural gas demand, and it was forced to import an additional 90 billion cubic meters of natural gas to meet its energy needs.

The CIS is currently the world's third largest coal producer, after the People's Republic of China and the United States. Coal production in the USSR peaked in 1988, with total production of almost 600 million tons. Since then, however, hard coal production has declined significantly, primarily as a result of labor disruptions, chronic equipment shortages, and difficult mining conditions. Lower coal production has resulted in coal shortages in many parts of the CIS, which have led to lower output in other industries (IMF, 1992).

Sectoral Energy Demand in the Former USSR

The USSR's final energy demand in 1990 was 40.1 exajoules[3] (EJ) (UNECE, 1991). Sectoral end-use is divided into three categories: industry (including manufacturing, mining, and construction), domestic (which includes households, agriculture, and commercial enterprises), and transportation (includes rail, road, water, and air)(Figure 3). In 1990, the industrial sector used 24.3 EJ and the domestic sector used 10.2 EJ, together accounting for 86 percent of the total energy consumed. The transportation sector accounted for the remaining 5.5 EJ, or 14 percent of energy consumed.

FIGURE 3. ENERGY DEMAND BY SECTOR IN THE USSR, 1990

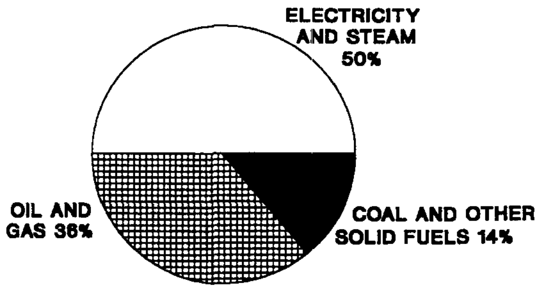


Source: UNECE, 1991

The large share of energy consumed by the industrial sector reflects the intense industrialization of certain regions of the CIS and the low energy efficiency of the industrial sector. This inefficiency in energy usage could be reduced through implementation of advanced technologies and transformation of the product structure of the economy. Improving industrial energy efficiency will require major capital expenditures, however, and will likely take several years (Bashmakov & Chupyatov, 1992).

In 1990, 50 percent of the energy used by the industrial sector was derived from electricity and steam, as shown in Figure 4. Direct consumption of oil and gas accounted for 36 percent of the energy used by the industrial sector, and solid fuel (nearly all of which was coal) generated the remaining 14 percent. According to a UNECE (1991) forecast, by 2010, 57 percent of the energy used by the industrial sector will be supplied by electricity and steam.

FIGURE 4. INDUSTRIAL SECTOR ENERGY SOURCES IN THE USSR, 1990



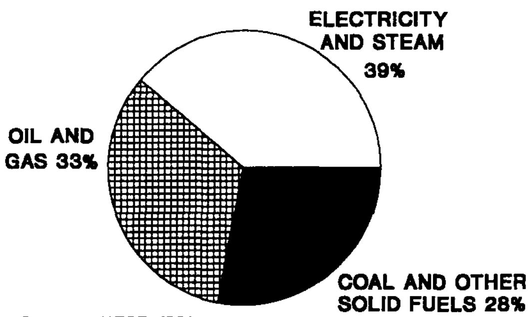
Source: UNECE, 1991

---

[3] 1 EJ = approximately 1 quadrillion (10^{15}) BTUs = 277.7 terawatts

As shown in Figure 5, in 1990, 39 percent of the domestic sector's energy came from electricity and steam, which was derived primarily from natural gas, but also coal, oil, and to a lesser extent, nuclear and hydroelectric sources. Direct consumption of oil and gas accounted for 33 percent of the domestic sector's energy use, and solid fuels (primarily coal) comprised the remaining 28 percent.

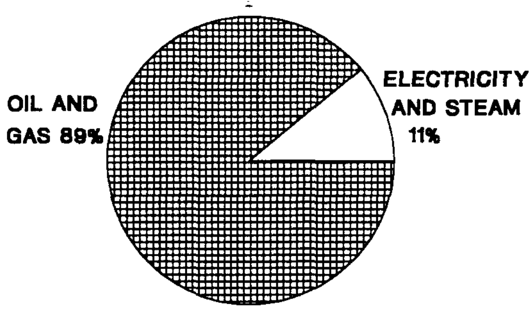
FIGURE 5. DOMESTIC SECTOR ENERGY SOURCES IN THE USSR, 1990



Source: UNECE, 1991

The transportation sector (Figure 6) is fueled primarily by oil (88 percent); natural gas contributes one percent to the fuel mix for a total oil and gas share of 89 percent. Electricity and steam account for 11 percent of the energy used by the transportation sector. These proportions are not expected to change substantially over the next twenty years (UNECE, 1991).

FIGURE 6. TRANSPORTATION SECTOR ENERGY SOURCES, 1990



Source: UNECE, 1991

1.2.2 PRIMARY ENERGY SOURCES OF THE CIS

Natural Gas: The Dominant Fuel

The CIS is the largest producer, transporter, consumer, and exporter of natural gas in the world, producing almost 40 percent more gas than the next largest producer, the United States. As shown in Table 1, the CIS produced more than 778 billion cubic meters of natural gas in 1992, which represented a decline of 4 percent from the previous year. This is relatively stable compared to the large decline in oil production. Natural gas production decreased between 1991 and 1992 in every republic except Kazakhstan (up 11 percent).[4]

Within the CIS, Russia is the dominant natural gas producer, and in 1992, it produced more than 640 billion cubic meters of natural gas, which was more than 80 percent of total production in the CIS. Over the last 20 years, the center of gas production has moved from the European part of Russia to western Siberia (IEA, 1991), and currently about two-thirds of total CIS production, and 90 percent of Russian production, comes from the Tyumen region of western Siberia. Accordingly, this region has witnessed explosive growth in production levels during the period 1980 through 1992 (nearly 300 percent), compared to modest growth in Uzbekistan, and declining production in Turkmenistan and Ukraine (Sagers, 1993).

Russia's gas industry is currently controlled by GAZPROM, a government-owned company that includes Russia, Ukraine, and Belarus as members. All other republics of the CIS, with the exception of Turkmenistan, have expressed interest in joining and forming a joint stock company, which would form a unified European gas distribution system extending from western Siberia to the Atlantic Ocean.

[4] See Appendix A for complete energy production figures.

TABLE 1. NATURAL GAS PRODUCTION AND CONSUMPTION IN THE CIS (IN BILLION CUBIC METERS)

YEAR	PRODUCTION				CONSUMPTION			
	RUSSIA	UKRAINE	OTHER	TOTAL CIS	RUSSIA	UKRAINE	OTHER	TOTAL CIS
1985	462.0	42.9	138.0	**642.9**	363.4	97.2	116.1	**576.7**
1986	503.0	39.7	143.4	**686.1**	391.8	101.6	115.7	**609.1**
1987	544.3	35.6	147.5	**727.4**	414.3	103.8	126.5	**644.6**
1988	589.8	32.4	147.8	**770.0**	437.2	110.0	135.9	**683.1**
1989	615.8	30.8	149.5	**796.1**	443.7	111.2	140.2	**695.1**
1990	640.6	28.1	146.1	**814.8**	460.7	115.3	131.0	**707.3**
1991	642.9	24.4	143.2	**810.5**	461.0	111.6	131.6	**709.1**
1992	640.4	20.9	117.1	**778.4**	454.4	111.3	116.8	**682.5**
Source: PlanEcon, Inc., 1992a, 1993b; U.S. DOE EIA, 1994								

As discussed in the previous section, natural gas is an extremely important fuel in the CIS. Gas consumption increased over 75 percent in the 1980's (U.S. DOE EIA, 1992b), and it provided about 45 percent of primary energy consumed in the CIS in 1992. However, natural gas consumption decreased by 4 percent between 1991 and 1992, due to plunging economic output and rising prices (especially outside of Russia).

The sale of natural gas currently accounts for about 40 percent of CIS hard currency earnings, with 99 billion cubic meters being exported in 1992 (PlanEcon, 1993b). Between 1991 and 1992, natural gas exports declined slightly (5 billion cubic meters), largely as a result of declining gas consumption in Eastern Europe and the tight gas market in Western Europe. Even at these lower levels, CIS exports still account for about 35 percent of world natural gas exports and represent approximately 25 percent of Europe's natural gas consumption. Russia is the CIS' largest gas exporter; in 1992, it exported more than 31 percent of total production to other CIS republics (the largest importer being Ukraine) and European countries. Russia's natural gas exports declined by 20 percent between 1992 and 1993, however, largely due to decreased consumption in Ukraine and other gas-producing republics.

The former Soviet Union built a sophisticated and complex system to provide natural gas to industrial and urban centers throughout its territory and for export. The extensive infrastructure currently includes:

- Approximately 9,000 producing wells in 200 gas and condensate fields;
- 300 small gas handling facilities to process gas at field sites;
- 6 large gas processing complexes, 4 of which are in Russia; and,
- over 220,000 km of pipeline in the gas supply system of the CIS (USEPA, 1993b).

However, a combination of rapid construction in harsh conditions, a shortfall of equipment supplies, and conflicting incentives and policy frameworks has challenged the ability of GAZPROM to maintain and improve the system over time. As a result, although natural gas production has so far remained relatively stable, there is some concern about potential production levels over the next few years. Preliminary information indicates that Russian gas production decreased about 3.6 percent between 1992 and 1993 (PlanEcon, 1993d).

Many energy specialists believe that increased use of natural gas will play an important role in pulling the energy economy out of its slump, particularly in Russia (Oil & Gas Journal, 1992c). Natural gas is significantly less expensive to produce, on an energy-equivalent basis, than coal because the coal mining industry in Russia and Ukraine is hindered by inefficient mining techniques, deep mines, and outdated or poorly maintained equipment (PlanEcon, 1992b). In addition, the CIS contains the largest natural gas reserves in the world, with an estimated 40 percent of the world's total reserves (U.S. DOE EIA, 1992b). Current reserve estimates are around 50 trillion cubic meters, with potential reserves estimated to be considerably higher. Between 80 and 90 percent of these reserves are located in Russia, with the largest fields located in the Tyumen Province of western Siberia. In addition, huge new reserves have also been discovered in the remote Arctic regions of the Yamal Peninsula and the Barents Sea.

There is great interest in increasing natural gas production in the CIS because of its importance within the energy economy and its significance as an export commodity. According to Russia's "State Energy Program for the Period up to the Year 2010", for example, the goals are to produce 860 billion cubic meters of natural gas in 1995 and 990-1000 billion cubic meters in 2010 (FBIS, 1992a). One gas utilization option targeted for expansion is power generation, and negotiations are underway with several foreign companies to develop advanced technology to generate electrical power with natural gas. In fact, much of the increase in power generation through the year 2010 is forecast to come from new gas-fired plants, which will require additional volumes of 52 to 60 billion cubic meters annually by the year 2000 just to meet their power and heating needs, and 110 to 120 billion cubic meters by 2010. In addition, GAZPROM officials believe that the demand for Russian gas in western Europe will increase as supplies from Netherlands and the North Sea shelf decline (Oil & Gas Journal, 1992c).

Achieving higher gas production levels will require massive investments in the development of new fields located in remote and difficult areas, such as the Yamal Peninsula, the Sea of Okhotsk and the Barents Sea. Costs to develop the gas resource in the Yamal Peninsula, for example, are estimated at $15 billion U.S. (Oil & Gas Journal, 1992c), and it is currently unclear whether these investments will be forthcoming over the time frame necessary to meet current targets. Pipelines and processing plants will also require upgrading and new pipelines will be necessary to link remote gas fields to consumers.

Oil

The CIS has a long history of oil production, and it has been the largest oil producing country in the world since 1974, when it surpassed the United States. Oil production peaked in 1987-1988 at 624 million tons (Table 2) and has decreased every year since. In 1992, oil production was only 450 million tons (or 72 percent) of peak production. Even at this level, however, the CIS still accounts for about 17 percent of the world's oil production (Oil & Gas Journal, 1992a).

TABLE 2. CRUDE OIL PRODUCTION AND CONSUMPTION IN THE CIS (IN MILLION TONS)

YEAR	PRODUCTION				APPARENT CONSUMPTION			
	RUSSIA	UKRAINE	OTHER	**TOTAL CIS**	RUSSIA	UKRAINE	OTHER	**TOTAL CIS**
1985	542.3	5.8	47.2	**583.0**	327.0	59.9	103.7	**490.6**
1986	561.2	5.7	47.9	**614.8**	330.5	60.3	109.0	**499.8**
1987	569.5	5.6	49.2	**624.3**	329.8	31.3	140.5	**501.6**
1988	568.8	5.4	50.1	**624.3**	329.8	61.1	109.1	**500.0**
1989	552.2	5.4	49.7	**607.3**	323.2	62.0	108.1	**493.3**
1990	516.2	5.3	49.3	**570.8**	312.5	51.0	106.9	**470.4**
1991	461.1	4.9	49.2	**515.2**	308.1	54.6	98.0	**454.7**
1992	395.8	4.4	49.6	**449.8**	258.2	N/A	N/A	**366.2**
Source: PlanEcon, Inc., 1992a, 1993b, 1993d								

As with natural gas, Russia is the largest oil producer in the CIS, accounting for about 90 percent of total production in recent years. As Table 2 indicates, Russia's oil production fell from a peak of 570 million tons in 1987 to only 396 million tons in 1992. Based on preliminary data, it appears that production for 1993 will not exceed 341 million tons (PlanEcon, 1993d).

Many factors have contributed to the rapidly declining oil production in the CIS, including:

- Lack of investment capital: The most serious obstacle confronted by the CIS oil industry has been the shortage of funds for investments and inputs in recent years (IMF, 1992). The growth rate of investment in the oil sector declined drastically after 1987, with the actual amount of capital expenditure in 1991 at only 50 percent of the planned level. The results of this lack of investment have been a major decline in both new production and maintenance. According to the Russian Ministry of Economics, for example, 62 million meters of boreholes should have been drilled in 1992, but only one-quarter of that level was achieved (FBIS, 1993). Moreover, only 14 percent of existing equipment and machinery is reported to meet world standards.

- Overemphasis on short-term production targets: In many oil fields, production has been emphasized with little regard to the overall efficiency of resource development. U.S. experts have noted an inordinate use of reservoir damaging techniques that maximize short-term production at the expense of overall productive potential (U.S. DOE EIA, 1992a).

- Shortages of necessary equipment: The CIS oil industry also suffers from an inability to distribute necessary supplies among the newly independent republics. The domestic production of oil field equipment is very concentrated. Historically, more than 60 percent of all petroleum industry equipment has been manufactured in Azerbaijan, in factories which are now obsolete, while tubular goods have been manufactured in Ukraine. These republics are now demanding hard currency for the equipment (Oil & Gas Journal, 1992d), a practice which is further complicated by the fact that the prices of oil field equipment have been freed while the price of oil remains controlled (IMF,1992). As a result of these changes, in recent years only 60 to 70 percent of planned supplies from domestic (inter-republic) sources have been delivered to the oil fields, and many wells have been shut-in due to equipment shortages.

As a result of these problems, the International Monetary Fund (IMF, 1992) estimates that at the end of 1991, 25-30 million tons of oil production was lost due to shut-in wells. In addition, it conservatively estimates that approximately 40,000 of a total 160,000 wells were not producing. Furthermore, in the past two years, no new oil fields have become operational.

It is unlikely that the decline in Soviet oil output can be reversed without a massive infusion of financial and technological resources into the oil and oil service industries. Given the lack of domestic capital for investment, the CIS is seeking assistance from various Western and other countries. The degree to which such assistance will be forthcoming and the rate at which it will lead to increased production is highly uncertain, however. The form it will take is also uncertain.

Oil consumption in the CIS has fallen and will continue to decline over the next few years, mainly as a result of low or negative economic growth and the transition from subsidized to market-determined prices. Demand could begin increasing again after 1995, however, largely as a result of increased consumption in the transportation sector.

Hard Coal

All coal production, transportation, and distribution in the former Soviet Union was owned and operated by the central government, with local central administrative units having responsibility for the day-to-day management of the mines. Following the break-up of the USSR, however, management of the coal sector has changed significantly.

Russia, for example, took control of its coal sector in 1992 and divided responsibilities between the new Ministry of Fuel and Power and the quasi-private Russian Coal Corporation. The Fuel and Power Ministry is responsible for drafting energy legislation, setting taxes and subsidies, and--together with other government agencies--issuing export licenses. The Russian Coal Corporation includes a majority of Russia's coal mines, equipment factories, and research institutes and its chief responsibility is to help the coal production associations convert their operations to a market economy (FBIS, 1992b). In Ukraine, much of the control of the coal sector is now in the hands of the State Committee for Coal, which reports to the Cabinet of Ministers.

Coal accounted for 18 percent of the CIS total primary energy requirements in 1992, down from 50 percent in 1960. It is likely that coal's share of total energy consumption will decrease a little more in the future, to be replaced largely by natural gas (U.S. DOE EIA, 1992b).

Hard coal production in the CIS is split between the European part of the country in the west (Ukraine), with its underground bituminous coal mines, and the Asian part in the east (Siberia), where output is divided between underground bituminous coal and low rank surface-mined coal. As shown in Appendix A, in 1991 the republics of Russia, Ukraine, and Kazakhstan accounted for 99.5 percent of total hard coal production in the CIS.

In 1992, Russia produced 216 million tons and Ukraine produced 127 million tons of hard coal, down 3 percent and 1 percent, respectively, from 1991 (Table 3). Russia has traditionally exported 20 to 30 million tons of coal per year outside the CIS, including 8 to 10 million tons per year to Japan, its single biggest customer. The majority of remaining exports have gone to Eastern European countries. The CIS also imports a small amount of coal, mostly from Poland.

TABLE 3. HARD COAL PRODUCTION AND CONSUMPTION IN THE CIS (IN MILLION TONS)

YEAR	PRODUCTION				APPARENT CONSUMPTION			
	RUSSIA	UKRAINE	OTHER	**TOTAL CIS**	RUSSIA	UKRAINE	OTHER	**TOTAL CIS**
1985	254.8	180.5	134.0	**569.3**	266.8	177.6	106.9	**551.3**
1986	263.0	184.0	140.4	**587.4**	272.9	179.7	113.1	**565.7**
1987	267.5	182.7	144.7	**594.9**	275.3	177.1	116.6	**569.0**
1988	273.5	182.0	144.0	**599.5**	279.2	175.0	117.8	**572.0**
1989	268.3	170.2	138.3	**576.8**	271.3	166.1	111.8	**549.2**
1990	257.4	155.6	130.0	**543.0**	257.6	154.5	104.1	**516.2**
1991	222.8	128.8	128.7	**484.5**	231.1	125.4	98.0	**444.3**
1992	215.8	127.3	124.5	**467.6**	227.1	130.4	93.2	**450.7**

Source: PlanEcon, Inc., 1992a, 1993b, 1993d; Skochinsky 1993; Sagers 1993
1991 hard coal production total does not equal sum of parts due to differing data sources.

The sharp decline in coal production has occurred for several reasons, including labor unrest, chronic equipment shortages, and increasingly difficult mining conditions:

- Labor unrest. One of the main factors limiting coal production in recent years have been labor problems at the coal mines. Strikes dramatically reduced coal production during the summer of 1990 and again in March and April 1991, for example, and the resulting agreements between labor and coal production associations have contributed to further reductions in coal production by requiring more extensive reporting of safety and health problems and shorter working hours for the miners. A strike in the Donetsk Basin in June 1993 idled about 200 mines and spread to other industries and regions (PlanEcon, 1993a). More recently, in Russia, back wages and benefits for miners and unpaid subsidies for the mining industry were the reasons given for a strike staged in September 1993 (Eastern European Energy Report, 1993).

- Equipment shortages. In addition, during 1991, coal mines continued to confront serious disruptions in equipment supply. Essential equipment such as rolled metal, pit props and long pit timbers, mechanized complexes, ventilation pipe, shaft drainage pumps, trucks and other equipment were not adequately supplied that year, for example, according to Moscow UGOL (1992). Russia's shortage of coal mining equipment was highlighted by its recent decision to allocate a portion of an IMF ($600 million USD) loan to import critical equipment and spare parts for the coal sector. Currently, about one-third of the equipment used by Russian coal enterprises is in need of replacement while only 10 to 15 percent is at a technical level comparable to world standards (FBIS, 1992b).

- Difficult mining conditions. Mining conditions in both the western and eastern regions of the CIS are harsh. In the west, coal lies at great depths, sometimes in excess of 1,000 meters underground. Increasing mine depth, deteriorating equipment, and poor safety practices have given the CIS coal sector a fatality rate almost 10 times that of the United States. The average depth of coal mines in the CIS increased from 457 meters in 1980 to 520 meters in 1990, and many mines are over 1000 meters deep, increasing the risk of high methane emissions. In Siberia, moreover, conditions at surface mines are difficult due to severe winters, which require special equipment.

The future of CIS coal production is uncertain for several reasons. First, production and transportation costs are very high, especially as compared with natural gas. Other problems facing the coal industry include the environmental problems associated with coal use and difficulties involved in transporting and using coal relative to natural gas. Furthermore, coal production is heavily subsidized. In Russia, for example, government subsidies to the industry shot up to a reported 1.3 trillion rubles per year in 1992, representing 6 percent of the total Russian Federal budget (PlanEcon, 1993b). Because of this huge drain on the budget, a presidential decree was signed that liberalized the prices of coal and coal products effective July 1, 1993. At the same time, a government resolution was passed that calls for a program of closing the most unprofitable mines. Russia's Minister of Fuels and Electric Power announced plans to close 40 mines in 1993, which account for about half of all state subsidies going to the coal industry. Russian coal miners protested these measures, and as a result the government promised to continue to pay subsidies for the mining sector, use oil (rather than coal) export quotas to pay for mine modernization, and delay mine closures until 2000 (PlanEcon, 1993d). Their closure will leave 9.1 million tons of coal in the ground and will put roughly 47,000 miners out of work.

Ukraine also faces an uncertain future in terms of coal production. Despite an announcement by the Cabinet of Ministers and Ukraine Gosugleprom (FBIS, 1992c) that coal production in Ukraine is expected to increase in the future, output in the first three quarters of 1993 was down 12 percent from the same period in 1992 (PlanEcon, 1993d). Production costs are very high in Ukraine's underground mines, and future prospects are not promising given the difficult mining conditions. With the combination of low state-set prices for coal and high production costs, the mines have required a large budget subsidy for their operations for some time. As the gap between prices and production costs has widened, the government has been spending increasing amounts of money to offset rising costs, worsening Ukraine's enormous budget deficit (Sagers, 1993).

Brown Coal and Lignite

Eighty-eight percent of the brown coal and lignite produced in the CIS is mined in Russia (Table 4). Historically, trade of brown coal and lignite within the republics has been negligible. In 1992, production of brown coal and lignite in the CIS amounted to 137.3 million tons, declining 20 percent from its 1988 peak of 172.4 million tons. Because almost all of this resource is mined from open pits, the labor strife which has affected hard coal production has had little effect. However, increased emphasis is being placed on the environmental consequences of burning low-quality coal, which is resulting in less demand for this low quality resource (PlanEcon,1992a).

TABLE 4. BROWN COAL AND LIGNITE PRODUCTION & CONSUMPTION IN THE CIS (IN MILLION TONS)

YEAR	PRODUCTION				APPARENT CONSUMPTION			
	RUSSIA	UKRAINE	OTHER	**TOTAL CIS**	RUSSIA	UKRAINE	OTHER	**TOTAL CIS**
1985	140.4	8.5	8.2	**157.1**	140.4	6.8	8.2	**155.4**
1986	144.9	9.1	9.5	**163.5**	144.9	7.0	9.5	**161.4**
1987	147.2	9.2	7.6	**164.0**	147.2	6.8	8.5	**162.5**
1988	152.0	9.7	10.7	**172.4**	152.0	6.0	10.7	**168.7**
1989	141.5	10.0	12.0	**163.5**	141.5	7.9	12.0	**161.4**
1990	137.3	10.3	12.4	**160.0**	137.3	7.0	12.4	**156.7**
1991	130.5	9.3	11.8	**151.6**	130.5	9.0	11.8	**151.3**
1992	121.4	6.7	10.1	**137.3**	117.5	6.4	9.0	**132.9**
Source: PlanEcon, Inc., 1992a, 1993b, 1993d ; Sagers, 1993								

1.2.3 THE NATIONAL ENERGY STRATEGY

The republics of the former USSR collectively are the world's largest energy producers and rank second in total energy consumption behind the United States. In addition, energy exports are the principal source of foreign exchange earnings. As the previous sections have indicated, however, the CIS energy sector confronts serious challenges. In recent years, the production of key energy resources has at best been stagnant and for some resources (such as coal and oil) has actually decreased substantially. Oil exports, which have been the country's major source of hard currency, have dropped 35 percent from 1988 to 1991 (PlanEcon, Inc, 1992a), and coal production, which was once the highest in the world, has fallen behind the United States and China.

The principal problems confronted by the CIS energy sector are similar to those of other countries making the transition from planned to market economies, and they include:

- Over-emphasis on short-term production targets. Traditionally, exploitation of fuel reserves has emphasized rapid short-term expansion of production at the expense of longer term recovery prospects. One result of this has been the eastward movement of exploitation to new, more remote and costlier reserves, to maintain production output. As a result, existing refineries, processing facilities, equipment suppliers, and power generating plants are inconveniently located, increasing both transportation and production costs for coal, petroleum, natural gas, and electricity.

- Lack of flexibility. Overall, the energy sector lacks the flexibility to respond to changing market conditions. Energy investment is centrally allocated and does not sufficiently consider variable conditions for different regions or individual enterprises. From a technical perspective, moreover, the storage capacity for oil and gas is inadequate to handle changes in demand, refinery shutdowns, or pipeline bottlenecks. Electricity generating capacity is strained while there are many delays in new construction. The existing pipeline capacity is capable of handling the equivalent of the peak levels of the late 1980's, but the refinery capacity is down and cannot match the load.

- Subsidized energy prices. The practice of setting consumer energy prices below production costs has led to the extremely inefficient use of energy. Russia illustrates the high energy intensity of the CIS republics, using 70 to 100 percent more energy per unit GNP than the United States and 250 to 300 percent more energy per unit GNP than western Europe (Bashmakov et al, 1990). In addition, all stages of development in the mineral fuel sectors--from exploration through processing and consumption--could be improved and made more efficient through the introduction of state-of-the-art technologies, equipment and services, as well as the recycling of waste (Mining Annual Review, 1991).

- Equipment problems. As described in previous sections, many energy production industries must contend with outdated technology, obsolete equipment, and poor maintenance.

Clearly, substantial reforms will be necessary to improve and modernize the energy sector, and a complete transformation will likely take several years. The current governments of the republics have been emphasizing the changes needed in the energy sector in their reform plans. In addition to increased energy efficiency, their goals include: emphasis on simultaneous achievement of energy and environmental goals; enhanced nuclear safety which would include incorporating international regulatory standards; expansion of facilities for clean, conventional thermal electricity generation; development and utilization of clean synthetic fuels; and development of new and renewable resources (UNECE, 1991a).

The likely methods for achieving these goals will include: price liberalization (raising prices to current world level) which would affect production, consumption, and government revenues; restructuring the tax system to encourage investment; appointing appropriate personnel to oversee the energy industry restructuring; initiating the privatization process in all areas of the energy sectors; reducing military spending; and transforming military factories to serve other productive functions (Oil & Gas Journal, 1992b; Eastern European Energy Report, 1992). Increased investment in advanced technology and equipment will also be essential to long-term success (IMF et al, 1990).

1.2.4 THE ROLE OF COALBED METHANE

Given the current condition of the energy sectors in Russia and Ukraine, and potentially other republics of the CIS, there are likely to be many opportunities for coalbed methane to contribute to energy needs. As mentioned previously, the CIS is a major emitter of methane from coal mining, and its coal mines are some of the gassiest in the world.

Of course, it will not be cost-effective to completely eliminate methane emissions to the atmosphere from coal mining. As long as coal is to be mined safely, methane will continue to be liberated to the atmosphere in ventilation air in relatively large quantities. However, methane emissions from coal mining can be significantly reduced through the expanded use of existing mine degasification techniques in conjunction with programs dedicated to expanding methane utilization.

Unutilized, coalbed methane is an environmental liability because it is a potent greenhouse gas. Utilized, it is a remarkably clean burning fuel. The burning of methane emits virtually no sulfur or ash, and only about 32 percent of the nitrogen oxides, 45 percent of the carbon dioxide, and 43 percent of the volatile compounds emitted by coal burning (Oil & Gas Journal, 1991; U.S. EPA, 1986).

In addition, the recovery of methane will make other significant contributions to the CIS energy sector, including:

- Improved mine safety and profitability. As mentioned previously, one of the reasons for declining coal production in Russia and Ukraine has been the increasing difficultly of mining, particularly related to increasing mine depths. One of the principal challenges associated with mining coal at greater depths can be higher methane concentrations, which create a safety hazard and can greatly increase mining costs by requiring major investments in ventilation and degasification systems. Expanded coalbed methane drainage in gassy coal mines can frequently improve mine economics by reducing ventilation requirements and enabling the more rapid extraction of coal.[5] In addition, the sale of this recovered methane can create another source of income for coal mines, and one which can make a substantial contribution to mine viability. Coalbed methane drainage also reduces the potential for methane explosions and sudden outbursts of coal and gas, improving safety conditions for miners. Improved safety conditions would help reduce labor unrest over this issue, potentially contributing further to improved economics.

- Improved local environmental quality. In the future, the republics of the CIS intend to rely less on low-grade hard coal and to address some the many environmental problems created by the extensive and inefficient use of coal. As mentioned previously, coalbed methane is a clean-burning fuel and can significantly contribute to improved local air quality where it is used to displace the burning of poor quality coal.

- An additional natural gas resource. The republics of Ukraine and Russia are both interested in increasing natural gas use. In Ukraine, where the consumption of natural gas is far greater than domestic production (Table 1), a comprehensive program of mine methane drainage and utilization, combined with coalbed methane development in areas lying beyond the mines, could supply enough energy to substantially reduce natural gas imports. Coalbed methane can play an important role in the coal basins of Russia as well, where low-quality coal is currently being used for many purposes.

Opportunities exist for increased recovery and utilization of methane in close conjunction with coal mining in Russia and Ukraine[6], as well as development of the coalbed methane resource independent of mining. The technologies for producing coalbed methane, whether it is recovered in conjunction with coal mines or produced independently, are currently well developed, although they remain to be demonstrated in the CIS.

The following chapters of this report will describe the coalbed methane potential in selected coal basins of Russia and Ukraine and outline potential opportunities to expand the recovery and use of this energy resource. Suggested components of a program to encourage expanded methane recovery and utilization from coal mines in the CIS will also be described.

---

[5] Further study using more detailed data on mine economics and the energy economy of the CIS would be necessary to quantify the economic benefits of increased methane recovery to mines.

[6] As stated in Section 1.2.2, coal production is declining in the CIS. However, the recoverability of coalbed methane should not be adversely affected by decreasing coal production, because in most cases methane continues to flow into abandoned mine workings for several years after a mine is closed.

CHAPTER 2

COALBED METHANE RESOURCES OF RUSSIA AND UKRAINE

2.1 INTRODUCTION

Coalbed methane liberated during mining poses a serious threat to mine safety unless it is diluted to non-explosive concentrations. Methane is explosive in concentrations of 5 to 15 percent in air, and in most mines, the concentrations are maintained below one percent to ensure safety. Methane concentrations may be reduced to safe levels by circulation of large volumes of air through the mine workings, diluting and evacuating the methane from the mine. During mining in very gassy seams, however, ventilation alone may be insufficient to maintain safe mining conditions. Additional methane drainage techniques, including inseam drilling, have been developed for these purposes. These technologies produce methane in higher concentrations before, during, and after mining and prevent it from being emitted into the mine workings. Many of the coal seams that are mined in Russia and Ukraine have high methane contents, and methane drainage and ventilation have been used for many years to ensure safety.

Coalbed methane can also be a significant gas resource that may be beneficial to develop in its own right. While various countries have long used this resource on a small scale, primarily for on-site needs at mines, it has been only within the past decade that coalbed methane has gained widespread recognition as a viable alternative to conventional fuels. Mining industry and government officials in Russia and Ukraine have stated their desire to recover and utilize more coalbed methane, but funding and technology transfer are needed in order for these countries to implement new coalbed methane resource development projects.

The following sections of this chapter describe the available data on coal resources of Russia and Ukraine, specifically for three coal basins within these republics: the Donetsk Coal Basin, the L'vov-Volyn Coal Basin, and the Kuznetsk Coal Basin. The chapter also provides estimates of associated coalbed methane resources. Most of the data on which these discussions are based were provided by the Skochinsky Mining Institute in Lyubertsy, Russia, and by mining enterprises and research institutes that have collected data for purposes of producing coal and maintaining mine safety. These estimates should be considered preliminary, but mining experience in Russia and Ukraine and available data indicate that the coalbed methane resource is large. It is clear that more detailed data collection activities are warranted to better assess the resource and identify the most promising production locations.

2.2 COAL RESOURCES

There are four coal basins in Russia and Ukraine where hard coal is mined and which have the potential for coalbed methane development (Figure 7). They are:

- The Donetsk Basin (Donbass): located in southeastern Ukraine and western Russia;
- The Kuznetsk Basin (Kuzbass) located in western Siberia;
- The L'vov-Volyn Basin: located in western Ukraine, is the southeastern extension of the Lublin Basin in Poland;
- The Pechora Basin: located in northern Russia, almost entirely above the Arctic Circle.

This report will focus on the Donetsk, Kuznetsk, and L'vov-Volyn basins (the Pechora basin has not yet been evaluated).

A stratigraphic correlation chart of coal bearing formations in three basins studied is shown in Figure 8. The L'vov-Volyn and Donetsk Coal Basins produce only from Carboniferous formations, while the Kuznetsk Basin produces coal from both Permian and Carboniferous strata. More detailed stratigraphic columns for each basin are shown in the following sections.

Of the three basins, the Donetsk and Kuznetsk appear to have the largest near-term potential for coalbed methane development. Both of these regions are heavily industrialized and would have many opportunities for coalbed methane utilization. The L'vov-Volyn region is predominantly agricultural, and it is likely that coalbed methane use would primarily be limited to the mines. Characteristics of each basin are summarized in Table 5 and a more detailed description of each basin is provided below.

The coal producing portion of each basin has been divided into coal production associations that are located within, or comprise one or more of, geological-commercial regions.[7] Each coal production association contains one or more mines, and they are analogous to trade co-operatives in many respects. The primary responsibilities of the coal production associations are:

- general mine management, including procurement for the mines
- achieving production targets
- to address problems common to their mines, such as health and safety conditions, as well as age and condition of the mining equipment;
- negotiations with the labor force and with government agencies, and;
- implementation of safety and environmental regulations.

In the following sections, data concerning coal production and methane emissions from the Kuznetsk and Donetsk basins are presented for each coal production association. Since the L'vov-Volyn Basin has only one coal production association, data concerning this basin are presented for each mine.

---

[7] Geological-commercial regions comprise coal resources of similar rank and quality, and are bounded by geological features such as folds, faults, or other geological disturbances.

FIGURE 7. MAJOR COAL BASINS OF THE FORMER SOVIET UNION

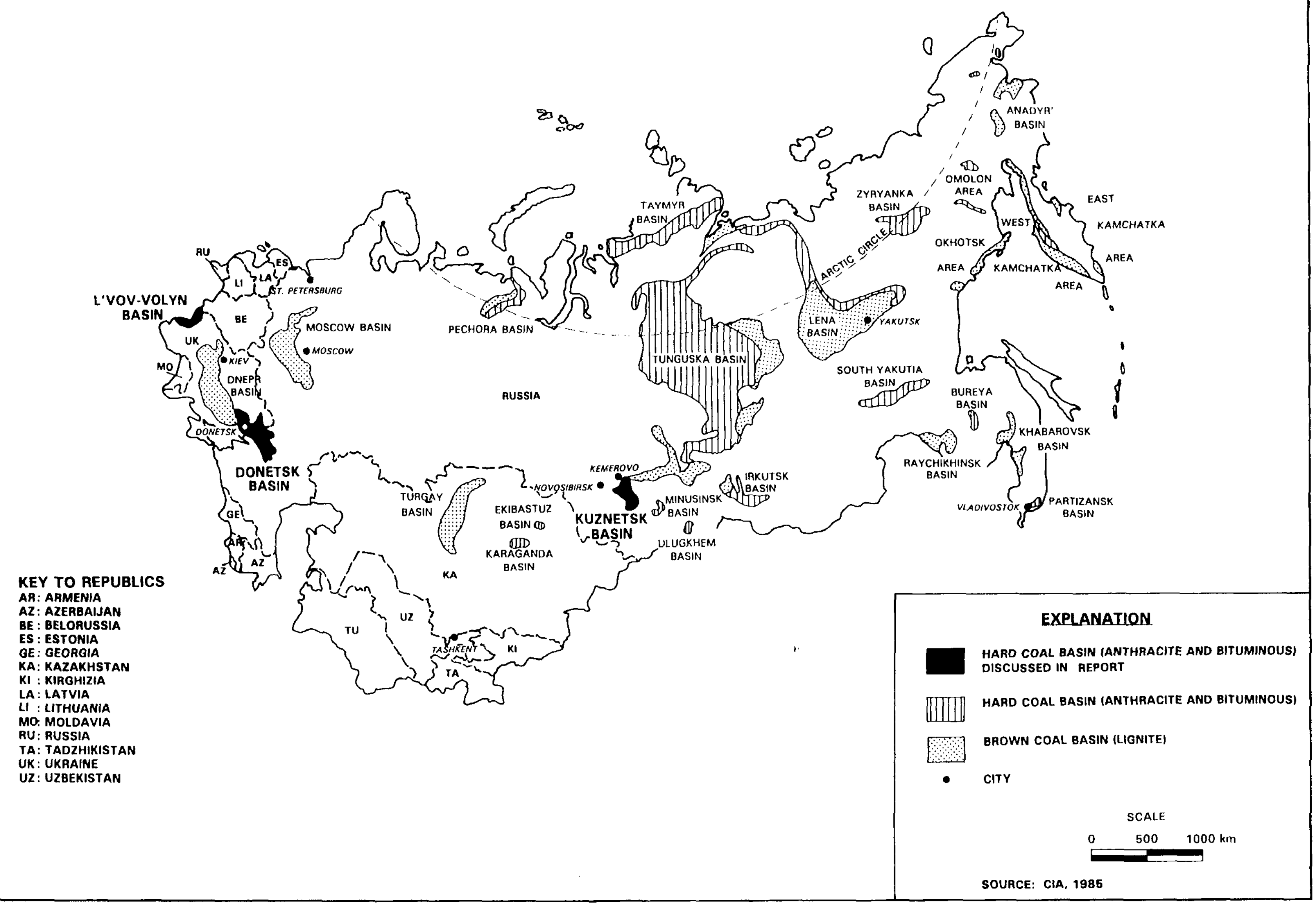


FIGURE 8. STRATIGRAPHIC CORRELATION OF COAL BEARING FORMATIONS IN THE L'VOV-VOLYN, DONETSK, AND KUZNETSK COAL BASINS, COMMONWEALTH OF INDEPENDENT STATES

SYSTEM	SERIES	L'VOV-VOLYN COAL BASIN STAGE	L'VOV-VOLYN COAL BASIN FORMATION	DONETSK COAL BASIN STAGE	DONETSK COAL BASIN FORMATION	KUZNETSK COAL BASIN STAGE	KUZNETSK COAL BASIN FORMATION
JURASSIC		HIATUS	HIATUS			*TARBAGONSK*	
TRIASSIC	LOWER	HIATUS	HIATUS			*MALTSEVSK* *(NO COALS)*	UPPER MALTSEVSK LOWER MALTSEVSK
PERMIAN	UPPER	HIATUS	HIATUS			*KOLCHUGINSK* *UPPER*	TAYLUGANSK GRAMOTEINSK LENINSK
PERMIAN	UPPER	HIATUS	HIATUS			*KOLCHUGINSK* *LOWER*	USKATSK KAZANKOVO-MARKINSK (NO COALS) KUZNETSK (NO COALS)
PERMIAN	LOWER	HIATUS	HIATUS			*UPPER* *BALAKHONSK*	USYATSK KEMEROVSK ISHANOVSK PROMEZHUTOCHNY
CARBONIFEROUS	UPPER	HIATUS	HIATUS	*KASIMOVSK* *(NO COALS)*	AVILOVSK	*LOWER* *BALAKHONSK*	ALYKAEVSK
CARBONIFEROUS	MIDDLE	HIATUS	HIATUS	*MOSKOVSK*	ISAEVSK GORLOVSK ALMAZ KAMENSK	*LOWER* *BALAKHONSK*	MAZUROVSK
CARBONIFEROUS	MIDDLE	*BASHKIRSK*	KRECHEVSK PAROMOVSK MOROZOVICHSK	*BASHKIRSK*	BELOKALITVENSK SMOLININOVSK MOSPINSK MANDRYKINSK	*LOWER* *BALAKHONSK*	MAZUROVSK
CARBONIFEROUS	LOWER	*SERPUKHOVSK*	BUZHANSK LISHNYANSK IVANICHSK PORITSK	*SERPUKHOVSK*	SAMARSK	?	OSTROGOSK (NO COALS)
CARBONIFEROUS	LOWER	*VIZEISK* *(NO COALS)*	USTILUGSK VLADIMIRSK NESTEROVSK VINNIKOVSK OLESKOVSK	*VIZEISK*	PODUGLENOSNY		
CARBONIFEROUS	LOWER	*TURNEISK*					

SOURCE: NALIVKIN, 1973, STRUEV ET AL, 1984, SKOCHINSKY INSTITUTE, 1992, AND BIKADOROV, ET AL, 1980

TABLE 5. SUMMARY OF SELECTED COAL BASIN CHARACTERISTICS (1991 DATA EXCEPT WHERE OTHERWISE NOTED)

CHARACTERISTIC	DONETSK COAL BASIN	L'VOV-VOLYN COAL BASIN	KUZ-NETSK COAL BASIN	TOTAL
GENERAL CHARACTERISTICS				
Basin Area (thousand square kilometers)	60	3.2	26.7	89.9
Total Documented Coal Reserves (Billion Tons)*	140.8	2.1	637.0	779.9
Coal Production, (Million Tons)	150.4	9.5	58.9	218.8
Average Methane Content (m^3/T)	14.7	6.9	11.9	
MINE DATA				
Number of Mines	308	17	71	396
Number of Mines That Emit Methane	211*	13	71	295
Number of Mines That Drain Methane	100	4	32	136
Number of Mines That Utilize Methane	17	0	0	17
METHANE LIBERATION DATA				
Total Methane Liberated (Mm^3)	3,390.4	153.0	942.3	4,485.7
Methane Liberated From Mines With Drainage Systems (Mm^3)	2,452.4	63.8	992.6	3,508.8
Methane Captured by Drainage Systems (Mm^3)	538.9	6.3	243.5	788.7
Methane Utilized (Mm^3)	170.2	0	0	170.2
Specific Emissions (m^3 methane/ton of coal mined)	22.5	12.8	21.0	

Sources: Zabourdyaev, 1992
Kozlovsky, 1986 & 1987
Skochinsky Mining Institute, 1993

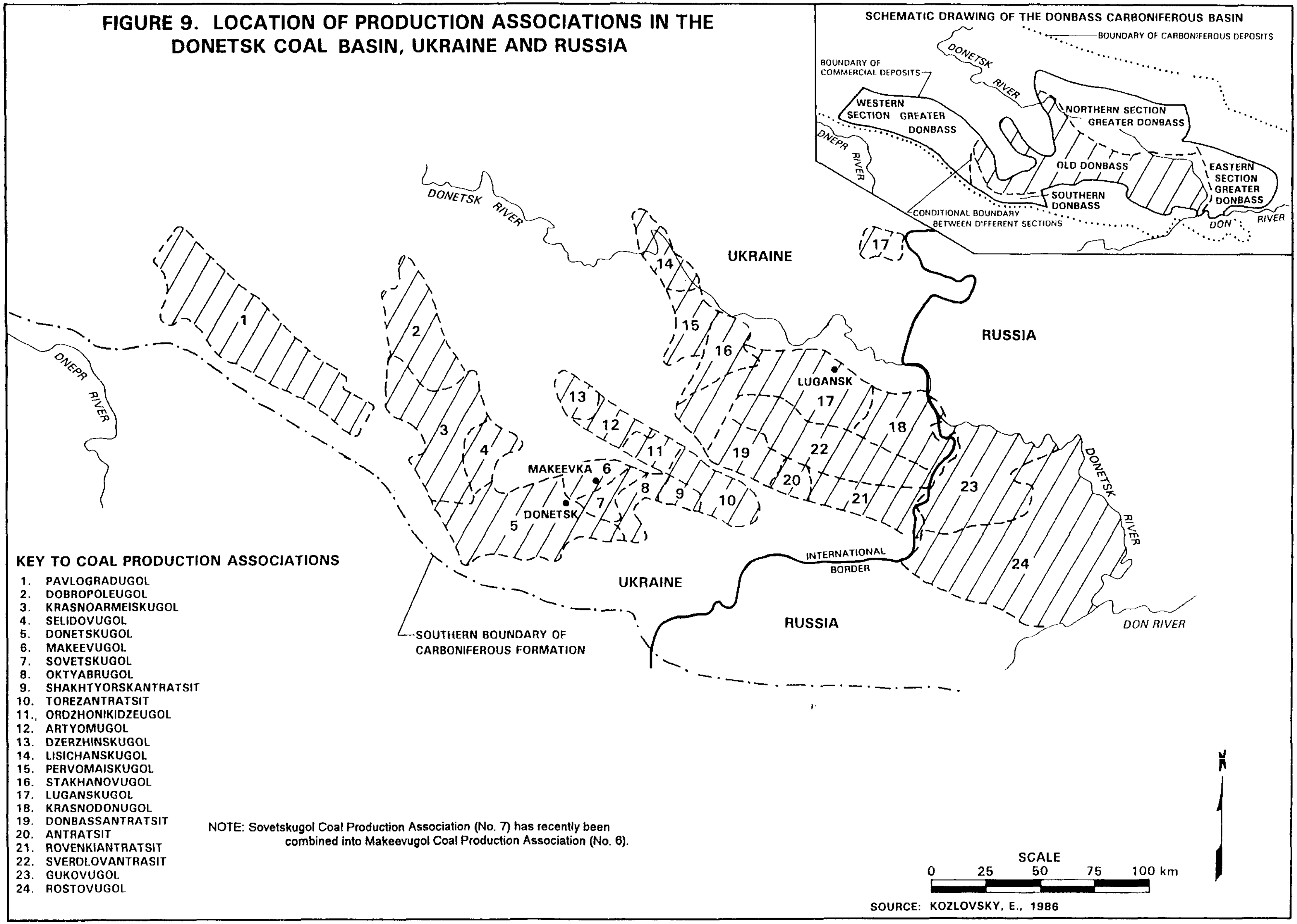
*1990 Data

2.2.1 THE DONETSK COAL BASIN

Introduction

As shown in Figure 9, the northwestern portion of the Donetsk Coal Basin is in Ukraine, while the southeastern portion is in Russia. Coal mining began in the basin in 1723, and as of 1991 there were 24 coal production associations operating 308 underground mines (Skochinsky, 1993). The Carboniferous deposits contain over three hundred seams, of which one hundred seams are considered workable. Seams vary in thickness from 0.45 to 2.5 meters, averaging 0.9 meters, and dip from horizontal to greater than 35°. Coal mines in the Donetsk are extremely deep. Over 40 percent of the mines have workings deeper than 700 meters, and one-third have workings deeper than 1000 meters (FBIS, 1992d).

FIGURE 9. LOCATION OF PRODUCTION ASSOCIATIONS IN THE DONETSK COAL BASIN, UKRAINE AND RUSSIA



KEY TO COAL PRODUCTION ASSOCIATIONS

1. PAVLOGRADUGOL
2. DOBROPOLEUGOL
3. KRASNOARMEISKUGOL
4. SELIDOVUGOL
5. DONETSKUGOL
6. MAKEEVUGOL
7. SOVETSKUGOL
8. OKTYABRUGOL
9. SHAKHTYORSKANTRATSIT
10. TOREZANTRATSIT
11., ORDZHONIKIDZEUGOL
12. ARTYOMUGOL
13. DZERZHINSKUGOL
14. LISICHANSKUGOL
15. PERVOMAISKUGOL
16. STAKHANOVUGOL
17. LUGANSKUGOL
18. KRASNODONUGOL
19. DONBASSANTRATSIT
20. ANTRATSIT
21. ROVENKIANTRATSIT
22. SVERDLOVANTRASIT
23. GUKOVUGOL
24. ROSTOVUGOL

NOTE: Sovetskugol Coal Production Association (No. 7) has recently been combined into Makeevugol Coal Production Association (No. 6).

SOURCE: KOZLOVSKY, E., 1986

Geologic Setting

The Donetsk Coal Basin covers approximately 60,000 km^2. It is located primarily in Ukraine, but extends into Russia to the east. The basin contains Cenozoic, Mesozoic, and Paleozoic sediments with numerous Upper Devonian, Permo-Triassic, and Jurassic igneous intrusives. The basin is a synclinorium bounded by the Voronezh Anticline to the south and the Precambrian Ukrainian Massif to the north, and was initially formed during the Hercynian orogeny that took place during the Carboniferous. While mountain building was occurring, sediments that eroded from the mountains were deposited into inland seas as huge deltas, over which coal swamps developed. This event is comparable to that of the Appalachian orogeny, which occurred at approximately the same time in North America. Most of Europe's mineral wealth was deposited largely as a result of the Hercynian orogeny (Dott & Batten, 1971).

The general stratigraphy of the Carboniferous coal-bearing units is shown in Figure 10. The majority of the workable coal seams are found in sediments of the Moskovsk and Bashkirsk Series of the Middle Carboniferous, but potentially workable coals can also be found in the Serpukhovsk Series of the Lower Carboniferous. The total thickness of the coal-bearing strata is more than 8000 m (Nalivkin, 1960). Salt containing evaporite layers occur in the Devonian and Permian strata deposited in the basin. Compression associated with the latest phases of the Kimmerian and earliest phases of the Alpine orogenies caused diapirism in the salt layers, forming domes in the northeastern part of the basin. These domes have been mined to supply salt to the eastern part of the former Soviet Union. Oil and gas have migrated up along the margins of these diapirs and have been trapped, making excellent exploration targets.

Coal Reserves and Production

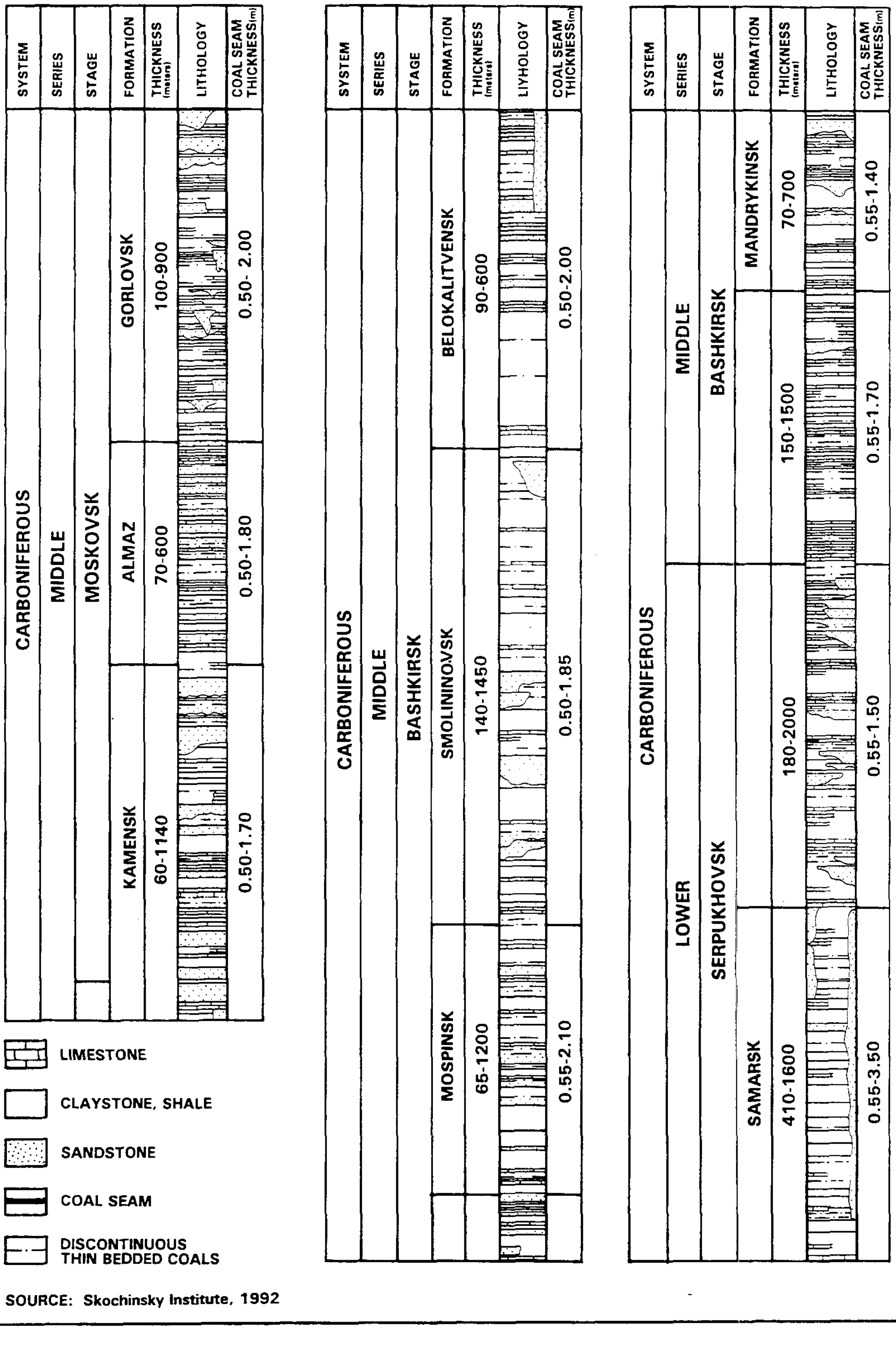
Total coal reserves in the Donetsk Basin, to a depth of 1800 m, are estimated at 140.8 billion tons, of which total balance reserves[8] are 108.5 billion tons (see Appendix B for comparison with western resource classification systems). Of the total balance reserves, 35.2 billion tons are contained in the basin's 24 coal production associations, 11.6 billion tons of which are associated with mines that are currently active (Table 6). Industrial reserves (those designated for extraction according to mine plans) total 8.7 billion tons. On average, Donetsk coal contains 19.2 percent ash, 6.5 percent moisture, up to 4 percent sulfur, and has a heating value of 25.4 MJ/kg. The coal rank ranges from sub-bituminous to anthracite, but generally is strongly caking bituminous coal.

Table 6 summarizes coal production, reserves, total methane liberated, and other key characteristics for Donetsk Basin coal production associations. Hard coal production in the Donetsk Basin in 1991 was 150.4 million tons, of which 128.8 million tons were produced in Ukraine and 21.5 million tons in Russia. Coal produced from the Ukrainian portion of the basin represents 93 percent of the total hard coal production in Ukraine, which has been declining in recent years. It is likely that some of the older and/or deeper, non-productive mines will be closed in the near future, and there are possibilities of new, more efficient and productive mines opening up. Some of the less-productive coal production associations are being combined with those whose production is greater. The Sovetskugol and Makeevugol Coal Production Associations, for example, were recently merged into a single association.

---

[8]Balance reserves must meet certain criteria for seam thickness ash content. In the Donetsk Basin, these criteria are: Brown coal: seams at least 0.6 m thick, ash content no greater than 40 percent; Long flame and gas coal and lean caking coal: seams at least 0.45 m thick, ash content no greater than 45 percent; Lean coal and anthracite: seams at least 0.45 m thick, ash content no greater than 40 percent (see Appendix B for a comparison of U.S. and Russian coal classification systems).

FIGURE 10. GENERAL STRATIGRAPHIC SECTION OF THE COAL BEARING SEQUENCE OF THE DONETSK COAL BASIN, RUSSIA AND UKRAINE



SOURCE: Skochinsky Institute, 1992

TABLE 6. KEY CHARACTERISTICS OF COAL PRODUCTION ASSOCIATIONS IN THE DONETSK COAL BASIN (1991)

COAL PRODUCTION ASSOCIATION	NUMBER OF MINES		COAL PRODUCTION (MILLION TONS)		BALANCE COAL RESERVES (MT)			METHANE LIBERATED (Mm³)	SPECIFIC EMISSIONS (m³/T)	AVERAGE METHANE CONTENT (m³/T)
	TOTAL	WITH DRAINAGE	ACTIVE MINES	MINES WITH DRAINAGE	ALL MINES[2]	ACTIVE MINES	INDUSTRIAL RESERVES[3]			
DONETSKUGOL	27	11	15.4	9.3	2340.9	1545.1	1118.2	569.2	37.1	12.9
MAKEEVUGOL	21	18	8.7	8.1	1934.9	598.7	458.2	463.8	53.5	21.1
OKTYABRUGOL	12	6	5.1	3.7	611.3	394.4	321.0	284.4	55.8	18.2
KRASNOARMEISKUGOL	7	4	7.3	5.6	982.4	497.9	406.8	253.2	34.5	12.8
KRASNODONUGOL	14	8	6.4	5.2	1742.8	526.7	398.7	246.2	38.4	21.9
SHAKHTERSKUGOL	13	6	4.6	3.4	624.1	316.4	254.9	221.7	47.8	29.9
DONBASSANTRATSIT	13	4	5.7	1.7	1589.0	362.1	261.3	215.9	38.0	15.9
LUGANSKUGOL	14	8	6.8	3.8	3644.2	788.8	554.1	158.7	23.3	15.1
ARTYMOUGOL	10	6	5.2	3.6	523.7	347.2	277.2	148.0	28.5	17.4
STAKHANOVUGOL	17	5	5.5	2.7	1909.4	457.5	280.9	130.2	23.7	14.2
TOREZANTRATSIT	21	5	6.9	0.9	1130.3	260.3	208.6	112.9	16.5	6.7
DOBROPOLEUGOL	7	4	5.1	3.2	3366.5	752.5	533.3	110.4	21.6	11.0
ORDZHONIKIDZEUGOL	12	1	4.0	0.5	488.6	232.4	186.2	100.9	25.2	15.4
PAVLOGRADUGOL	11	1	11.2	0.7	5048.8	1268.1	1002.9	100.2	8.9	7.9
PERVOMAISKUGOL	8	2	2.6	1.0	1682.8	360.9	269.2	67.4	25.7	14.4
GUKOVUGOL[1]	15	2	7.2	0.7	1130.3	566.9	400.7	59.1	8.2	7.8
DZERZHINSKUGOL	9	2	2.0	1.0	295.0	149.9	107.8	54.2	26.8	16.8
LISICHANSKUGOL	7	5	2.8	2.2	702.9	241.2	176.5	48.7	17.5	10.9
ROSTOVUGOL[1]	31	2	14.3	0.4	2188.9	665.7	560.4	45.4	3.2	12.5
SOVETSKUGOL	6	0	2.5	0.0	912.7	161.0	60.6	0.0	0.0	0.0
ROVENKIANTRATSIT	8	0	6.6	0.0	688.9	311.4	226.7	0.0	0.0	0.0
SELIDOVUGOL	8	0	5.4	0.0	134.6	227.2	161.4	0.0	0.0	0.0
SVERDLOVANTRATSIT	11	0	5.9	0.0	1024.9	426.4	310.7	0.0	0.0	0.0
ANTRATSIT	6	0	3.3	0.0	470.2	179.6	115.9	0.0	0.0	0.0
TOTAL	308	100	150.4	57.4	35168.2	11638.2	8652.2	3390.4		
AVERAGE									22.5	14.7

[1] Gukovugol and Rostovugol coal production associations are located in Russia

[2] "All mines" includes both active and inactive mines

[3] Industrial reserves are balance reserves designated for extraction according to mine plans

Methane Liberation

Coal mines in the Donetsk Basin are some of the gassiest in the world. Of the basin's 25 coal production associations, 19 contain mines that liberated methane in 1991 (Table 7). Nearly 3.4 billion cubic meters of methane were liberated, with 16 percent, or 539 billion cubic meters captured by methane drainage systems in 100 mines. Only 170 million cubic meters of this methane were used (exclusively in boilers at the mines), thus 3.2 billion cubic meters were emitted to the atmosphere. Methane used by the mines represents 32 percent of the total drained methane, and only 5 percent of the total methane liberated.[9]

These data suggest that there are good opportunities for increased methane drainage and utilization at Donetsk Basin mines. For example, Pochenkova, a typical mine in the Makeevugol coal production association, drained only 20 percent of the methane it liberated in 1991, and used only about half of the methane it drained. Conditions at some of the Donetsk coal production associations with potentially significant project opportunities are summarized in Box 1.

BOX 1: METHANE CONDITIONS AT SELECTED DONETSK COAL PRODUCTION ASSOCIATIONS

Donetskugol is the largest coal production association in the Donetsk coal basin. In 1991, its 27 mines produced 15.4 million tons of coal and liberated 569 million cubic meters of methane. Eleven mines have drainage systems in place. These mines produced 9.3 million tons of coal and liberated 418 million cubic meters of gas, of which 110 million cubic meters (approximately 26 percent) were recovered by mine drainage systems. Only 58 percent of the drained methane (63 million cubic meters) was used; approximately 47 million cubic meters of medium-quality gas were emitted to the atmosphere, along with 459 million cubic meters of methane contained in ventilation air.

Makeevugol contains 21 mines, which produced 8.7 million tons of coal and liberated 464 million cubic meters of methane in 1991. Drainage systems are in place at 18 mines, which produced 8.1 million tons of coal and liberated 442 million cubic meters of gas, of which 94 million cubic meters (approximately 21 percent) were recovered by mine drainage systems. Slightly more than half of the drained methane (51 million cubic meters) was used; approximately 43 million cubic meters of medium-quality gas was emitted to the atmosphere, along with 370 million cubic meters of methane contained in ventilation air.

Krasnoarmeiskugol has 7 mines which, in 1991, produced 7.3 million tons of coal and liberated 253 million cubic meters of methane. Four mines have drainage systems in place. These mines produced 5.6 million tons of coal and liberated 220 million cubic meters of gas, of which 71 million cubic meters (approximately 32 percent) were recovered by mine drainage systems. None of this medium quality gas was used; it was emitted to the atmosphere, along with 182 million cubic meters of methane contained in ventilation air.

Shakhterskugol contains 13 mines, which produced 4.6 million tons of coal and liberated 222 million cubic meters of methane in 1991. Six mines have drainage systems in place. These mines produced 3.4 million tons of coal and liberated 198 million cubic meters of gas, of which 63 million cubic meters (approximately 28 percent) were recovered by mine drainage systems. Only 23 percent (less than 15 million cubic meters) was used; approximately 48 million cubic meters of medium-quality gas were emitted to the atmosphere, along with 159 million cubic meters of methane contained in ventilation air.

Luganskugol has 14 mines which, in 1991, produced 6.8 million tons of coal and liberated 159 million cubic meters of methane. Drainage systems are in place at 8 mines, which produced 3.8 million tons of coal and liberated 134 million cubic meters of gas, of which 35 million cubic meters (approximately 26 percent) were recovered by mine drainage systems. None of this medium quality gas was used; it was emitted to the atmosphere, along with 124 million cubic meters of methane contained in ventilation air.

---

[9] Note the distinction between "liberated" and "emitted"; liberated methane is that released from the coal, whether or not it is utilized; emissions, in the strict sense, refer to liberated methane that has not been utilized and therefore enters the atmosphere.

TABLE 7. 1991 METHANE LIBERATION DATA FROM COAL PRODUCTION ASSOCIATIONS OF THE DONETSK COAL BASIN

COAL PRODUCTION ASSOCIATION	NUMBER OF MINE		METHANE LIBERATED BY MINING (Mm³)				DRAINED METHANE UTILIZED (Mm³)	METHANE EMITTED TO ATMOS-PHERE (Mm³)	% OF TOTAL LIBERATE METHANE DRAINED	% OF DRAINED METHANE UTILIZED	% OF TOTAL LIBERATED METHANE UTILIZED	% SHARE OF TOTAL METHANE LIBERATED
			FROM ALL MINES			FROM MINES WITH DRAINAGE SYSTEMS						
	TOTAL	WITH DRAINAGE SYSTEMS	BY VENTI-LATION	BY DRAIN-AGE	TOTAL LIBER-ATED							
DONETSKUGOL	27	11	459.1	110.1	569.2	417.8	63.3	505.9	19.3	57.5	11.1	16.8
MAKEEVUGOL	21	18	369.6	94.2	463.8	441.7	51.4	412.4	20.3	54.6	11.1	13.7
OKTYABRUGOL	12	6	257.7	26.7	284.4	229.3	10.5	273.8	9.4	39.4	3.7	8.4
KRASNOARMEISKUGO	7	4	181.9	71.3	253.2	220.2	0.0	253.2	28.2	0.0	0.0	7.5
KRASNODONUGOL	14	8	226.5	19.7	246.2	118.3	9.5	236.7	8.0	48.1	3.8	7.3
SHAKHTERSKUGOL	13	6	159.0	62.7	221.7	197.5	14.5	207.2	28.3	23.1	6.5	6.5
DONBASSANTRATSIT	13	4	197.7	18.2	215.9	133.9	13.1	202.8	8.4	72.0	6.1	6.4
LUGANSKUGOL	14	8	123.6	35.1	158.7	134.3	0.0	158.7	22.1	0.0	0.0	4.7
ARTYMOUGOL	10	6	139.7	8.3	148.0	108.3	0.0	148.0	5.6	0.0	0.0	4.4
STAKHANOVUGOL	17	5	117.6	12.7	130.2	74.8	0.0	130.2	9.7	0.0	0.0	3.8
TOREZANTRATSIT	21	5	98.1	14.7	112.9	81.1	7.9	105.0	13.0	53.6	7.0	3.3
DOBROPOLEUGOL	7	4	75.2	35.2	110.4	86.6	0.0	110.4	31.9	0.0	0.0	3.3
ORDZHONIKIDZEUGOL	12	1	96.4	4.6	100.9	16.1	0.0	100.9	4.5	0.0	0.0	3.0
PAVLOGRADUGOL	11	1	98.0	2.2	100.2	21.6	0.0	100.2	2.2	0.0	0.0	3.0
PERVOMAISKUGOL	8	2	64.6	2.8	67.4	38.5	0.0	67.4	4.2	0.0	0.0	2.0
GUKOVUGOL[1]	15	2	53.1	6.0	59.1	34.5	0.0	59.1	10.1	0.0	0.0	1.7
DZERZHINSKUGOL	9	2	50.3	3.9	54.2	28.5	0.0	54.2	7.3	0.0	0.0	1.6
LISICHANSKUGOL	7	5	42.9	5.9	48.7	42.8	0.0	48.7	12.1	0.0	0.0	1.4
ROSTOVUGOL[1]	31	2	40.7	4.7	45.4	26.8	0.0	45.4	10.3	0.0	0.0	1.3
TOTALS	269	100	2851.5	538.9	3390.4	2452.4	170.2	3220.2	15.9	31.6	5.0	100.0

[1] Gukovugol and Rostovugol coal production associations are located in Russia

SOURCE: SKOCHINSKY MINING INSTITUTE, 1993

2.2.2 THE L'VOV-VOLYN BASIN

Introduction

The L'vov-Volyn Coal Basin, located in western Ukraine, is the southeastern extension of the Lublin Coal Basin in Poland. Coal mining began in 1954 and there is currently one coal production association, Ukrzapadugol, operating 17 mines. The average seam thickness is 0.95 m and the depth of mining ranges from 300 to 600 m (Kozlovsky, 1987).

Geologic Setting

The L'vov-Volyn Basin is an elongated, north-south trending asymmetrical basin (Figure 11) with numerous northwest-southeast trending horst and graben features. The main coal-bearing horizons dip gently to the southwest; dips average 0.5 to 1 degree, and range up to 5 to 7 degrees locally. The depth of overburden varies from 250 m in the eastern part of the basin up to 750 m in the western part.

The stratigraphy of the coal-bearing strata is shown in Figure 12. The main coal horizons are found in Lower Carboniferous sediments of the Serpukhovsk Stage and Middle Carboniferous sediments of the Bashkirsk Stage. Middle Jurassic deposits unconformably overlie these Carboniferous deposits. The total thickness of the coal-bearing sequence varies from 400 to 1200 m (Struev, et al, 1984).

Coal Reserves and Production

Total coal reserves of the L'vov-Volyn basin are estimated at 2.1 billion tons, of which 610 million tons are balance reserves[10] (Struev et al, 1984; Kozlovsky, 1987). Balance reserves of coal contained in the basin's mines are 193 million tons. The basin is divided into two regions (northern and southern) and has 17 operating mines, 5 in the northern region and 12 in the southern region. Reserves of the northern region (Novovolynsk mines) are small, and mining in this region is expected to cease soon. One of these mines, the No. 8 Novovolynsk, has been mining non-balance reserves. In the southern region, the No. 5 Velikomostovsk, No. 7 Velikomostovsk, and No. 9 Velikomostovsk mines are also expected to close soon, due to depleted reserves.

Coal production in the L'vov-Volyn basin was 9.5 million tons in 1991 (Table 8); this amounts to only 7 percent of the total Ukraine production, and only 2 percent of the total coal produced in the CIS. On average, coal of the L'vov-Volyn basin contains 5-10 percent moisture, 23-42 percent ash, 36-39 percent volatile matter, 3.3-4.5 percent sulfur, and has a heating value of 32.2-34.5 MJ/kg. The coal is predominantly long-flame, gas, gas-fat and fat coals (all high volatile bituminous - see Appendix B for a comparison of U.S. and Russian coal classification systems). Fifty percent of the coal produced is used for power generation, and the remaining 50 percent is sent to the Donetsk region and used for coking (in many cases, this coal is mixed with Russian coal to dilute the sulfur content before coking).

---

[10] Balance reserves must meet certain criteria for seam thickness and ash content (see Appendix B for an explanation of the former USSR resource classification system). Balance criteria for the L'vov-Volyn Basin were not available, but they are presumably similar to those stated for the Donetsk Basin (Section 2.2.1) and the Kuznetsk Basin (Section 2.2.3).

FIGURE 11. L'VOV-VOLYN COAL BASIN, UKRAINE

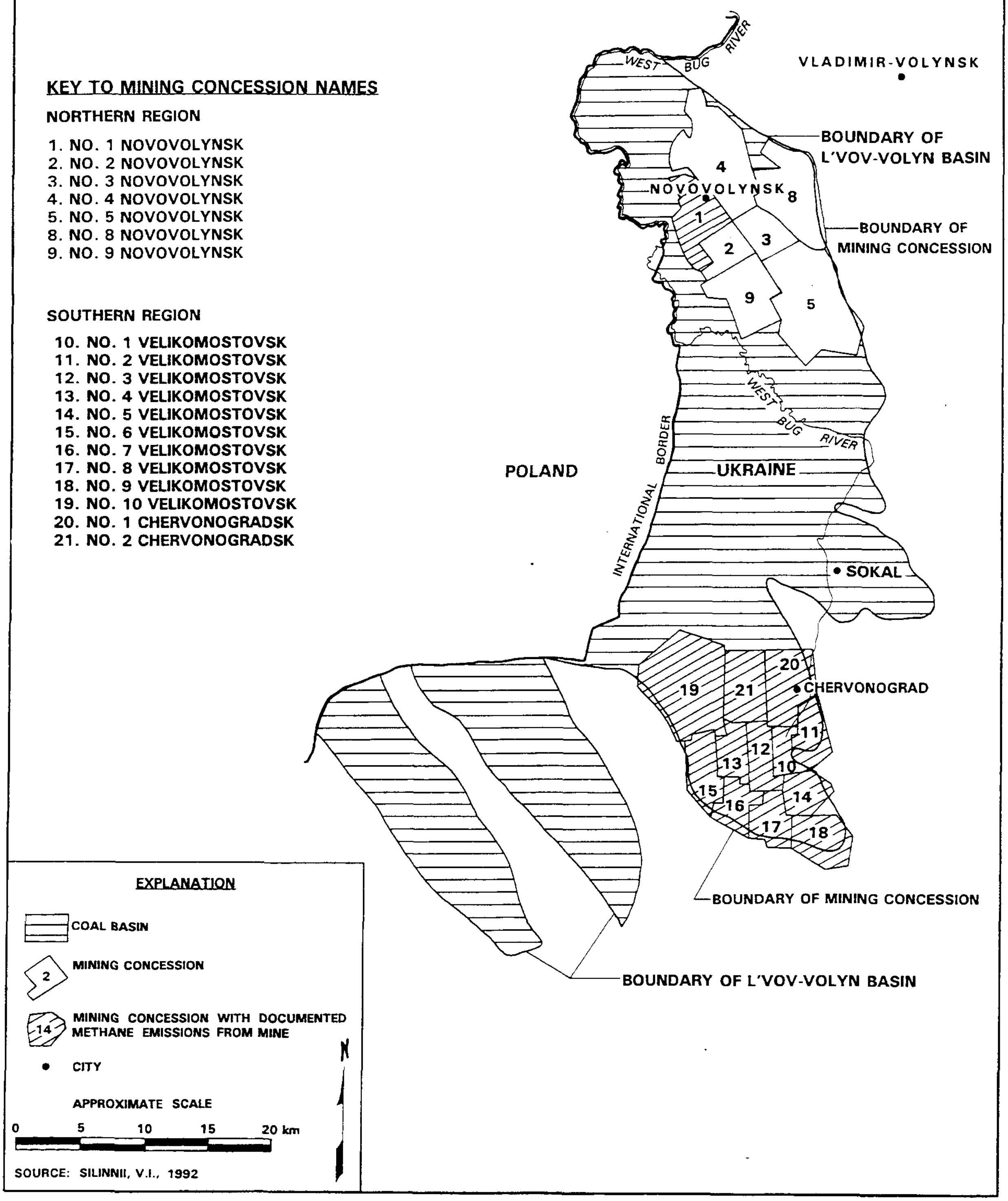
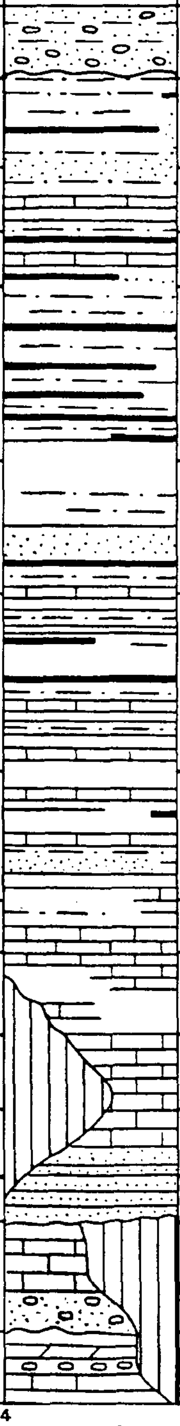


FIGURE 12. GENERAL STRATIGRAPHIC SECTION OF THE COAL BEARING SEQUENCE, L'VOV-VOLYN COAL BASIN, UKRAINE



SYSTEM	SERIES	STAGE	FORMATION	THICKNESS (meters)	DESCRIPTION
PERMIAN					
CARBONIFEROUS	MIDDLE	BASHKIRSK	KRECHEVSK	TO 100	SANDSTONES AND SILTSYONES WITH SOME CLAYSTONES AND INTERBEDDED COALS.
CARBONIFEROUS	MIDDLE	BASHKIRSK	PARO-MOVSK	60-90	INTERBEDDED CLAYSTONES, SILTSTONES, SANDSTONES AND LIMESTONES.
CARBONIFEROUS	MIDDLE	BASHKIRSK	MOROZO-VICHSK	30-80	ALTERNATING CLAYSTONES, SILTSTONES AND SANDSTONES WITH INTERBEDDED LIMESTONES AND COAL.
CARBONIFEROUS	LOWER	SERPUKHOVSK	BUZHANSK	120-310	SANDSTONES, SILTSTONES AND CLAYSTONES WITH INTERBEDDED HARD COALS, SOME OF MINABLE THICKNESS.
CARBONIFEROUS	LOWER	SERPUKHOVSK	LISHNYANSK	35-180	CLAYSTONES AND SILTSTONES WITH INTERBEDDED SANDSTONES AND COALS, AND OCCASIONAL LIMESTONES.
CARBONIFEROUS	LOWER	SERPUKHOVSK	IVANICHSK	92-193	CLAYSTONES AND SILTSTONES WITH INTERBEDDED SANDSTONE, LIMESTONE AND COALS.
CARBONIFEROUS	LOWER	SERPUKHOVSK	PORITSK	77-207	CALYSTONES AND SILTSTONES WITH INTERBEDDED SANDSTONES, LIMESTONES AND RARE PARTINGS OF COAL.
CARBONIFEROUS	LOWER	VIZEISK	USTI-LUGSK	35-115	ARGILLACEOUS LIMESTONE WITH PARTINGS OF CLAYSTONE.
CARBONIFEROUS	LOWER	VIZEISK	VLADI-MIRSK	75-96	LIMESTONES AND CLAYSTONES WITH PARTINGS OF SANDSTONE AND SILTSTONE.
CARBONIFEROUS	LOWER	VIZEISK	NES-TEROVSK	90-95	CALCAREOUS CLAYSTONE, GRADING TO ARGILLACEOUS AND CRYSTALINE LIMESTONE.
CARBONIFEROUS	LOWER	VIZEISK	VIN-NIKOVSK	13-115	LIMESTONES ALTERNATING WITH CLAYSTONE.
CARBONIFEROUS	LOWER	VIZEISK	KULICH-KOVSK	40-50	SANDSTONES AND POROUS LIMESTONES WITH CLAYSTONES PARTINGS TOWARDS BOTTOM.
CARBONIFEROUS	LOWER	TURNEISK	KHOREVSK	0-26	CLAYSTONES AND LIMESTONES UNDERLAIN BY SANDSTONES AND BASAL CONGLOMERATE.
DEVONIAN					

SOURCE: STRUEV, ET AL, 1984

TABLE 8. KEY CHARACTERISTICS OF MINES IN THE L'VOV-VOLYN COAL BASIN (ALL DATA ARE FROM 1991 EXCEPT BALANCE RESERVES, WHICH ARE 1990)

MINE	COAL PRODUCTION (THOUSAND TONS)	BALANCE COAL RESERVES (MILLION TONS)	METHANE LIBERATED (Mm^3)	SPECIFIC EMISSIONS (m^3/T)	AVERAGE METHANE CONTENT (m^3/T)
#10 VELIKOMOSTOVSK	1,008.50	29.48	28.02	27.8	7.3
#7 VELIKOMOSTOVSK	705.18	10.42	19.73	28.0	6.0
#8 VELIKOMOSTOVSK	885.86	2.82	17.92	20.2	10.0
#2 CHERVONOGRAD	951.92	31.72	14.90	15.7	5.7
#3 VELIKOMOSTOVSK	848.63	24.96	14.82	17.5	6.9
#5 VELIKOMOSTOVSK	572.32	4.80	11.87	20.7	3.0
#4 VELIKOMOSTOVSK	792.78	9.85	11.86	15.0	11.4
#6 VELIKOMOSTOVSK	379.60	15.08	9.02	23.8	7.2
#1 CHERVONOGRAD	381.42	18.65	5.64	14.8	4.6
#9 VELIKOMOSTOVSK	263.17	3.40	5.57	21.2	2.9
#2 VELIKOMOSTOVSK	804.83	7.50	5.31	6.6	2.5
#1 VELIKOMOSTOVSK	396.76	7.33	5.20	13.1	2.4
#1 NOVOVOLYNSK	323.76	6.34	3.15	9.7	1.0
#2 NOVOVOLYNSK	285.07	11.89	0.00	0.0	0.0
#5 NOVOVOLYNSK	338.72	3.07	0.00	0.0	0.0
#8 NOVOVOLYNSK[11]	169.36	0.00	0.00	0.0	0.0
#9 NOVOVOLYNSK	390.92	5.61	0.00	0.0	0.0
TOTAL	9,498.80	192.92	153.01		
AVERAGE				12.8	6.9
SOURCE: SKOCHINSKY MINING INSTITUTE (1993 AND 1991b)					

Methane Liberation

The twelve mines in the southern part of the basin, together with one in the northern part, emitted 153 million cubic meters of methane in 1991 (Table 9). This amount represents only 5 percent of total coal mining methane emissions from Ukraine. Although four of the mines have methane drainage systems, only 6 percent of all methane liberated is captured by those drainage systems, and none is utilized.

Potentially significant project opportunities exist at several mines. No. 10 Velikomostovsk, for example, produced more than 1 million tons of coal in 1991, and emitted 28 million cubic meters of methane to the atmosphere. Of this, nearly 3 million cubic meters (approximately 10 percent) were medium-quality gas recovered by mine drainage systems, and the remaining 25 million cubic meters were released in mine ventilation air. No. 4 Velikomostovksk produced 792.8 thousand tons of coal, and emitted nearly 12 million cubic meters of methane to the atmosphere. Of this, approximately 4 million cubic meters (35 percent) were medium-quality gas recovered by drainage systems.

[11] Balance reserves have been fully exploited at this mine; non-balance reserves are now being mined

TABLE 9. 1991 METHANE LIBERATION DATA FROM MINES OF THE L'VOV-VOLYN COAL BASIN (1991)

MINE	METHANE LIBERATED BY MINING (Mm^3)			PERCENT OF TOTAL LIBERATED METHANE DRAINED	PERCENT SHARE OF TOTAL METHANE LIBERATED
	BY VENTILATION	BY DRAINAGE	TOTAL LIBERATED		
#10 VELIKOMOSTOVSK	25.26	2.76	28.02	10.0	18.3
#7 VELIKOMOSTOVSK	19.73	0.00	19.73	0.0	12.9
#8 VELIKOMOSTOVSK	17.92	0.00	17.92	0.0	11.7
#2 CHERVONOGRAD	12.85	2.05	14.90	13.8	9.7
#3 VELIKOMOSTOVSK	14.82	0.00	14.82	0.0	9.7
#5 VELIKOMOSTOVSK	11.87	0.00	11.87	0.0	7.8
#4 VELIKOMOSTOVSK	7.66	4.20	11.86	35.4	7.8
#6 VELIKOMOSTOVSK	8.39	0.63	9.02	7.0	5.9
#1 CHERVONOGRAD	5.64	0.00	5.64	0.0	3.7
#9 VELIKOMOSTOVSK	5.57	0.00	5.57	0.0	3.6
#2 VELIKOMOSTOVSK	5.31	0.00	5.31	0.0	3.5
#1 VELIKOMOSTOVSK	5.20	0.00	5.20	0.0	3.4
#1 NOVOVOLYNSK	3.15	0.00	3.15	0.0	2.1
TOTAL	143.37	9.64	153.01	6.3	100.0
SOURCE: SKOCHINSKY MINING INSTITUTE (1993)					

2.2.3 THE KUZNETSK BASIN

Introduction

The Kuznetsk Coal Basin, also known as the Kuzbass, is the second largest coal basin in the CIS and is located in western Siberia. Coal mining began in the mid-nineteenth century as the Trans-Siberian railway was being developed. Kemerovo, located in the northern end of the basin, and Novokuznetsk in the south are important industrial centers. The basin contains 25 geological-commercial regions, 10 of which do not have active mines. As of 1991, the basin contained 71 mines operated by 6 coal production associations (Figure 13). More than 100 seams, with an average thickness of 2.5 m., are being mined. The thickness of the overburden of the seams mined underground ranges from 300 to 800 m (Airuni, 1991).

Geologic Setting

The Kuznetsk Basin is an asymmetrical basin which occupies a large intermontane trough, flanked by the Salarian range to the west, the Kuznetskian Altai Mountains to the east, and the Rocky Shorias to the south (Nalivkin, 1973). The main coal-bearing horizons (Figure 14) occur in Permian-Carboniferous sediments deposited during Balakhonsk and Kolchuginsk time, which crop out around the perimeter of the basin. Coal seams also occur in Jurassic sediments of the Tarbagansk Series, which were deposited in discontinuous, fold and fault bounded synclinal features in the center of the basin. These coal deposits are predominantly brown coal with some gas and long-flame coal deposits.

FIGURE 13. LOCATION OF COAL PRODUCTION ASSOCIATIONS IN THE KUZNETSK COAL BASIN IN RUSSIA

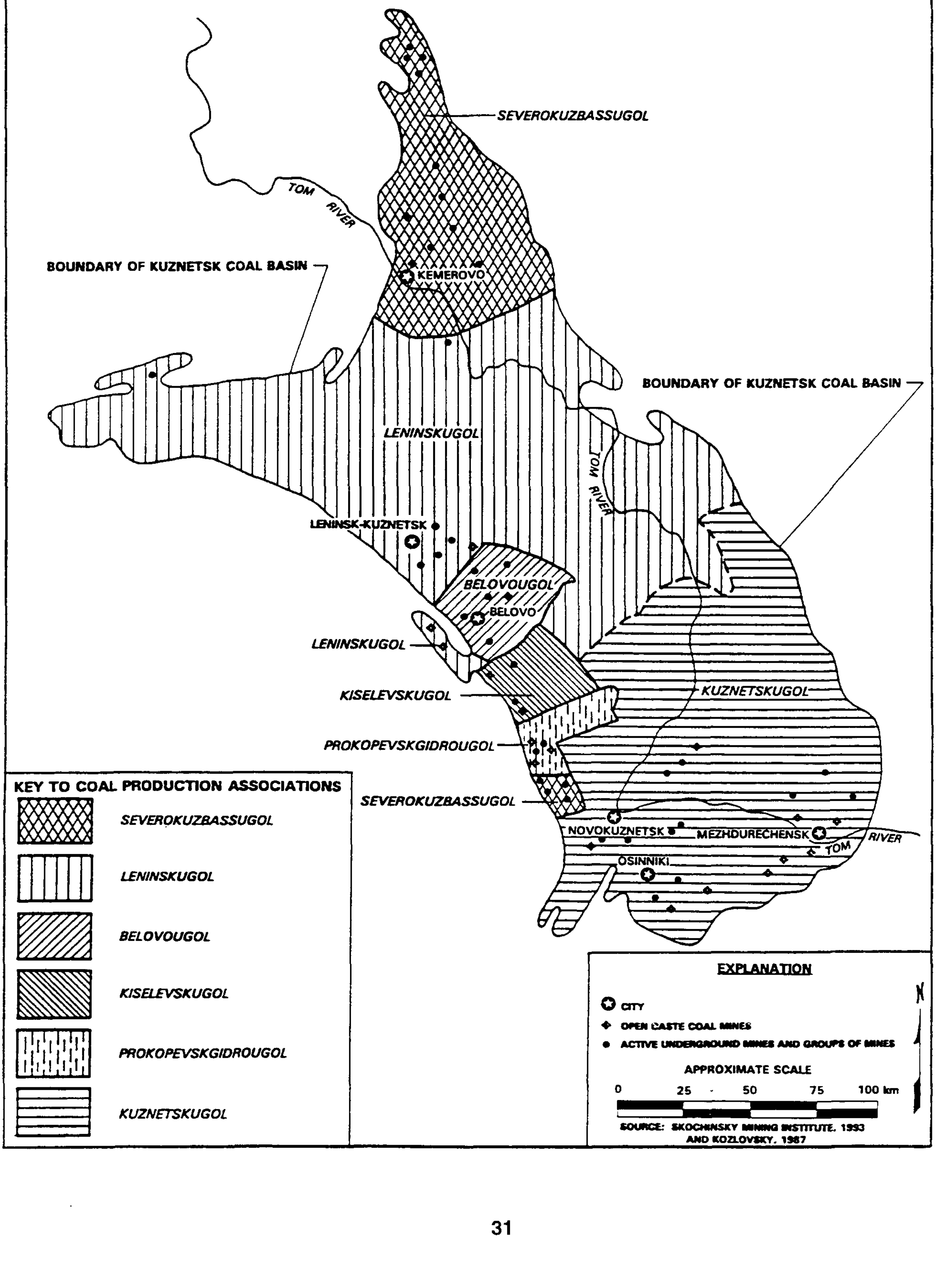
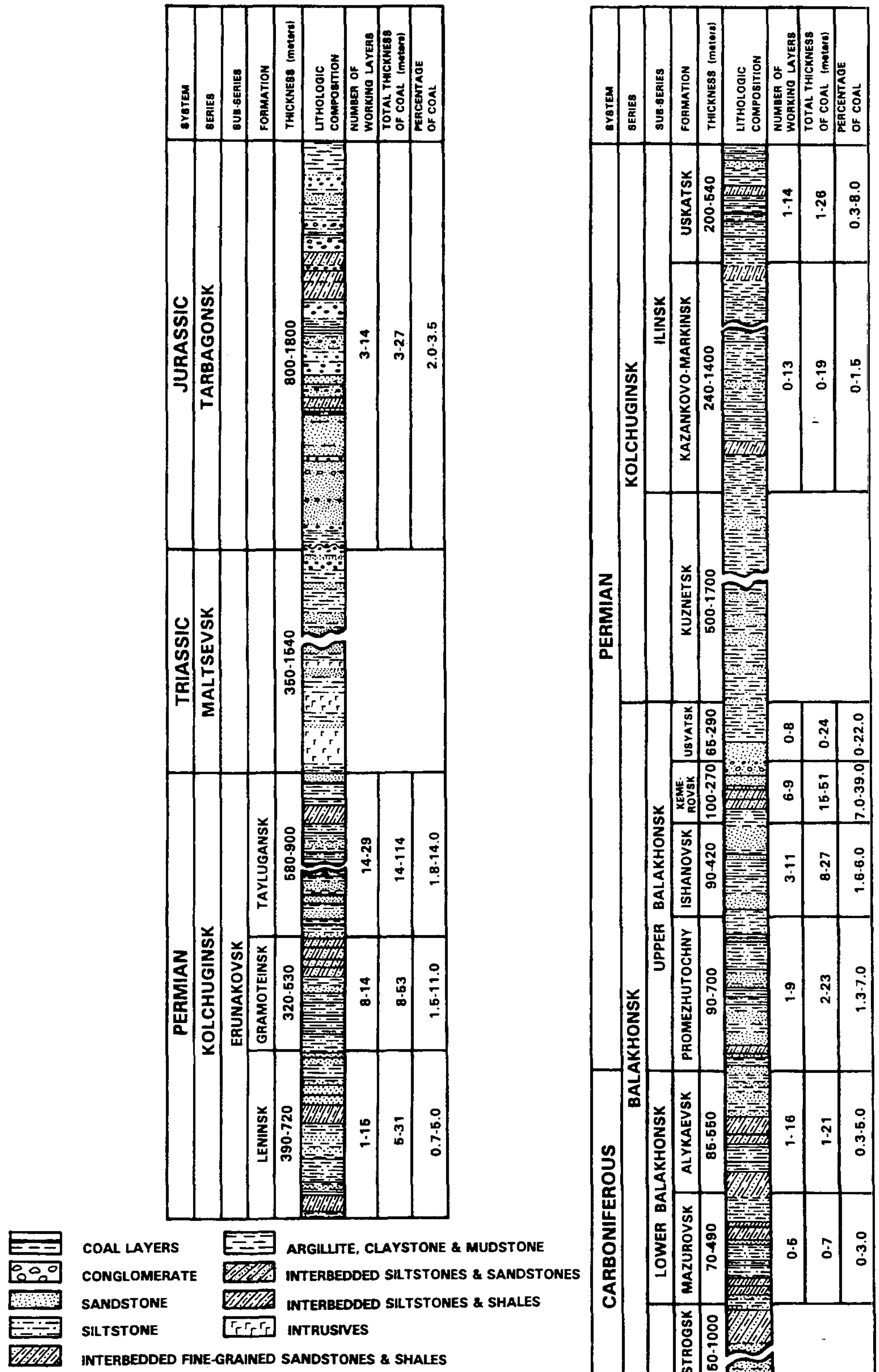


FIGURE 14. GENERAL STRATIGRAPHIC SECTION OF COAL BEARING SEQUENCE OF THE KUZNETSK COAL BASIN, RUSSIA



SOURCE: BIKADOROV, ET AL, 1980

Coal Reserves and Production

Total documented coal reserves of the Kuznetsk Basin, estimated to a depth of 1800 m, are 637 billion tons, of which 548 billion tons are balance reserves.[12] Of the balance reserves, 67 billion tons are explored reserves, and 44 billion tons are estimated reserves (Kozlovsky, 1987; CIA, 1985). Balance reserves of coal associated with the basin's six coal production associations total 16.1 billion tons (Table 10). Production is mostly from underground mines, but surface mines also produce hard coal in the Kuznetsk Basin. Total coal production in 1991 was 58.9 million tons, which represents 26 percent of Russia's coal production and 12 percent of the total production of the CIS. Production has declined in recent years, primarily due to increasingly difficult mining conditions, equipment shortages and use of outdated equipment, and increasing labor costs. Kuznetsk Basin mines are heavily subsidized, and it is likely that the most unprofitable mines will be closed in the near future; however, this basin remains a key source of Russia's coal and will receive continued investment.

On average, Kuznetsk hard coal contains 10.2 percent moisture, 19.0 percent ash, less than 0.5 percent sulfur, and has a heating value of 23.2 MJ/kg. Predominantly rock coal and coking coal are mined; at one time one-fifth of all the steam coal and one-third of all the coking coal mined in the former USSR was mined from the Kuznetsk Basin (Kozlovsky, 1987).

Methane Liberation

In 1951, the Kuznetsk Coal Basin became the first area to utilize methane drainage systems in underground mining in the USSR. All of the active underground mines are gassy, liberating more than 1.2 billion cubic meters in 1991 (Table 11). In spite of highly gassy conditions, only 211.9 million cubic meters (17 percent) of this gas were removed by drainage systems in 32 mines. All of this gas was then emitted to the atmosphere, as none was utilized. Conditions at some of the coal production associations with potentially significant project opportunities are summarized in Box 2.

BOX 2: METHANE CONDITIONS AT SELECTED KUZNETSK COAL PRODUCTION ASSOCIATIONS

Kuznetskugol currently operates 20 mines, which produced 24.2 million tons of coal and emitted 588 million m^3 of methane to the atmosphere in 1991. Less than ten percent of this methane was recovered by drainage before being emitted. Only ten of the mines have methane drainage systems in place. These ten mines produced 14.8 million tons of coal and liberated 363 cubic meters of methane, of which 57 million m^3 (approximately 16 percent) were recovered by drainage. All of this medium-quality gas was emitted to the atmosphere, along with 531 million cubic meters contained in ventilation air.

Leninskugol currently operates 9 mines, which produced 11 million tons of coal and emitted 262 million m^3 of methane to the atmosphere in 1991. Approximately 37 percent of the total methane liberated is first recovered by drainage systems before being emitted. Eight of the nine mines have methane drainage systems. These mines produced 10.2 million tons of coal and liberated 254 million cubic meters of methane, of which 98 million m^3 (approximately 38 percent) were recovered by drainage. All of this medium-quality gas was emitted to the atmosphere, along with 164 million cubic meters contained in ventilation air.

Belovougol contains 7 mines, which, in 1991, produced 5.8 million tons of coal and emitted 104 million m^3 of methane to the atmosphere. Approximately 31 percent of this methane was recovered by drainage before being emitted. Only three of the mines have methane drainage systems. These three mines produced 2.8 million tons of coal and liberated 96 million cubic meters of methane, of which 32 million m^3 (approximately 33 percent) were recovered by drainage. All of this medium-quality gas was emitted to the atmosphere, along with 72 million cubic meters contained in ventilation air.

---

[12] Balance reserves must meet certain criteria for seam thickness and ash content (see Appendix B for an explanation of the former USSR reserve classification system). In the Kuznetsk Basin, balance criteria are: Seams that dip 35 degrees or less: minimum thickness of 0.7 m; Seams that dip more than 35 degrees: thickness at least 0.6 m. Coal must contain no more than 40 percent ash (regardless of seam dip angle).

TABLE 10. KEY CHARACTERISTICS OF COAL PRODUCTION ASSOCIATIONS IN THE KUZNETSK COAL BASIN (1991)

COAL PRODUCTION ASSOCIATION	NO. OF MINES	COAL PRODUCTION (MILLION TONS)		BALANCE COAL RESERVES (MILLION TONS)			METHANE LIBERATED (Mm^3)	SPECIFIC EMISSIONS (m^3/T)	AVERAGE METHANE CONTENT (m^3/T)
		ACTIVE MINES	MINES WITH DRAINAGE SYSTEMS	ALL MINES	ACTIVE MINES	INDUSTRIAL RESERVES			
KUZNETSKUGOL	20	24.21	14.80	6985.7	3531.7	2326.7	587.78	24.3	13.3
LENINSKUGOL	9	10.96	10.19	3271.4	1558.4	911.6	261.70	23.9	9.4
PROKOPEVSKIDROUGOL	11	6.08	3.06	1632.5	1497.8	724.8	145.85	24.0	11.7
BELOVOUGOL	7	5.78	2.81	778.4	778.4	593.0	103.70	17.9	13.1
SEVEROKUZBASSUGOL	13	7.50	1.55	1642.3	1016.1	480.5	90.82	12.1	12.4
KISELEVSKUGOL	10	4.37	0.14	1834.9	1572.2	683.3	50.67	11.6	11.1
TOTAL	70	58.90	32.55	16145.2	9954.6	5719.9	1240.52		
AVERAGE								21.0	11.9

SOURCE: SKOCHINSKY MINING INSTITUTE (1993 AND 1991c)

TABLE 11. 1991 METHANE LIBERATION DATA FROM COAL PRODUCTION ASSOCIATIONS OF THE KUZNETSK COAL BASIN

COAL PRODUCTION ASSOCIATION	NUMBER OF MINES		% OF MINES WITH DRAINAGE SYSTEMS	METHANE LIBERATED (AND EMITTED, SINCE NO METHANE IS UTILIZED) MILLION CUBIC METERS				% OF TOTAL LIBERATED METHANE THAT IS DRAINED	% SHARE OF TOTAL METHANE LIBERATED
	TOTAL	WITH DRAINAGE SYSTEMS		BY VENTI-LATION	BY DRAINAGE	TOTAL	FROM MINES WITH DRAINAGE SYSTEMS		
KUZNETSKUGOL	20	10	50	531.22	56.56	587.78	362.66	9.6	47.4
LENINSKUGOL	9	8	89	163.83	97.87	261.70	254.29	28.5	21.1
PROKOPEVSKIDROUGO	11	7	64	127.09	18.76	145.85	121.62	12.9	11.8
BELOVOUGOL	7	3	43	72.06	31.64	103.70	96.13	30.5	8.4
SEVEROKUZBASSUGOL	13	3	23	85.83	4.99	90.82	31.43	5.5	7.3
KISELEVSKUGOL	10	1	10	48.62	2.05	50.67	10.88	4.0	4.1
TOTAL	71	32	45	1028.65	211.87	1240.52	877.01	17.1	100

SOURCE: SKOCHINSKY MINING INSTITUTE (1993)

2.3 COALBED METHANE RESOURCE ESTIMATES

Preliminary estimates suggest that the coalbed methane resources associated with balance reserves of coal contained in mines of the Donetsk, Kuznetsk, and L'vov-Volyn Coal Basins are substantial, ranging from 627 billion to 1.1 trillion cubic meters (Table 12). Additional methane resources are present in non-balance coal reserves and in areas beyond the boundaries of the coal production associations and their associated mines. According to data from the former USSR Academy of Sciences (1990) and the Eastern Mine Safety Research Institute (1992), the total estimated coalbed methane resource contained in just the coal seams of the three basins is greater than 7.8 trillion cubic meters. Additional methane resources are contained in the partings and strata surrounding the coal seams. It is estimated by the above mentioned institutions that the total coalbed methane resource contained in the three basins is more than 52.1 trillion cubic meters.

TABLE 12. SUMMARY OF ESTIMATED METHANE RESOURCES ASSOCIATED WITH BALANCE RESERVES OF COAL IN THE DONETSK, L'VOV-VOLYN, AND KUZNETSK COAL BASINS

COAL BASIN	ESTIMATED METHANE RESOURCES (BILLION m^3) ASSOCIATED WITH BALANCE RESERVES OF COAL, CALCULATED ACCORDING TO:		
	ALL MINES	ACTIVE MINES	INDUSTRIAL RESERVES[13]
DONETSK	433-788	144-279	109-209
L'VOV-VOLYN	Not Available	1-3	Not Available
KUZNETSK	194-342	119-204	69-120
TOTAL	627-1131	264-486	178-329

To fully evaluate the coalbed methane development potential of each coal basin, it will be necessary to estimate coalbed methane resources and assess what percentage is recoverable using available technologies. This effort will require detailed information on the coal reserves, including geologic and reservoir characteristics, which would be generated by a carefully designed exploration program.

Such information is not currently available for the coal reserves of the Donetsk, Kuznetsk and L'vov-Volyn basins. Thus, in this report the coalbed methane resources associated with the balance coal reserves of these basins have been estimated based on available data using two approaches. To reflect the uncertainties associated with preparing such estimates where data are limited, the coalbed methane resource estimates are presented as ranges. For the low end of the range, estimates were based on the measured methane contents of coal reserves in each basin. The high-end estimates were developed using specific emissions (i.e., the amount of methane liberated per ton of coal mined). These methods, and the uncertainties associated with them, are discussed briefly below.

[13] Industrial coal reserves are that portion of the balance reserves that is designated for extraction according to the mine plans and using available technology.

Average Methane Content Method

Under this method, resource estimates were prepared using methane content data published by the Skochinsky Mining Institute and developed for the coal resources that are expected to be mined through 1995 or 2000, depending upon the coal basin. The Skochinsky reports contain measured gas contents and coal reserves of each seam slated for mining. Using this data, Raven Ridge Resources developed an average gas content, weighted on coal reserves, for each coal production association (or active mine, in the case of the L'vov-Volyn coal basin). Methane content values were then multiplied by the balance coal reserves of each coal production association (or mine), to estimate coalbed methane resources.

This method should yield reasonably accurate resource estimates because it relies on measured methane contents. There are a variety of sources of uncertainty associated with these estimates, however, and the data on which they are based.

- First, methane content data were only reported by the Skochinsky Mining Institute for the those coal seams that are scheduled to be mined through the year 2000. Methane contents of other coal seams, or of the same seams in other areas of the coal production associations not included in the mine plans, may differ. This resource estimate could thus be inaccurate to the extent that the actual average gas content for the entire coal basin differs from the gas content of the coals expected to be mined over the next few years.

- Second, the techniques used for measurement of lost gas (unmeasured gas that desorbs during the time that elapses from the moment the coal sample is cut from the seam, until the moment it is sequestered in an airtight container) were not explained to the authors. There are many techniques used for estimating lost gas, and the optimal technique to use in any given situation depends on the depth from which the coal sample is taken, the pressure conditions of the reservoir, and the way in which the methane is contained in the coals. Details concerning sampling methods and reservoir characteristics were not available. As a result, it is not clear how accurate the reported measured gas content data are or how they compare to gas content data developed in the U.S.

Specific Emissions Method

The second method for estimating coalbed methane resources has been used by the Skochinsky Mining Institute. It relies on the specific methane emissions associated with coal mining, which refers to the volume of methane liberated per unit weight of coal mined during a given time period (in this case, one year), commonly expressed in cubic meters per ton. Specific emissions can be calculated for any coal production association or mine by dividing total methane liberation by coal production. To prepare the resource estimates, the specific emissions of a given coal production association (or mine, in the case of the L'vov-Volyn Basin) were multiplied by the balance coal reserves of that coal production association (or mine) to yield the estimated methane resource associated with those coal reserves.

The specific emissions method can be useful for the most preliminary of estimates. However, it can lead to inflated resource estimates in that it includes methane contained in the entire coal bearing package, rather than just the potential target coal seams. This method can also potentially overestimate resources when adjacent coal seams included in the coal resource estimate are the source of some of the methane that is emitted into the mine workings during mining. Where this occurs, the resource estimate may be "double counted" (i.e., the weighted average of the gas liberated during mining would include the gas from the adjacent minable seams and the target seam, but would not consider that some of the methane would be depleted from the resource).

2.3.1 COALBED METHANE RESOURCES OF THE DONETSK BASIN

The coalbed methane resources associated with the balance coal reserves of all mines in Donetsk coal basin are estimated to range from 430 to 790 billion cubic meters. Of these resources, an estimated 140 to 280 billion cubic meters of methane are associated with the coal contained in active mining areas and 109 to 210 billion cubic meters are associated with the basin's industrial coal reserves (i.e., those scheduled for mining).

Additional methane resources are associated with non-balance reserves of coal, as well as with coal resources located beyond the boundaries of the coal production associations. According to the former USSR Academy of Sciences (1990) the total estimated methane resources in the coal seams in the Donetsk basin are 1.2 trillion cubic meters, and the total estimated methane resources contained in the basin (including the coal seams, partings, and surrounding strata) are 25.4 trillion cubic meters.[14] If these estimates are accurate, the coalbed methane resources contained in the coals account for less than five percent of the total methane resources, indicating that there are potentially numerous other types of prospective gas reservoirs within the basin including conventional stratigraphic and structural traps. The methane resources in coal and other strata could be produced if a program of pre-mining drainage or stand-alone development is initiated.

Table 13 summarizes the coalbed methane resource estimates prepared for different coal production associations and types of coal resources in the Donetsk coal basin. As mentioned previously, the low end of the ranges was estimated using the "Average Methane Content" method.[15] The average methane contents shown in Table 13 were calculated using gas content values (determined by desorption measurements) published by the Skochinsky Mining Institute (1991a) for each coal seam identified for mining through the year 2000. These values were multiplied by the various types of coal reserves (shown in Table 6) to estimate coalbed methane resources. The high end of the ranges was estimated using the "Specific Emissions" method. To prepare these estimates, the specific methane emissions were multiplied by the various types of coal reserves.

2.3.2 COALBED METHANE RESOURCES OF THE L'VOV-VOLYN BASIN

The coalbed methane resources associated with the balance coal reserves of all mines in the L'vov-Volyn coal basin are estimated to range from 1.0 billion to 3.3 billion cubic meters. Since coal resource data for all mines and for industrial reserves were not available, methane resource estimates could not be calculated for these categories.

Additional methane resources are associated with non-balance reserves of coal, as well as with coal resources located beyond the boundaries of the mines ("reserve regions"). Based on average gas contents calculated from data supplied by the Skochinsky Mining Institute (1993 and 1991b), and coal reserve data contained in Struev et al (1984), it is estimated that these additional methane resources may amount to 1.9 billion cubic meters of methane.

---

[14] These are volumetric estimates, i.e, based on the area and gas content of the strata

[15] The only exception is the Rostovugol Coal Production Association, whose average methane content (12.5 cubic meters/ton) is higher than its specific emissions content (3.2 cubic meters/ton).

TABLE 13. ESTIMATED METHANE RESOURCES ASSOCIATED WITH COAL PRODUCTION ASSOCIATIONS OF THE DONETSK COAL BASIN

COAL PRODUCTION ASSOCIATION	AVERAGE METHANE CONTENT (m^3/T)	SPECIFIC EMISSIONS	ESTIMATED METHANE RESOURCES (BILLION CUBIC METERS) ASSOCIATED WITH BALANCE RESERVES OF COAL		
			ALL MINES	ACTIVE MINES	INDUSTRIAL RESERVES
DONETSKUGOL	12.9	37.1	30.2 - 86.9	19.9 - 57.3	14.4 - 41.5
MAKEEVUGOL	21.1	53.5	40.8 - 103.5	12.6 - 32.0	9.7 - 24.5
OKTYABRUGOL	18.2	55.8	11.1 - 34.1	7.2 - 22.0	5.8 - 17.9
KRASNOARMEISKUGOL	12.8	34.5	12.6 - 33.9	12.6 - 33.9	5.2 - 14.0
KRASNODONUGOL	21.9	38.4	38.2 - 66.9	11.5 - 20.2	8.7 - 15.3
SHAKHTERSKUGOL	29.9	47.8	18.7 - 29.8	9.5 - 15.1	7.6 - 12.2
DONBASSANTRATSIT	15.9	38.0	25.3 - 60.4	5.8 - 13.8	4.2 - 9.9
LUGANSKUGOL	15.1	23.3	55.0 - 84.9	11.9 - 18.4	8.4 - 12.9
ARTYMOUGOL	17.4	28.5	9.1 - 14.9	6.0 - 9.9	4.8 - 7.9
STAKHANOVUGOL	14.2	23.7	27.1 - 45.3	6.5 - 10.8	4.0 - 6.7
TOREZANTRATSIT	6.7	16.5	7.8 - 18.7	1.7 - 4.3	1.4 - 3.4
DOBROPOLEUGOL	11.0	21.6	37.0 - 72.3	8.3 - 16.3	5.9 - 11.5
ORDZHONIKIDZEUGOL	15.4	25.2	7.5 - 12.3	3.6 - 5.9	2.9 - 4.7
PAVLOGRADUGOL	7.9	8.9	39.9 - 44.9	10.0 - 11.3	7.9 - 8.9
PERVOMAISKUGOL	14.4	25.7	24.2 - 43.3	5.2 - 9.3	3.9 - 6.9
GUKOVUGOL[1]	7.8	8.2	8.9 - 9.3	4.4 - 4.7	3.1 - 3.3
DZERZHINSKUGOL	16.8	26.8	5.0 - 7.9	2.5 - 4.0	1.8 - 2.9
LISICHANSKUGOL	10.9	17.5	7.7 - 12.3	2.6 - 4.2	1.9 - 3.1
ROSTOVUGOL[1]	12.5	3.2	7.0 - 27.4	2.1 - 8.3	1.8 - 7.0
TOTAL			433.1 - 788.9	144.0 - 278.7	108.6 - 209.4
AVERAGE	14.7	22.5			

[1] Gukovugol and Rostovugol Coal Production Associations are located in Russia
SOURCE: SKOCHINSKY MINING INSTITUTE, 1993 AND 1991a

Table 14 summarizes the coalbed methane resource estimates prepared for different mines in the L'vov-Volyn Coal Basin. As mentioned previously, the low end of the range was estimated using the "Average Methane Content" method. The average methane contents shown in Table 14 were calculated using gas content values (determined by desorption measurements) published by the Skochinsky Mining Institute (1991b) for each coal seam identified for mining by the year 1995. These values were multiplied by the balance coal reserves (shown in Table 8) to estimate coalbed methane resources. The high end of the range was estimated using the "Specific Emissions" method. To prepare these estimates, the specific emissions associated with each mine were multiplied by its coal reserves.

TABLE 14. ESTIMATED METHANE RESOURCES ASSOCIATED WITH MINES OF THE L'VOV-VOLYN COAL BASIN (1991)

MINE	AVERAGE METHANE CONTENT (m^3/T)	SPECIFIC EMISSIONS (m^3/T)	ESTIMATED METHANE RESOURCES (Mm^3) ASSOCIATED WITH BALANCE RESERVES OF COAL
10 VELIKOMOSTOVSK	7.3	27.8	215 - 820
#7 VELIKOMOSTOVSK	6.0	28.0	63 - 292
#8 VELIKOMOSTOVSK	10.0	20.2	28 - 57
#2 CHERVONOGRAD	5.7	15.7	181 - 498
#3 VELIKOMOSTOVSK	6.9	17.5	172 - 436
#5 VELIKOMOSTOVSK	3.0	20.7	14 - 99
#4 VELIKOMOSTOVSK	11.4	15.0	112 - 148
#6 VELIKOMOSTOVSK	7.2	23.8	109 - 359
#1 CHERVONOGRAD	4.6	14.8	86 - 276
#9 VELIKOMOSTOVSK	2.9	21.2	10 - 72
#2 VELIKOMOSTOVSK	2.5	6.6	19 - 50
#1 VELIKOMOSTOVSK	2.4	13.1	18 - 96
#1 NOVOVOLYNSK	1.0	9.7	6 - 62
TOTAL			1,033 - 3,264
AVERAGE	6.9	12.8	
SOURCE: SKOCHINSKY MINING INSTITUTE (1993 AND 1991b)			

2.3.3 COALBED METHANE RESOURCES OF THE KUZNETSK BASIN

The coalbed methane resources associated with balance coal reserves of all mines in the Kuznetsk coal basin are estimated to range from 194 to 342 billion cubic meters. Of these resources, an estimated 119 to 204 billion cubic meters of methane are associated with the coal contained in active mining areas and 69 to 120 billion cubic meters are associated with the basin's industrial coal reserves (i.e., those scheduled for mining).

Additional methane resources are associated with non-balance reserves of coal, as well as with coal resources located beyond the boundaries of the coal production associations. According to the Eastern Mine Safety Research Institute, the total estimated methane resources contained in coal seams of the Kuznetsk Basin are 6.6 trillion cubic meters, and the total estimated methane resources contained in the basin (including the coal seams, partings, and surrounding strata) are 26.7 trillion cubic meters.[16] If these estimates are accurate, the coalbed methane resources contained in the coals of the basin account for less than 25 percent of the basin's total methane resources.

[16] These are volumetric estimates, i.e., based on the gas content and area of the strata

Table 15 summarizes the coalbed methane resource estimates prepared for different coal production associations and types of coal resources in the Kuznetsk coal basin. As mentioned previously, the low end of the ranges was estimated using the "Average Methane Content" method.[17] The average methane contents shown in Table 15 were calculated using gas content values (determined by desorption measurements) published by the Skochinsky Mining Institute (1991c) for each coal seam identified for mining through the year 1995. These values were multiplied by the various types of coal reserves (shown in Table 10) to estimate coalbed methane resources. The high end of the ranges was estimated using the "Specific Emissions" method. To prepare these estimates, the specific emissions associated with each mine were multiplied by its coal reserves.

TABLE 15. ESTIMATED METHANE RESOURCES ASSOCIATED WITH COAL PRODUCTION ASSOCIATIONS OF THE KUZNETSK COAL BASIN

COAL PRODUCTION ASSOCIATION	AVERAGE METHANE CONTENT (m^3/T)	SPECIFIC EMISSIONS	ESTIMATED METHANE RESOURCES (BILLION CUBIC METERS) ASSOCIATED WITH BALANCE RESERVES OF COAL		
			ALL MINES	ACTIVE MINES	INDUSTRIAL RESERVES
KUZNETSKUGOL	13.3	24.3	93.0 - 169.8	47.0 - 85.8	30.9 - 56.5
LENINSKUGOL	9.4	23.9	30.8 - 78.2	14.6 - 37.3	8.6 - 21.8
PROKOPEVSKIDROUGOL	11.7	24.0	19.1 - 39.2	17.5 - 36.0	8.5 - 17.4
BELOVOUGOL	13.1	17.9	10.2 - 13.9	10.2 - 13.9	7.8 - 10.6
SEVEROKUZBASSUGOL	12.4	12.1	19.9 - 20.4	12.3 - 12.6	5.8 - 6.0
KISELEVSKUGOL	11.1	11.6	20.4 - 21.3	17.5 - 18.2	7.6 - 7.9
TOTAL			193.9 - 342.3	119.4 - 203.5	69.4 - 120.0
AVERAGE	11.9	21.0			

SOURCE: SKOCHINSKY MINING INSTITUTE, 1993 AND 1991c

[17] The only exception is Severokuzbassugol, whose average methane content (12.4 m^3) is higher than its specific emissions (12.1 m^3).

CHAPTER 3

COALBED METHANE RECOVERY AND UTILIZATION POTENTIAL IN RUSSIA AND UKRAINE

3.1 COALBED METHANE RECOVERY

Many opportunities for increased recovery of coalbed methane exist in Russia and Ukraine. Nearly 4.5 billion cubic meters of methane were liberated from coal mining activities in the Donetsk, Kuznetsk, and L'vov-Volyn coal basins in 1991 (Table 5). Of the 396 mines currently operating in these three basins, 136 mines, or 34 percent, had methane drainage systems in 1991. Drainage systems at these mines recovered 740.7 billion cubic meters, or 17 percent, of the methane liberated by mining, but only 170 million cubic meters (3.8 percent of total liberated) were utilized, resulting in methane emissions of over 4.3 billion cubic meters. Methane that is currently being drained but then vented to the atmosphere could now be used rather than wasted, and significantly more gas could be available for utilization with an integrated approach to methane recovery in conjunction with mining operations.

Reduction of the methane concentration in mine ventilation air for safety reasons is a prime concern in gassy coal mines throughout the world. This can be accomplished by increasing ventilation, or by decreasing the amount of gas liberated into the mine workings from the coals. Increased ventilation can be achieved by increasing the size of the fans or adding additional ventilation shafts. As the amount of methane liberated per ton of coal mined increases, the capacity of the ventilation system must also increase. Experience elsewhere has shown that there are economic limits to the amount of methane that can be removed by ventilation systems alone, and there are no economic benefits to simply venting methane to the atmosphere. Expanded methane drainage can be a profitable means of reducing the methane concentration in ventilation air, in that ventilation requirements are reduced, coal can be more rapidly extracted, and that gas recovered by drainage is often of saleable quality.

3.1.1 METHANE DRAINAGE METHODS

There are several techniques for recovering methane in conjunction with coal mining. The optimal choice among these methods depends on site specific conditions, including:

- the thickness and depth of the targeted seam;
- the amount of methane contained in the coals;
- the number of mined seams;
- the efficiency of the ventilation system.

Table 16 summarizes methane recovery and use options, and shows the support technologies that are necessary to apply these techniques.

TABLE 16. SUMMARY OF OPTIONS FOR REDUCING METHANE EMISSIONS FROM COAL MINING

Considerations	Enhanced Gob Well Recovery	Pre-Mining Degasification	Ventilation Air Utilization	Integrated Recovery *combined strategies*
Recovery Techniques	• In-Mine Boreholes • Vertical Gob Wells	• Vertical Wells • In-Mine Boreholes	• Fans	• All Techniques
Support Technologies	• In-Mine Drills and/or Basic Surface Rigs • Compressors, Pumps, and other support facilities	• In-Mine Drills and/or Advanced Surface Rigs • Compressors, Pumps, and other support facilities	• Surface Fans and Ducting	• All Technologies • Ability to Optimize Degasification using Combined Strategies
Gas Quality	• Medium Quality (11-29 MJ/m^3) (300-800 Btu/cf) (approx. 30-80% CH_4)	• High Quality (32-37 MJ/m^3) (900-1000 Btu/cf) (above 90% CH_4)	• Low Quality (<1% CH_4; usually below 0.5%)	• All Qualities
Use Options	• On-Site Power Generation • Gas Distribution Systems • Industrial Use	• Chemical Feedstocks *in addition to those uses listed for medium quality gas*	• Combustion Air for On-Site/Nearby Turbines and Boilers	• All Uses
Availability	• Currently Available	• Currently Available	• Requires Demonstration	• Currently Available
Capital Requirements	• Low	• Medium/High	• Low/Medium	• Medium/High
Technical Complexity	• Low	• Medium/High	• Medium/High	• High
Applicability	• Widely Applicable • Site Dependent	• Technology, Finance, and Site Dependent	• Nearby Utilization • Site Dependent	• Technology, Finance, and Site Dependent
Methane Reduction*	• Up to 50%	• Up to 70%	• 10-90% recovery	• 80-90% recovery

* These reductions are acheivable at specific sites or systems

Source: U.S. EPA, 1993b

Russian and Ukrainian scientists are among the early pioneers in the development of methane drainage techniques, and tend to use pre-mining degasification and gob well recovery methods. It is important to note that pre-mining recovery in the CIS is done just months before the seam is to be mined, unlike in the U.S., where some mines recover methane several years in advance of mining. Under the CIS approach, the only gas drained is that contained in the coal panel targeted for mining. The principal methods of pre-mining recovery currently in use in the CIS are:

- drainage of the seams from boreholes drilled from the surface;
- drainage from in-seam boreholes drilled from within the mine workings, and;
- drainage from cross-measure boreholes drilled from within the mine workings into the strata surrounding the coal seam.

Concentrations of methane in the gas mixture drained from surface boreholes in the CIS range from 30 to 90+ percent.[18] Concentrations of methane drained from in-seam and cross-measure boreholes average 40 to 50 percent, but they fluctuate greatly and can be as low as 1.5 percent, making utilization of this gas very difficult.

Methods used for drainage of methane from gob areas at some mines include:

- boreholes drilled into the sealed gob areas from the surface;
- boreholes drilled into the sealed gob areas from within the mine workings, either vertically or laterally, and;
- large diameter boreholes (up to 1 m) drilled from the surface into the roadway behind the retreating longwall.

The methane concentrations in the gas mixture obtained with surface gob recovery range from 25 to 50 percent.

Two methods that are used less frequently in all three of the basins are lateral boreholes drilled into the seam to be mined, and downward inclined boreholes, drilled from the entryways. Lateral boreholes are often ineffective because of the thinness of the seams and the low permeability of the coal, which inhibits drainage of the methane at economic or timely rates. Downward inclined boreholes are ineffective because they fill up with water which is either produced naturally in the course of mining, or is piped down from the surface for use in mining operations.

More detailed descriptions of the principal methane recovery techniques used in each coal basin are presented below.

The Kuznetsk Basin: Of the 71 mines in the Kuznetsk Coal Basin, 32 have methane drainage systems. The principal systems of drainage include the use of small diameter boreholes drilled from the surface into the coal seam targeted for mining, and large diameter boreholes drilled from the surface into the roadway located behind the retreating longwall. The small diameter boreholes drilled into the coal in advance of mining provide dual service by pre-draining methane and then being converted into gob wells after mining has passed. Portable pumping

[18] Concentrations as low as 30 percent exist due to leakage of air into the wellbore, and/or leaks in the gathering system. There is no monitoring equipment in place to shut off the system when leaks occur.

stations on the surface are connected to these wells to insure the evacuation of the gas from the gob, and can be moved to other wells as mining progresses. The large diameter boreholes are fitted with a manifold and fan system to remove the gas that is being produced in the gob areas. This methane is vented to the surface, which keeps it from migrating back into the active working face area.

In many active mines of the Kuznetsk Basin, underground drainage methods have been insufficient to drain the quantities of methane needed to meet safe mining standards. This is due to a pressure differential in the mines caused by the conventional ventilation systems and booster auxiliary fans. In many mines, these systems prevent efficient flow of methane into in-mine drainage systems, which cannot create a sufficient vacuum.

Donetsk and L'vov-Volyn Basins: Of the 269 mines in the Donetsk Coal Basin, 100 have methane drainage systems; four of the 17 mines in the L'vov-Volyn Coal Basin drain methane. Because of the depth of mining, underground drainage is the preferred methane recovery technique used in both basins. The two most widely used methods are cross-measure boreholes drilled from the roadways into surrounding strata and boreholes drilled from the roadways into gob areas. Underground booster pumping stations are often used to drain the methane from the boreholes. The methane is either discharged into the ventilation system away from the active mining areas, or pumped to a central vertical well and piped to the surface via surface vacuum pumps.

3.1.2 OPTIONS FOR INCREASED RECOVERY

As indicated by the discussion above, a variety of methane recovery methods are used in Russia and Ukraine, but many mines confront technical difficulties in their application. In addition, in many cases, necessary investment capital is not available to support the development of a fully integrated system of methane recovery. Methane recovery could be significantly improved in Russia and Ukraine through a variety of measures applied in the near term or over longer periods.

In the near term, basic technical improvements could increase the quality and quantity of gas recovered. Such improvements could include:

- gas quality monitoring to prevent large fluctuations in methane concentration;
- repair of leaks in the in-mine and surface gas gathering systems;
- modified drilling and completion techniques, including hydraulic fracturing, for both in-mine and surface drainage wells. This could also include changing the type of material used to cement stand pipes in place and better positioning of drainage wells.

In the longer term, an integrated approach to mine drainage could maximize the recovery of methane and improve mine profitability and safety. This approach could include recovery of methane before, during, and after mining, both from the surface and within the mine. Table 16 summarizes the four main methane recovery options and indicates the potential for recovery of each.

If technical programs were instituted which included the near-term improvements suggested above, an immediate result would be reduced fluctuation of methane concentration in the gas, thereby increasing the options for use. If all methods of recovery were implemented and coordinated with mining activity, as much as 80-90 percent of the methane liberated during mining could be recovered.

The design of an optimal methane recovery program will be determined by many factors, including technical considerations such as mining conditions and mine safety requirements, gas quality and quantity, economic factors, investment considerations, regional energy needs, environmental objectives, and time considerations. In some cases, the full range of approaches could be applicable while in others, only one or two methods would be feasible.

3.2 COALBED METHANE UTILIZATION

Increased methane recovery will not be economically and environmentally feasible unless it is accompanied by an aggressive program to increase methane utilization. As shown in Table 5, only 170 million cubic meters of the methane drained from mines in Russia and Ukraine in 1991 were utilized, only at mines in the Donetsk Basin, and almost exclusively in boilers. An additional 570.5 million cubic meters was captured by drainage systems only to be vented to the atmosphere. The venting of this recovered gas, which is suitable for use as fuel in many applications, represents a serious waste of energy. Improved methane drainage could greatly reduce this waste by increasing the amount and quality of coalbed methane available for utilization.

The best utilization options for methane from coal mines will vary from region to region, depending on the quality and quantity of the gas and local energy markets. In the Donbass and the L'vov-Volyn Basin, coalbed methane could be used as an alternative to natural gas. Ukraine is a net importer of natural gas so any replacement of natural gas with coalbed methane would reduce its dependence on imports. In the Kuznetsk Basin, high-quality coal is exported out of the region while low-quality coal is consumed locally in the domestic and industrial sectors. Thus, in this region coalbed methane use could replace this low-quality coal consumption, which would improve local air quality. The principal utilization options are discussed in more detail below.

3.2.1 DIRECT INDUSTRIAL USE OPTIONS

The Donetsk and Kuznetsk Basins are both heavily industrialized regions, and coal is used extensively for steam and electrical generation. The largest consumers of energy in these regions are machine factories, petrochemical plants, metallurgical factories, and of course the coal industry. The mining, power, and industrial complexes which dominate both regions were originally developed with an emphasis on large-scale production, often at the expense of efficiency, profitability, and the environment. The sheer size of these complexes makes the task of addressing economic, social, and environmental reforms very difficult.

Coalbed methane utilization would clearly benefit these regions by helping them meet increasing energy needs with a less polluting, local energy source. Like conventional natural gas, coalbed methane is an environmentally acceptable fuel because when burned, it emits virtually no pollutants such as sulfur dioxide or particulates, and it emits much less carbon dioxide than coal and oil. Some fuels that coalbed methane could replace are brown coal, low-quality hard coal, and coke oven gas. Specific uses will be dependent on the conditions in the vicinity of the mines, but could include:

- on-site coal drying;
- on-site heating of water and air;
- heating of ventilation air;
- substitution for coke gas, coal, or gas in local industries.

Displacement of Brown Coal and Low-Quality Hard Coal

Combined heat and power generation facilities located at mine sites, as well as commercial and residential boilers, often use low-quality hard coal or brown coal as a fuel. These fuels can be rejected material from coal preparation plants, sub-quality coal that a mine does not ship to a preparation plant, or inexpensive brown coal mined locally that has little value on the world market. The fuels often have low heating value, high ash and high sulfur content. During winter months when heat and electrical requirements are high and atmospheric inversions are common, air pollution generated by these facilities can overwhelm the surrounding communities.

Coalbed methane could readily displace the use of these low-grade coals. In the Donetsk Basin, some of the methane that is recovered by drainage is already used in boilers, but in the Kuznetsk and L'vov-Volyn Basins, none of the methane is used after being drained from the mines. The availability of coalbed methane may permit conversion of existing coal-fired boilers to gas, reducing local pollution. Any displacement of brown coal or low-quality hard coal use with coalbed methane would provide environmental benefits (Box 3).

BOX 3: THERMAL DRYING OF COAL WITH COALBED METHANE

At many mines, drying of coal at coal preparation plants is accomplished by using low quality coal to heat air that is circulated through the coal to remove surface moisture. A preparation plant visited in L'vov-Volyn used high sulfur coal for thermal drying, and is now being required to install sulfur removal systems on the smokestacks. The cost of the additional equipment is high and may be prohibitive. As an alternative, the large quantities of methane emitted from nearby coal mines could be used for this purpose. The circumstances described here are not unusual, and similar situations are found in each of the basins that were studied.

Most of the coal preparation plants are owned by a coal trading company to which the raw coal is sold. The trading company then sells the washed coal to power plants or other consumers, leaving only the lowest quality unwashed or reject coal for the preparation plant to use for its energy needs. The methane produced by the nearby coal production associations could be used for generation of the thermal energy requirements by direct firing of the methane, which would have substantial local and global air quality benefits.

Displacement of Coke-Oven Gas

In 1991, an estimated 11.3 billion cubic meters of coke-oven gas were produced in the Donetsk region. Unlike in the U.S., much of the coke gas is transported to off-site users. Information concerning consumption by sector was unavailable. It has been estimated, however, that 10 percent or more of the coke-oven gas is being vented or underutilized. No information on coke-oven gas production or consumption was available for the other study regions.

The majority of coke-oven gas is produced as a by-product of the conversion of coal to coke for use in metallurgical industries. As heavy industry in the region declines, however, coke oven gas production will also decrease. Present consumers of coke-oven gas will need to identify alternative gas fuels, such as coalbed methane, to meet their energy needs.

Coke-oven gas and methane recovered by coal mines can have similar calorific values. Thus, as production of coalbed methane increases at mines, it could be transported via the existing coke-oven gas pipelines, and over time, it may be possible to phase out the off-site transportation of coke-oven gas and replace it with coalbed methane. It should be recognized, however, that there is a limit to the distance that mine drainage gas of this quality can be economically transported, as compression costs increase with distance.

Displacement of Imported Natural Gas

In some regions, coalbed methane could displace natural gas imports, eliminating the need to purchase or trade for natural gas. For example, methane emissions from mines in the L'vov-Volyn Basin and Ukrainian portion of the Donetsk Basin were nearly 3.3 billion cubic meters in 1991. If the quality of the recovered coalbed methane can be improved, this gas could displace natural gas imported into these regions, as the infrastructure for natural gas transportation and utilization is already in place.

3.2.2 NATURAL GAS PIPELINE SYSTEMS

Coalbed methane that is produced in sufficient quantity and quality can be transported in natural gas pipeline systems to end-users. Several U.S. coal mines have been able to do this with methane recovered during coal mining, and it may also be possible at some coal mines in Russia and Ukraine. Coalbed methane drained from surface wells in advance of mining should be pipeline quality, and it may be possible to produce pipeline-quality methane from gob wells as well.

The feasibility of this methane utilization option depends on the availability of the pipeline infrastructure to transport the methane. In general, Russia and Ukraine have well developed pipeline systems (Figure 15), although some regions are bypassed. The Donetsk and Kuznetsk regions are heavily industrialized and natural gas is an important source of energy in these areas, which indicates that the required pipeline infrastructure may already be in place. The L'vov-Volyn region, in contrast, is less industrialized and may have a more limited infrastructure. Thus, the most attractive utilization options may be to use recovered methane at mines or affiliated industries.

In all three regions, it will be necessary to evaluate the adequacy of existing infrastructure on a site-specific basis during project development. The issues that should be investigated include the energy value of the gas vs. transmission costs (i.e., the economics of compression); the proximity of the production site to gas markets; and the life of the resource.

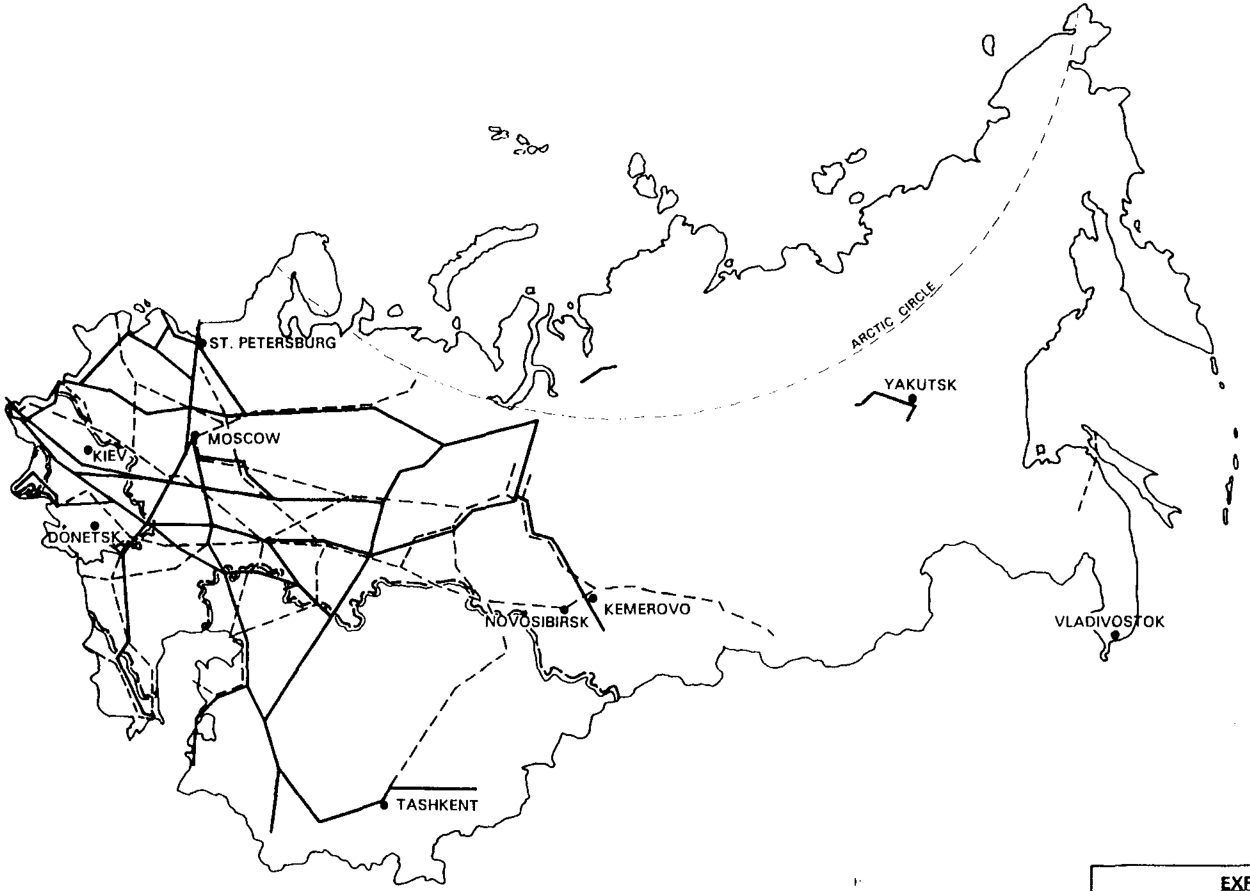
3.2.3 POWER GENERATION OPTIONS

Currently, there are only 17 mines in the Donetsk Basin that utilize coalbed methane, and all of them use it in boilers at the mine site. No mines in the L'vov-Volyn or Kuznetsk regions utilize coalbed methane. Opportunities exist for the generation of electricity and steam at mine power plants; electrical power is used at all coal mines and thermal heat is supplied to the surrounding communities for district heating. Currently, these mines generate the majority of their electricity and steam from coal. Coalbed methane could displace the burning of coal which pollutes, and, in regions such as the Donetsk Basin, is in increasingly short supply. Several power generation options are discussed below.

Converting Boilers to Intermittent Use of Gas

It may be possible to expand the use of coalbed methane in mine boilers, so that they consume only gas or burn it intermittently with hard coal (Box 4). The idea of intermittent, rather than year-round gas use may be particularly attractive for larger power plants in the event that there is not enough coalbed methane to meet year-round needs. Intermittent gas use would allow the power plant to take advantage of low summer prices for methane, while maintaining the flexibility of being able to burn coal when gas is unavailable or more expensive. Additional benefits for plant operations would include reduced furnace corrosion and erosion, reduced soot and slag formation, less ash disposal, reduced need for electrostatic precipitators, and reduced NOx emissions (Fay et al, 1986).

FIGURE 15. MAJOR OIL AND GAS PIPELINES, COMMONWEALTH OF INDEPENDENT STATES



EXPLANATION

- – – – OIL PIPELINE *
- —— GAS PIPELINE *
- ● CITY
- * *MAY REPRESENT MULTIPLE LINES*

SCALE

0 500 1000 km

SOURCE: CIA, 1985

BOX 4: GENERATION OF ELECTRICAL AND THERMAL ENERGY FOR MINE USE

In the Donetskugol Production Association, there is a mine that uses coalbed methane as fuel for its boiler plant. Eight years ago, the boiler used methane exclusively, but since then the amount of methane being produced by the mine's drainage program has decreased from 2,200 cubic meters per hour to around 800 cubic meters per hour. Presently this boiler uses methane when it is available and switches to low quality coal when the quantity or quality of the gas is insufficient.

Although overall production of gas has decreased over the years, large amounts of gas are periodically encountered during mining, indicating that a comprehensive methane drainage program could potentially result in higher gas production. Furthermore, this mine is one of eleven in the coal production association that have methane drainage programs in place. Only five of these mines use any recovered methane in their boiler plants, however; the rest rely entirely on low quality coal for fuel. Even in the years when methane production was high, no attempt was made to fuel these other boilers with methane due to lack of capital for investment in the required surface facilities to collect, process, and transport the gas to the boiler.

Similar situations exist in most of the coal basins in the CIS. Many mines need to heat water for space heating and bathhouses. In addition, it is essential and to heat mine ventilation air during the winter months in many areas, particularly in the Kuznetsk Basin. With installation of improved methane drainage systems to recover gas of reliable quantity and quality and access the necessary capital to invest in surface equipment, methane from the coal mines could be readily used for these purposes.

Gas Turbines

Gas turbine generators are widely used in the United States by electric utilities to provide power during peak demand times. Gas turbines are more efficient than coal-fired generators, cost less to install, and are available in a large range of sizes. This allows for the addition of smaller increments of capacity to handle peak consumption, rather than investing in larger, capital intensive coal-fired units that would be underutilized.

In addition, gas turbine exhaust is a good source of waste heat which can be utilized to generate steam in a heat recovery boiler. When this steam is used for process or district heating, this process is known as cogeneration. If this steam is used in a turbine generator for additional electrical power production, the system is known as a combined cycle. If the steam were injected into the hot gases flowing to the thermal turbine, the system would be known as a steam injected turbine (STIG). All of these uses improve the thermal efficiency of the system.

Gas turbines fueled by coalbed methane recovered from mining gob areas have been successfully operated in England, Australia, Germany, and China, and have undergone experimental use in the United States (Sturgill, 1991). In most of these cases the waste heat is being recovered from the turbine stack for use in an auxiliary thermal process. These projects range in size from about 3 to 20 MW, which can frequently supply a significant portion of the mine's electrical needs. Gassy coal mines in Russia and Ukraine should have no problem producing similar amounts of power (Boxes 5 and 6).

The Gas Institute in Kiev, Ukraine has initiated preliminary research on development and utilization of turbine generators fueled with methane mixtures ranging from 20-100 percent (Karp, 1992). To date, this technology has not been used at coal mines in Russia or Ukraine, however.

BOX 5: COALBED METHANE- FUELED DESALINATION OF EFFLUENT MINE WATERS

One potentially attractive use of coalbed methane is powering mine water desalination plants. Approximately 870 million cubic meters of saline water are pumped from the coal mines of the Donetsk Basin annually. In addition to salts, the water contains heavy metals and lubricants used in the mining equipment. Approximately 80 percent of this volume is discharged into the rivers and the remaining 20 percent, which is likely the least saline, is used by the mines. The water that is discharged into the rivers is typically pumped from the mines into settling ponds to separate silt and other suspended materials. However, these ponds are not lined, which allows seepage of water into the underlying strata. Virtually no desalination of mine waters is performed before allowing discharge into the rivers. As a result of these practices, fresh groundwater supplies have been contaminated and there is a shortage of fresh water in the Donetsk.

Mines in the Donetsk are investigating various water treatment and disposal options, and desalination plants represent one potentially attractive option. Ultimately, water clean-up is likely to be the responsibility of the mining production association, and since the mining enterprise owns the coalbed methane recovered in conjunction with mining, the use of the methane as an energy source for an integrated desalination system may make these types of projects economically feasible. An integrated desalination plant that discharges no saline water is very energy intensive. A zero salt discharge system couples a reverse osmosis system with a brine distillation plant to optimize the recovery of fresh water. This design requires both electrical and thermal energy for operation, suggesting that the feasibility of a coalbed methane fueled cogeneration system powering an integrated desalination plant is worth investigation.

BOX 6: REFRIGERATION OF AIR FOR VENTILATION OF DEEP HOT MINES IN THE DONETSK BASIN

A problem common to many of the mines in the Donetsk Basin is the increase in heat associated with the increase in depth of mining. As an example, the Zasyadko mine operated by the Donetskugol Production Association is currently mining at depths of 1250 m where the temperature of the rocks is in excess of 50 degrees C. To comply with regulations and for the workers in the mine to be able to do their job effectively, the temperature of the ventilation air in the mine must be lowered to 30 degrees C.

A facility is currently being constructed at this mine to cool the ventilation air, using low-quality coal to generate electricity to power the refrigeration system. This system will require three 1600 kW motors to supply 9 million kcal/hr of cooling capacity. An alternative to the coal-fired generator would be a new efficient gas turbine, which could generate the 4800 kW needed to power the three motors. Assuming 25 percent efficiency for the turbine, a total of 65.4 million BTU/hr would be required, or 2067 cubic meters of pure methane per hour. Currently, 6000 cubic meters per hour of 38 percent methane is being recovered at the mine. All of this gas is being vented from the mine drainage system into the atmosphere. It is estimated that 5440 cubic meters per hour of this recovered methane would be needed to power the refrigeration system.

Internal Combustion Engines

Internal combustion (IC) engines can generate electrical power utilizing medium to high-quality coalbed methane. Typical capacities of IC engines range from several kilowatts to several megawatts. These sizes are much smaller than gas turbines and would be more compatible with the production of coalbed methane from a single well. As an example, a 1 MW IC engine would require approximately 10,000 cubic meters of methane per day. IC engines can use medium-quality gas (30-80 percent methane) such as that produced by pre-mine drainage and surface gob recovery.

Internal combustion engines are modular in design and require little specialized expertise to install and maintain. Due to their small sizes, they can be relocated easily if the gas supply is depleted. Previously, variations in gas quality caused some problems with the use of mine gas in IC engines, but with modern integrated control systems it now appears possible to accommodate these fluctuations.

Plans have been announced to install small mobile diesel generators at two mines in the Kuznetsk Basin, with plans to eventually install seven in this region, and a total of 30-40 annually in Russia. These motors have been designed by the Skochinsky Institute (Serov, 1992) and are built in a converted military factory in Russia. Presently, the design allows the use of a mixture of 10 percent diesel and methane with concentrations ranging from 5 to 100 percent. The final design will be able to use exclusively methane. These generators have an electrical generating capacity of 2500 kW plus heat.

Cofiring with Natural Gas

Cofiring is the concurrent firing of natural gas and coal in a boiler (with the gas typically providing 5 to 15 percent of the thermal input). The only modifications required to the boiler are the addition of gas supply piping, gas ignitors, and warmup guns. Cofiring with gas has many potential benefits, including reduced sulfur dioxide emissions, greater fuel flexibility (allowing the utilization of lower cost, lower quality coal without the affects of increased pollutants), improved plant capacity factor, and production of saleable fly ash. Cofiring can be accomplished at very low capital costs and with no technological risk. At some power plants in the United States, cofiring has reduced operating costs by millions of dollars per year (Vejtasa et al, 1991; CNG, 1987). In addition, if for any reason natural gas was no longer available, the boiler could continue to operate entirely on coal.

3.2.4 VENTILATION AIR UTILIZATION OPTIONS

Currently, there are no demonstrated uses for methane contained in mine ventilation air, due to its low concentration. Numerous studies have examined the possibilities of purifying this gas, but with currently available technology, the expense is prohibitive. However, as technology progresses, it may become economically feasible to enrich the gas contained in mine ventilation air using some of the methods discussed in Section 3.2.5.

At present, the best options for utilization of ventilation air appear to be as part of the fuel mixture in steam boilers or gas turbine generators. The ventilation air could supply all or most of the combustion air required, while the methane in the air would supply a portion of the needed fuel.

In order to assess the potential for use of ventilation air, the following issues should be investigated (Energy Systems Associates, 1991):

- the number of ventilation shafts, flow rates, and volume of air leaving each shaft;
- the methane concentration in the ventilation air;
- the distance between the ventilation shafts and the mine power plants, and;
- detailed information on power plant characteristics, annual output, efficiency, and projected power utilization.

The feasibility of using recovered ventilation air must also be evaluated. If it is feasible, the use of ventilation air should be considered as part of an integrated methane drainage program. It is important to note that for this to be economic, the targeted boiler should be within about 2 km. of the source for the ventilation air. In cases where it is not feasible for either technical or economic reasons, integrated recovery programs should be employed to reduce the amount of methane that is liberated by the ventilation systems. Studies indicate that with aggressive use of these three methane drainage systems, up to 90 percent of the methane could be recovered without use of ventilation air.

Ventilation Air Use in Coal-Fired Boilers

Preliminary technical feasibility analyses have indicated that ventilation air from mines could be transported within many types of power plants through the existing boiler air ducts and coal circuits without modifying the stability or safety of the boiler operation (Energy Systems Associates, 1991; Bain, 1991). Methane contained in the ventilation air would be consumed in the boiler, delivering heat to the process. The amount of heat would depend on the concentration of methane. With typical boiler efficiencies and air requirements, if the ventilation air contained 0.5 percent methane, it would supply approximately 7 percent of the boiler's energy, and if the ventilation air contained 1 percent methane would supply 14 percent of the boiler's energy.

In addition, if methane were used to generate a percentage of a boiler's energy, reducing the amount of coal required, the results would be less coal handling, lower pulverizer power requirements and maintenance costs, reduced furnace slagging, lower ash handling, and lower emissions of particulates, SOx, and NOx (Pilcher et al, 1991). As coal-fired boilers are currently used at every mine in the coal basins studied, the possibilities of utilizing ventilation air in the boilers should be investigated.

Ventilation Air Use in Gas Turbines

The combustion air requirements of a gas turbine correlate to its generating capacity. The combustion air required for simple cycle gas turbines is approximately 10 m^3/hr of air per kilowatt of installed turbine capacity. This calculation is based on manufacturer operating and design data for turbines in the 1 to 100 MW size range. Slightly lower air flows are required for the more complex combined cycle plants. This flow is about three times the flow required for steam boilers as a result of turbine cooling requirements. The turbine temperature should be sufficient to totally combust the methane in ventilation air, providing heat to the process.

At 0.5 percent methane, ventilation air would supply about 15 percent of the heat to the turbine. When the ventilation air contains 1 percent methane, approximately 30 percent of the turbine energy can be derived from this waste product. Obviously, this would significantly increase the viability of a gas turbine operation.

Currently, there are no known turbines operating in the three specified coal regions of Russia and Ukraine. If turbines are installed to use medium quality mine gas, the possibility of also using mine ventilation air should be considered.

3.2.5 GAS ENRICHMENT

Much of the 1.4 billion cubic meters of gas recovered annually by mine methane drainage systems and then vented to the atmosphere has methane concentrations ranging from 30 to 50 percent. This gas is not considered "pipeline quality" (more than 95 percent methane). Furthermore, its concentration may decrease over the life of the producing well. If a more aggressive mine drainage and gob gas recovery program is pursued in the mines presently operating, the amount of recovered gas with methane concentrations above 50 percent could likely increase.

To the extent that pipeline quality gas is required for various uses, it may be necessary to enrich the gas recovered by mine methane recovery systems. Current research suggests that two types of gas enrichment technologies are best suited to small-scale applications, such as coal mines, typically producing less than 300,000 cubic meters of gas per day. These technologies are pressure swing adsorption and membrane gas separation.

Cost comparisons among various processes are complex and situation dependent. Because these technologies do not have a long history, actual costs are not yet well established. However, the following cost approximations provide general guidelines. To enrich a feed gas containing 70-80 percent methane to pipeline quality, operating costs range from approximately \$0.01/m^3 to \$0.04/m^3 USD for pressure swing adsorption systems, and from \$0.03/m^3 to \$0.09/m^3 USD for membrane gas separation systems (Sinor, 1992; Meyer et al, 1990). The cost of enrichment of a mixture of 30-50 percent methane is not known and should be researched where such projects are considered for coal mines. It is important to bear in mind that, because this gas would otherwise be vented to the atmosphere, the cost of the feed gas is effectively zero, enhancing the economics.

Pressure Swing Adsorption

In this process, a molecular sieve is used to remove nitrogen or carbon dioxide from the feed gas stream. The process proceeds in stages. The gases are separated by an adsorbent bed, which selectively adsorbs either the unwanted gases or the hydrocarbon gas under pressure. In the second stage, a vacuum is applied to the adsorbent bed, causing the adsorbed gas to be released. By alternately exerting pressure and placing a vacuum on the system, timing the pressure swing to take advantage of the rate at which the gases are selectively adsorbed, gas separation is achieved.

Presently available pressure swing systems use carbon molecular sieves. Another type of molecular sieve, zeolites, holds promise for gas separation applications. In the past, synthetic zeolites have been used for limited gas separation applications, and a recent research development project demonstrated that some species of naturally occurring zeolites perform at least as well as the carbon molecular sieve for separation of nitrogen and carbon dioxide from methane.

Membrane Gas Separation

Membrane gas separation is based on the differences in the diffusivities and solubilities of various gases within a membrane material. The relative rate at which different gases pass through the membrane is called the selectivity. A polymeric organic membrane system has been used for carbon dioxide removal, and the development of a membrane system to selectively remove nitrogen from natural gas is underway.

Membrane separation units have several features that make them attractive for gas separations. Within the basic unit itself, there are no moving parts, membranes can be easily replaced, variations in flow rates can be easily accommodated, and startup can be accomplished in a very short time.

3.2.6 UNDERGROUND GAS STORAGE

Underground storage should be considered an integral part of any coalbed methane use strategy. With storage facilities, gas can be used as demand dictates. For example, gas produced when demand is low (such as during the summer) can be stored and used during periods of higher demand. This strategy would also reduce the dependency on imported natural gas.

In many gas producing areas of the world, underground storage is the most common means of storing gas to meet peak seasonal market requirements. Preferred reservoirs are porous reservoirs, including depleted oil and gas fields as well as aqueous reservoirs. Other sites used for storage are natural and man-made salt and rock caverns. Underground gas storage was first utilized in the United States in 1916, and today there are more than 400 storage fields with a total capacity of over 228 billion cubic meters of gas, which is equivalent to almost half the annual U.S. gas consumption. In addition, utilization of underground gas storage is beginning to allow capitalization of spot gas market purchases, managing of transportation imbalances, handling of short-term standby supply needs, enhanced oil recovery, hedging on the gas futures market, and managing of marketing and production by producers (Thompson, 1991).

Underground gas storage could play a key role in expanding methane recovery and utilization in Russia and Ukraine. Coalbed methane in the Donetsk Coal Basin, for example, is used only for mine-related activities, such as heating of ventilation air and surface facilities; during the winter months, most of the methane that is recovered is utilized, but during the summer months, much of it is wasted. Storage facilities could help make the supply more reliable, eliminating the summer waste, and allowing for expansion of utilization systems.

In the Kuznetsk Basin, methane is not even used at the mines. The Kuznetskugol Coal Production Association, for example, recovered 57 million cubic meters of methane in 1991, but states that, at any given mine, the quality and quantity of methane are not sufficiently consistent to warrant development of utilization systems. Similar situations exist elsewhere in the Kuznetsk Basin and in the other basins studied. In cases such as this, a mine that does not produce a sufficient methane could join with similar mines in linking to a central gas storage facility, resulting in adequate quantities of methane for use at the mines and perhaps beyond.

In addition to conventional storage facilities, another available option is gas storage in abandoned hard coal mines. Two abandoned mines have been utilized for imported natural gas storage at two locations in Belgium since the early 1980's. Criteria essential to the success of gas storage in abandoned coal mines have been identified (Moerman, 1982) as follows:

- The mine must be separated from adjacent workings by impermeable barriers.
- The overburden rock must be thick enough and preferably water-bearing, to secure a tight cap with no natural communication to the surface.
- The abandoned workings must be dry, no water should be flowing into the mine.

If a selected mine meets all of these criteria, the next step in development is to identify and seal all openings (shafts and galleries). Pipes would need to be installed through some of these seals for future gas injection. In addition, the storage capacity of the mine and the maximum operating pressure would have to be determined. Finally, consideration must be given to the reaction of the rock mass to the gas, specifically, the ability of the unmined coal to adsorb any gas injected into the mine. This phenomenon greatly enhances the ultimate storage capacity of the mine.

The Belgian mines using this technique are described as having an impermeable Miocene clay cap over the coal bearing strata, a water saturated zone overlying this cap, a well-understood geological setting, and structural isolation created by faults. In addition, much of the gas stored in the Belgian facilities is actually stored in the remaining coal through adsorption, greatly increasing the current storage volume of the mine.

Potentially appropriate conditions for underground gas storage in mines exist in some parts of the basins studied in Russia and Ukraine. Further evaluation would, of course, be necessary to determine feasibility. In assessing the economic feasibility, the cost of developing facilities should be weighed against the costs of importing and/or the transporting of natural gas, and the cost of venting valuable coalbed methane to the atmosphere.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER ACTION

4.1 OVERVIEW

Development of coalbed methane as an integral part of the energy economies of Russia and Ukraine will require developing and implementing comprehensive programs for resource development and utilization. Such programs would recognize the importance of developing coalbed methane in concert with coal extraction. As has been described in previous chapters, economic benefits to coal mining are enhanced when methane drainage and use are improved. Many opportunities for the near-term use of coalbed methane exist. The most likely candidates for near-term increases in coalbed methane development are projects that will directly impact the economics of the mining industry and improve the safety and health of miners and the surrounding community. Furthermore, regional economic benefits, such as jobs and an increased domestic energy base, will occur as coalbed methane recovery and use increases. As has been stated previously, coalbed methane is most valuable when used locally by the mine from which the coalbed methane is being recovered or in nearby allied industries. Value of the methane as a substitute for other fuels is increased when enrichment, drying, and compression of the gas are not required. Of course, if large amounts of imported conventional natural gas are consumed, preparation required for upgrading coalbed methane for injection into pipelines may be a viable economic option.

There is a keen interest in coalbed methane development in both Russia and Ukraine. Agencies such as the Ministry of Fuel and Energy of Russia and the State Coal Committee of Ukraine, numerous coal industry research institutes, as well as several of the coal production associations of the L'vov-Volyn, Donetsk, and Kuznetsk basins are all actively investigating opportunities to expand methane recovery and use.[19] Based on the results of this study, it is clear that the development and utilization of coalbed methane in Russia and Ukraine, and specifically the three study regions, should be further investigated. Mechanisms for encouraging or facilitating coalbed methane use should be evaluated, appropriate policies and incentives should be developed, and development and utilization of coalbed methane should be a priority in the energy sector restructuring programs of the two republics.

[19] An example is the Skochinsky Mining Institute's "Methane" program, a proposed project whose goal is development of improved techniques for coalbed methane recovery and utilization.

Foreign governments and international agencies, as well as foreign companies, can assist Russia and Ukraine with this process by providing financial and technical assistance for coalbed methane projects. Follow-up efforts to this report should be designed to inform, educate, and train the appropriate technical experts and government personnel regarding the potential role for coalbed methane development. Subsequent studies should evaluate the feasibility of coalbed methane development and utilization at specific sites, ultimately leading to the implementation of demonstration projects and/or commercial coalbed methane projects.

4.2 FOLLOW-UP TECHNICAL ASSISTANCE ACTIVITIES

4.2.1 TECHNICAL PRE-FEASIBILITY ASSESSMENTS

The first step in identifying attractive project opportunities is to prepare pre-feasibility assessments of the applicability of several methane recovery and utilization approaches at mines and/or coal production associations in the L'vov-Volyn, Donetsk, and Kuznetsk basins. On the recovery side, the assessments should evaluate opportunities to expand methane recovery using pre-drainage vertical wells, intensified in-mine drainage, and post-mining drainage using in-mine and vertical gob wells. In assessing alternative technical approaches, the opportunity to both increase gas quantities and improve gas quality (concentration), while at the same time decreasing the methane liberated to the atmosphere during mining, should be evaluated. The viability of different utilization options should also be examined. Several possible pre-feasibility assessments are detailed below.

The purpose of the pre-feasibility studies should be to examine the conditions at one or more coal production associations or mines to determine where particular project types might be most attractive and which types of projects would have the best applicability elsewhere in Russia and Ukraine. Based on the results of the pre-feasibility assessments, candidate projects for more detailed feasibility studies and development as demonstration or commercial projects could be identified.

Given the magnitude of the coal basins in Russia and Ukraine and the wide range of potential project types, it is likely that several pre-feasibility studies could be undertaken. Depending on particular conditions in the study areas, a wide range of projects and issues would likely be considered in different areas. Some of the components of the pre-feasibility analyses are discussed briefly below.

Evaluation of Opportunities to Expand Methane Drainage

One of the most important issues to be examined in the pre-feasibility assessments will be the potential to expand methane drainage, thereby increasing the amount of available fuel and reducing methane emissions to the atmosphere. The pre-feasibility studies should examine the current methane drainage practices employed at selected mines and evaluate the potential to expand methane recovery, either through modifications in existing practices or introduction of new drainage techniques.

This aspect of any pre-feasibility assessment should be undertaken by methane drainage consultants in conjunction with in-country mining officials. Analyses would likely include a review of geologic and other data, mining plans, methane drainage designs, and ventilation and methane drainage data. The team would identify new methane recovery approaches that could be further evaluated and tested during later feasibility studies.

Evaluation of Opportunities to Expand Methane Utilization

As discussed in Chapter 3, there are many opportunities for methane utilization that should be evaluated at the coal mines of Russia and Ukraine. These opportunities include: power generation, chemical feedstocks, and direct use by industry and residences, as well as the use of ventilation air as combustion air for on-site/nearby turbines and boilers.

During the pre-feasibility studies, methane utilization experts, working closely with mining officials and other relevant local representatives (i.e., local industries, power generation facilities) would assess the most attractive utilization opportunities in the vicinity of the selected sites. These analyses would be conducted in conjunction with the assessment of opportunities to expand methane drainage so as to optimize the use of as much methane liberated by the mines as possible. Based on the results of the pre-feasibility assessments, one or more utilization options might be recommended for further study through a feasibility assessment.

Evaluation of Gas Enrichment Opportunities

Depending upon the energy needs in the vicinity of particular mines, and the methane recovery programs that are most feasible, it may be necessary in some areas to upgrade medium-quality methane in order to develop uses for it.

As discussed in Section 3.2.5, two types of gas enrichment technologies may be well-suited to enriching low-methane gas recovered by mine methane drainage systems. These technologies, pressure-swing adsorption and membrane gas separation, have proven feasible for feed gas streams containing 70-80 percent methane. However, the feasibility of enriching low-methane gas (30-50% methane) has not been tested.

The need for gas enrichment should be considered as part of ongoing pre-feasibility studies, to ensure that the most effective utilization options are identified. For sites where gas enrichment appears to be necessary and potentially attractive, the pre-feasibility study phase would likely be followed by preparation of a detailed feasibility study and, if warranted, a demonstration project.

Evaluation of Underground Gas Storage Opportunities

Similarly, at some sites expanded gas storage capacity may be required in order to effectively utilize the methane that is produced by the mine. The ability to store coalbed methane can result in more effective utilization by allowing for seasonal fluctuations in demand. Options for increasing gas storage could include enlarging existing underground storage facilities, developing new facilities in depleted natural gas reservoirs, and developing new facilities in abandoned mines.

Gas storage experts, working closely with local gas storage experts, should identify potential storage sites. The need to expand gas storage in various areas should be considered during the pre-feasibility analyses, and the most attractive gas storage options should be identified. For selected projects, the feasibility of expanding gas storage capacity could then be evaluated in the later phases of project development.

The technical and economic feasibility of a proposed gas storage project would need to be assessed. One aspect of such an assessment would be a comparison of the cost of transporting natural gas from outside the region or even outside the republic, or of using other fuels such as coal, versus the potential benefits of expanding underground storage for coalbed methane.

Evaluation of Water Disposal Options

When considering a coalbed methane recovery program in any region of the world, it must be recognized that production of gas, particularly using vertical pre-drainage, often results in coproduction of water present in the coal seams, and/or the strata adjacent to the seams. The volume of water produced depends on the hydrogeologic characteristics of the coal-bearing formations, and it is difficult to predict this volume when planning exploration in a new area. It is possible that coalbed methane production in the three study regions will also result in water production, but given the structural complexity of each of the regions, the volume of water produced could vary widely. It is also difficult to predict the salinity of the water which may be produced, but it is likely that it will resemble that produced by nearby coal mines.

Although it is difficult to predict how much, if any, water would be produced from coalbed methane wells in the coal basins in Russia or Ukraine, the potential for water production and the need for environmentally sound disposal must be an important consideration in project development. Fortunately, there are many economically and environmentally successful water treatment and/or disposal methods that could be applicable to the treatment of both mine water and coalbed methane water. In cases where water quality is sufficiently high, water can be discharged to streams after relatively simple pretreatment procedures, as is done in some coalbed methane producing regions of the U.S. For waters of lesser quality, options include injection of saline water into wells (into reservoirs shallower or deeper than the coal seams, depending on the circumstances); treatment of saline water by reverse osmosis, distillation, or electrodialysis; or a combination of these methods. These and other saline water management techniques are discussed in Wacinski et al (1992).

Historically, saline water produced from coal mines in Russia and Ukraine has been discharged into rivers and streams with little or no treatment. Because this practice has had severe environmental and economic consequences, programs aimed at improving management of saline mine water should be formulated. If saline water is co-produced with coalbed methane, it would be advantageous to jointly dispose of water produced by mines and coalbed methane wells. Some saline water treatment systems, such as distillation plants, could be fueled by coalbed methane.

Issues related to water disposal should be considered in conjunction with the analyses undertaken during the pre-feasibility stage related to the introduction of new methane drainage technologies. At sites where water disposal could be required, a preliminary assessment of the most promising water disposal options should be included in the pre-feasibility assessment. The economic and technical feasibility of these options could then be evaluated in later stages of project development, as warranted.

4.2.2 FEASIBILITY ASSESSMENTS

Based on the results of pre-feasibility assessments, more detailed studies that examine the technical and economic feasibility of the most promising projects should be undertaken at selected sites. These studies could be financed by private companies or using various U.S. government and other programs which are available to encourage project development. The U.S. Trade and Development Agency, for example, can finance feasibility assessments for projects that meet its criteria and are requested by an agency of the host government.

Feasibility studies should obviously consider all issues necessary to determine if project development is warranted. Among the important considerations will be the technical viability of the project and the technical risks associated with the project, in terms of both the methane recovery and methane utilization options. Further, project economics and the project's financial viability should be investigated. Finally, important regulatory, legal, environmental and other issues related to project development and implementation should be examined.

In preparing feasibility studies, consultants or corporate experts should work closely with in-country personnel from the mining community, as well as from relevant local government agencies and industries, and national government agencies. Close cooperation will facilitate transfer of the methods and intent of feasibility study analyses, which is an important skill to be learned as the CIS moves toward a market economy. In addition, widespread participation during the project design and assessment stages may help expedite the project approval and development stages for those projects that are considered worth implementing.

4.2.3 METHANE RECOVERY TECHNOLOGY CENTERS

The establishment of one or more Coalbed Methane Recovery Technology Centers in Russia and Ukraine could greatly contribute to the development of coalbed methane projects by addressing two major barriers to project development in the CIS:

- the lack of a CIS coalbed methane industry to serve as project partners, and;
- the difficulty private companies confront with respect to gathering information about project opportunities and identifying potential partners.

In addressing these barriers, the centers could undertake the following activities:

- dissemination of information about recent accomplishments in methane recovery from coal seams throughout the CIS, by establishing a comprehensive information collection, publishing a technical journal and organizing seminars and workshops;
- creation of a domestic industry network for information exchange and project development, by arranging for opportunities to domestic experts to meet and exchange information (i.e., through seminars and meetings), and;
- support of the efforts of private companies to gather information and identify project opportunities, by undertaking small research projects, arranging meetings, and conducting important studies and investigations.

The functions of the center could be modelled after the Polish Coalbed Methane Clearinghouse, which was established in Katowice, Poland, in 1991 by the U.S Environmental Protection Agency. The Polish Center, which is a part of the Polish Foundation for Energy Efficiency (FEWE), has been extremely effective in organizing a Polish coalbed methane industry and in supporting the project development efforts of private companies.

4.2.4 TRAINING

Training programs may be necessary to educate both mining industry technical personnel and government representatives. Technical personnel training should emphasize methane recovery, especially pre-mine drainage from the surface, methane use, and resource assessment. Programs for government representatives could include developing appropriate environmental and other regulatory frameworks to ensure safe and effective implementation of methane recovery projects, legal and economic training, training in project feasibility assessment, and training related to project approval processes. In addition, government representatives and mine managers would likely benefit from training in mining economics and business management. These training programs should be developed in conjunction with the development of the clearinghouse and other follow-up studies. Agencies interested in providing training should work closely with appropriate Russian and Ukrainian representatives to identify specific needs and design efficient programs.

4.3 IMPACT ASSESSMENTS

As part of the effort to further assess coalbed methane development in the three study regions, it may be desirable to examine all potential impacts. These assessments should consider the impacts of both expanded methane recovery at active coal mines, and coalbed methane exploitation utilizing vertical wells in non-mining areas. They will facilitate the development of methane recovery activities that are encouraged through this project and also those that may proceed commercially. Included in the topics that should be considered are:

- Environmental impacts - air, water, and soil quality, and natural habitats;
- Socioeconomic impacts - changes in land use, employment, and economics;
- Infrastructure impacts - transportation services, including pipelines.

These assessments could be prepared by international experts working closely with personnel from the local and regional mining and government sectors. The assessments should be undertaken in a manner that transfers the experience of preparing such impact statements to in-country personnel. The implement and results of such assessments should be closely coordinated with the local and national planning agencies who are developing future energy sector plans and resource development policies.

4.4 REGULATORY ASSESSMENT

The adequacy of existing regulations, fees, and fines affecting coalbed methane development should be evaluated. The assessment would include an examination of the structure and suitability of coalbed methane pricing, ownership, and leasing laws. It should also include an examination of project approval processes and permitting requirements. Environmental regulations to be evaluated include those regarding water disposal, siting, and land rehabilitation. To accomplish these tasks, cooperation with in-country experts will be essential as the systems in Russia and Ukraine are quite different than in the United States. Initially, it will be important to identify potential barriers and educate local and federal officials to the goals of the tasks.

Based on this assessment, appropriate recommendations for modifications to existing regulations, as well as implementation of new regulations, could be made. Further, incentives for encouraging coalbed methane development could be assessed, if it is determined that national governments want to aggressively promote this resource.

4.5 DEMONSTRATION PROJECTS

Finally, it may be desirable to undertake demonstration projects for selected methane recovery and utilization options, if it is determined that such projects would expedite the more rapid development of the coalbed methane resources and effectively transfer necessary technologies. Several different types of demonstration projects could be undertaken depending on the objectives of the international funding agencies and national and local officials.

Demonstration projects could be warranted, for example, for a number of technologies which are not widely used at coal mines in other regions of the world but could be attractive in regions of the CIS. Possible examples could include developing uses for mine ventilation air or the application of gas enrichment technologies.

Demonstration projects might also be desirable in cases where the technologies have been applied internationally but have not yet been used in the CIS. For these, the objective would be to effectively transfer key technologies to in-country personnel. Some possible projects might be:

- investigating various technical issues (such as appropriate completion and/or stimulation techniques) related to methane production using vertical wells drilled in advance of mining in a particular coal basin;

- investigating the technical viability of various water disposal technologies; and/or,

- investigating the technical viability of various methane utilization technologies, such as cofiring methane with coal or the conversion of a coal-fired boiler to use methane.

Following any successful demonstration project, it is expected that widespread replication of the project would be undertaken by the private sector. Demonstration projects should expedite project development for those projects considered too risky or uncertain for the private sector to undertake without some assistance. Further, demonstrations would be useful in demonstrating to the CIS experts that certain technical options that they might be unfamiliar with or skeptical of could work in their specific conditions. Finally, because the results of any demonstration project could be made public, it would serve as an example to others within the CIS and internationally that various methane recovery and use options were feasible and could generate wide interest in project development.

4.6 INVESTMENT CONSIDERATIONS

In addition to the technical requirements of project development, encouraging foreign participation in coalbed methane development will also require resolution of issues that will affect the desirability of investments by foreign companies. Some of these issues--such as taxation policies, repatriation of profits, and legal frameworks for project development--are relevant to a wide range of business opportunities in the CIS and will likely be addressed through general government initiatives to encourage foreign investment. There are also a variety of investment issues specifically related to coalbed methane development, however, which cannot be overlooked if the development of this resource is to be effectively encouraged in Russia and Ukraine.

Among the critical issues specifically related to coalbed methane development are:

- Ownership of the resource is presently unclear, and needs to be ascertained for both virgin coal areas and areas where coalbed methane is being liberated as part of the mining process.

- Policies for foreign participation in resource development, in both mining and non-mining areas, need to be developed. Presently, structures of joint ventures are not well defined, and this must be resolved in order for investment to occur.

- Commercial incentives for coalbed methane production will be necessary to ensure realistic pricing of the resource. Presently, coalbed methane is produced only to achieve a reduction the amount of methane in mine ventilation air, rather than for its value as a substitute for coal or conventional natural gas.

- Permits and regulations concerning coalbed methane production are presently ill defined. Among the matters that need to be addressed is whether the extraction of coalbed methane falls under the jurisdiction of mining regulations, or whether it should be subject to oil and gas industry regulations.

A number of models exist for addressing these issues related to coalbed methane development. Poland, for example, has developed a legal and regulatory framework, as well as a system for granting coalbed methane development concessions to foreign companies, which is successfully encouraging development of this resource. By evaluating such existing systems, the governments of Russia and Ukraine should be able to develop appropriate frameworks that meet their coalbed methane development goals and encourage foreign development in the resource.

REFERENCES CITED

Airuni, A.T., 1991, Sposoby bor'by s vydeleniem metana na ugol'nykh shakhtakh: published by TsNIElugol, Moscow, 64 p.

Bashmakov, I.A., Beshinsky, N. Bogoslavskaya, et al., 1990, Comparison of main energy development and energy efficiency of production for the USSR, the USA, and Western Europe: Energy Research Institute, Moscow, Russia.

Bashmakov, I.A., and V.P. Chupyatov, 1992, Energy conservation: the main factor for reducing greenhouse gas emissions in the former Soviet Union: Battelle Pacific Northwest Laboratories, Richland, Washington, 15 p.

Bain, E., 1991, personal communication with R.C. Pilcher at World Coal Institute Conference, London, April 1991.

Bibler, C.J., J.S. Marshall, and R.C. Pilcher, 1992, Assessment of the potential for economic development and utilization of coalbed methane in Czechoslovakia: U.S. EPA, Washington D.C., 76 p.

Bikadorov, B.C., Y.B. Nikitina, L.M. Lomteva, A.I. Sverchkova, M.C. Stadnitskaya, and C.O. Ozerova, 1980, General stratigraphic section of the coal bearing sequence of the Kuznetsk Coal Basin, Russia: Ministry of the Coal Industry of the USSR.

Central Intelligence Agency (CIA), 1985, USSR Energy Atlas: Central Intelligence Agency, Langley, VA, 79 p.

Consolidated Natural Gas Company (CNG), 1987, Co-firing: a new combustion technique: Consolidated Natural Gas Company, 4 p.

Dott, Jr., R. H. and R. L. Batten, 1971, Evolution of the Earth: published by McGraw-Hill Book Company, p.481-483.

Eastern European Energy Report, 1992, Energy savings in Russia, vol. 3, no. 7, p. 2.

Eastern European Energy Report, 1993, Russian coal miners strike, vol. 4, no. 9, p. 4

Eastern Mine Safety Research Institute, 1992, Data sheet given to J.S. Marshall and R.C. Pilcher during meeting in Kemerovo, Russia, 13 April, 1992.

Economist Intelligence Unit (EIU), 1991, USSR country profile 1991-1992: The Economist Intelligence Unit, London, 56 p.

Energy Systems Associates, 1991, Opportunities for the utilization of mine ventilation air: Prepared for the U.S. EPA, Division of Global Change, Washington, D.C.

Fay, J.A., D.S. Golomb, S.C. Zachariades, 1986, Feasibility and cost of converting oil- and coal-fired utility boilers to intermittent use of natural gas: Massachusetts Institute of Technology, Energy Laboratory, 32 p.

Foreign Broadcast Information Service (FBIS), 1992a, Energy program concept outlines, FBIS-USR-92-012-I, 6 November 1992, p. 42-49.

Foreign Broadcast Information Service (FBIS), 1992b, Fact sheet on Russia's coal sector, FBIS-USR-92, 28 September 1992.

Foreign Broadcast Information Service (FBIS), 1992c, Coal production potential examined FBIS-USR-92-150, 23 November 1992, p. 71-73.

Foreign Broadcast Information Service (FBIS), 1992d, Data on safety conditions in mining sector/Ukraine, FBIS-USR-92-085, 8 July 1992, p. 94.

International Energy Agency (EIA), 1991, Natural Gas - Prospects and Policies, OECD, Paris, France.

International Monetary Fund (IMF), 1992, Economic Review: The economy of the former U.S.S.R. in 1991: International Monetary Fund, Washington, D.C. April 1992, 103 p.

International Monetary Fund (IMF) et al, 1990, The economy of the USSR: published by The World Bank, Washington, D.C., 51 p.

International Petroleum Encyclopedia, 1992: Pennwell Publishing Co., Tulsa, Oklahoma, 358 p.

Karp, I., 1992, Personal communication with J.S. Marshall and R.C. Pilcher during meeting in Kiev, Ukraine on 31 March 1992.

Kozlovsky, E., ed., 1986, Gornaya Encyclopedia: Sovietskaya Encyclopedia, Moscow, vol. 2.

Kozlovsky, E., ed., 1987, Gornaya Encyclopedia: Sovietskaya Encyclopedia, Moscow, vol. 3.

Kruger, D.W., 1991, Coalbed methane - environmental protection at a profit *in* The 1991 Coalbed Methane Proceedings: University of Alabama, Tuscaloosa, p. 193-202.

Martonhegyi, Frank, 1992, personal communication on 19 August, 1992.

Meyer, H.S., D. Leppin, and J.L. Savidge, 1990, Gas Research Institute's gas processing research and development program: Unpublished document submitted to the Gas Research Institute, Chicago.

Mining Annual Review, 1991, published by Mining Journal, London, p. 149.

Moerman, A., 1982, Internal report on gas storage in Peronnes-Lez-Binche, S.A. Distrigaz, 19 p.

Nalivkin, D.V., 1960, The geology of the U.S.S.R. - a short outline: International Series of Monographs on Earth Sciences-vol. 8, Pergamon Press, 170 p.

Nalivkin, D.V., 1973, Geology of the U.S.S.R.: University of Toronto Press, 855 p.

Oil & Gas Journal, 1991, IGU details environmental qualities of gas: Oil & Gas Journal, V. 89, No. 29, p. 31.

Oil & Gas Journal, 1992a, Worldwide crude oil and gas production: Oil & Gas Journal, March 9, 1992, p. 25.

Oil & Gas Journal, 1992b, Russia vows to end oil export tax: Oil & Gas Journal, July 27, 1992, p. 56.

Oil & Gas Journal, 1992c, Russia pins energy hopes on western Siberia gas: Oil & Gas Journal, Sept. 7, 1992, p. 17-20.

Oil & Gas Journal, 1993, Russian gas production hits hydrocarbon slide: Oil & Gas Journal, V. 91, No. 38, p. 40.

Pilcher, R.C., C.J. Bibler, R. Glickert, L. Machesky, and J.M. Williams, 1991, Assessment of the potential for economic development and utilization of coalbed methane in Poland: U.S. EPA, Washington, D.C., 83 p.

PlanEcon, Inc., 1992a, PlanEcon Energy Report, Washington, D.C., vol. 2, no. 1, 84 p.

PlanEcon, Inc., 1992b, PlanEcon Energy Report,Washington, D.C., vol.2, no. 2, 92 p.

PlanEcon, Inc., 1993a, PlanEcon Energy Outlook for the Former Soviet Republics, Washington, D.C., June 1993.

PlanEcon, Inc., 1993b, PlanEcon Energy Report, Washington, D.C., vol. 3, no.1, 40 p.

PlanEcon, Inc., 1993c, PlanEcon Energy Report, Washington, D.C., vol. 3, no. 2, 44 p.

PlanEcon, Inc., 1993d, PlanEcon Energy Report, Washington, D.C., vol. 3, no. 4, 44 p.

Sagers, M.J., 1993, The energy industries of the former USSR: A mid-year survey: Post-Soviet Geography, v. 34, p. 341-418.

Serov, V.I., 1992, Personal communication with J.S. Marshall and R.C. Pilcher during meeting at the Skochinsky Mining Institute in Lyubertsy, Russia on 17 April 1992.

Silinnii, V.I., 1992, Map given to J.S. Marshall and R.C.Pilcher during meeting at Ukrainian Volynsk Geological Exploration Expedition, Vladimir-Volynsk, Ukraine, 4 April 1992.

Sinor, J.E., 1992, Economic and market potential of the clinoptilolite process for methane purification: Unpublished document prepared for Gas Separation Technology, Lakewood, Colorado.

Skochinsky Mining Institute, 1991a, Prognosnyi katalog shakhtoplastov Donetskogo Ugolnogo Basseina s kharakteristikoi gorno-geologicheskikh i gornotekhnicheskikh faktorov na 1995 i 2000: published by The Skochinsky Mining Institute, Moscow, 439 p.

Skochinsky Mining Institute, 1991b, Prognoznyi katalog shakhtoplastov Podmoskovnogo, Lvovsko-Volynskogo, i Dneprskogo Ugolnykh Basseinov s kharakteristikoi gorno-geologicheskikh i gornotekhnicheskikh faktorov na 1995 i 2000: published by The Skochinsky Mining Institute, Moscow, 38 p.

Skochinsky Mining Institute, 1991c, Prognosnyi katalog shakhtoplastov Kuznetskogo Ugolnogo Basseina s kharakteristikoi gorno-geologicheskikh i gornotekhnicheskikh faktorov na 1995 i 2000: published by The Skochinsky Mining Institute, Moscow, 172 p.

Skochinsky Mining Institute, 1992, Maps of the Donetsk basin given to Eden Allswang in Moscow, 23 April, 1992.

Skochinsky Mining Institute, 1993, Data tables received during visit to Skochinsky Mining Institute in Lyubertsy, Russia, March 1993.

Struev, M.I., V.I. Isakov, V.B. Shpakova, et al, 1984, L'vovsko-Volynskii kamennouogol'nyi bassein, Geologo-promyshlennyi ocherk: published by Naukova Dumka, Kiev, Ukraine, 270 p.

Sturgill, C.L., 1991, Power generation - on-site use and sale to utilities: Report prepared for ICF Incorporated, Washington, D.C., 26 p.

Thompson, H.A., 1991, It's 10° outside - do you know where your gas is?, in GRID, Gas Research Institute Digest, Fall/Winter 1991-1992, The Gas Research Institute, Chicago, p. 12-23.

United Nations Economic Commission for Europe (UNECE), 1991, Energy reforms in Central and Eastern Europe - the first year: UNECE Energy Series No. 7, United Nations, New York.

United Nations Economic Commission for Europe (UNECE), 1992, The coal situation in the ECE region in 1991 and global prospects for coal: UNECE Economic and Social Council, Committee on Energy, Working Party on Coal, Geneva, Switzerland.

U.S. DOE, EIA, 1992a, International Energy Outlook 1992, Washington, D.C., 50 p.

U.S. DOE, EIA, 1992b, International Energy Annual 1990, Washington, D.C., 187 p.

U.S. DOE, EIA, 1992c, EIA analysis brief - The former Soviet Republics, Washington, D.C., 34 p.

U.S. DOE, EIA, 1994, International Energy Annual 1992, Washington, D.C.

U.S. EPA, 1986, Supplement A to a compilation of air pollutant emission factors, v. 1: Stationary and point sources: Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. EPA, 1993, International Methane Emissions Estimates: 1990: Office of Policy, Planning & Evaluation, in preparation.

U.S.S.R. Academy of Sciences, 1990, Gazobil'nost' kamenougol 'nykh shakht SSSR: Kompleksnoe osvoenie gazonosnykh ugol'nykh mestorozhdenii, Moscow: Nauka, p. 39-3.

Vejtasa, S.A., F.E. Biasca, D.V. Giovanni, and R.C. Carr, 1991, Gas cofiring for coal-fired utility boilers: Draft report prepared for the Electric Power Research Institute, Palo Alto, California, and the Gas Research Institute, Chicago.

Wacinski, A.K., L.F. Machesky, C.J. Bibler, and R.C. Pilcher, 1992, Management of saline water from coal mines of the Upper Silesian Coal Basin, Poland: Draft report submitted to the World Bank.

Zabourdyaev, V., 1992, Data tables received during visit to Skochinsky Mining Institute in Lyubertsy, Russia, April 1992.

APPENDIX A: ENERGY FUEL PRODUCTION, TRADE, AND APPARENT CONSUMPTION OF REPUBLICS OF THE FORMER SOVIET UNION

TABLE A-1: ENERGY FUEL PRODUCTION, TRADE, AND APPARENT CONSUMPTION OF REPUBLICS OF THE FORMER SOVIET UNION

REPUBLIC	PRODUCTION			EXPORTS		IMPORTS		NET EXPORTS		APPARENT CONSUMPTION		
	1990	1991	1992	1990	1991	1990	1991	1990	1991	1990	1991	1992
NATURAL GAS (MILLION CUBIC METERS)												
RUSSIA	640,566	642,890	640,400	249,766	245,764	70,166	68,764	179,600	177,000	460,966	465,890	454,400
UKRAINE	28,083	24,363	20,900	0	0	87,200	87,200	(87,200)	(87,200)	115,283	111,563	111,300
BELARUS	297	294	200	0	0	14,600	14,600	(14,600)	(14,600)	14,897	14,894	N/A
KAZAKHSTAN	7,114	7,885	8,800	2,846	3,154	8,746	9,054	(5,900)	(5,900)	13,014	13,785	N/A
AZERBAIJAN	9,926	8,621	7,800	0	0	0	0	0	0	9,926	8,621	N/A
GEORGIA	50	50	negligible	0	0	5,400	5,400	(5,400)	(5,400)	5,450	5,450	N/A
KYRGYZSTAN	96	83	100	0	0	1,800	1,800	(1,800)	(1,800)	1,896	1,883	N/A
TAJIKISTAN	111	92	100	0	0	1,600	1,600	(1,600)	(1,600)	1,711	1,692	N/A
TURKMENISTAN	87,767	84,348	60,100	71,900	70,000	0	0	71,900	70,000	15,867	14,348	N/A
UZBEKISTAN	40,761	41,882	40,000	2,900	2,900	8,400	8,400	(5,500)	(5,500)	46,261	47,382	N/A
TOTAL	**814,771**	**810,508**	**778,400**	**327,412**	**321,818**	**197,912**	**196,818**	**129,500**	**125,000**	**685,271**	**685,508**	**682,500**
CRUDE OIL & NGL (THOUSAND TONS)												
RUSSIA	516,183	461,138	395,800	229,429	171,147	25,776	18,110	203,653	153,037	312,530	308,101	258,200
UKRAINE	5,252	4,933	4,400	0	0	53,729	49,708	(53,729)	(49,708)	58,981	54,641	N/A
BELARUS	2,054	2,060	2,000	0	0	37,387	33,709	(37,387)	(33,709)	39,441	35,769	N/A
KAZAKHSTAN	25,820	26,633	27,800	21,947	22,638	13,981	14,011	7,966	8,627	17,854	18,006	N/A
AZERBAIJAN	12,513	11,742	11,000	0	0	3,819	4,078	(3,819)	(4,078)	16,332	15,820	N/A
GEORGIA	180	180	200	0	0	1,920	1,620	(1,920)	(1,620)	2,100	1,800	N/A
KYRGYZSTAN	155	143	100	155	143	0	0	155	143	0	0	N/A
TAJIKISTAN	144	108	100	144	108	0	0	144	108	0	0	N/A
TURKMENISTAN	5,642	5,449	5,300	260	0	82	1,683	178	(1,683)	5,464	7,132	N/A
UZBEKISTAN	2,810	2,832	3,100	0	0	5,208	5,117	(5,208)	(5,117)	8,018	7,949	N/A
TOTAL	**570,753**	**515,218**	**449,800**	**251,935**	**194,036**	**141,902**	**128,036**	**110,033**	**66,000**	**460,720**	**449,218**	**366,200**
HARD COAL (THOUSAND TONS)												
RUSSIA	256,800	226,600	215,800	52,100	38,400	52,300	46,700	(200)	(8,300)	257,000	234,900	227,116
UKRAINE	155,500	128,800	127,300	20,000	14,600	18,900	13,300	1,100	1,300	154,400	127,100	130,395
KAZAKHSTAN	128,000	127,000	122,900	53,900	53,000	12,200	8,000	41,700	45,000	86,300	82,000	81,702
GEORGIA	1,000	700	400	300	0	900	400	(600)	(400)	1,600	1,100	764
KYRGYZSTAN	1,600	1,500	900	1,900	1,470	2,900	2,670	(1,000)	(1,200)	2,500	2,700	2,288
UZBEKISTAN	200	200	200	600	530	3,700	3,070	(3,100)	(2,540)	3,300	2,740	1,432
OTHER	0	0	0	300	0	12900	9340	(9143)	(10,135)	11,243	10,135	7,003
TOTAL	**543,100**	**484,800**	**467,600**	**130,300**	**108,000**	**103,800**	**83,480**	**28,757**	**23,725**	**516,343**	**460,675**	**450,700**

SOURCE: PLANECON, 1992a, 1993a, 1993b; Skochinsky, 1993; Sagers, 1993

1991 hard coal production total does not equal sum of its parts due to differing data sources.

APPENDIX B - EXPLANATION OF FORMER USSR RESOURCE CLASSIFICATION AND COAL RANK SYSTEMS

MINERAL RESOURCE CLASSIFICATION SYSTEM

The coal resource data presented in this report pertain to documented, or explored reserves. As in other countries, documented reserves are categorized according to the degree of assurance that they exist. In Russia, documented reserves comprise degrees of assurance A, B, C_1, and C_2. They are based on the degree of exploration that has been carried out. The classification terms used in Russia are equivalent to descriptive terms used in the U.S., as shown in Table B-1.

FIGURE B-1. CLASSIFICATION OF DOCUMENTED RESERVES

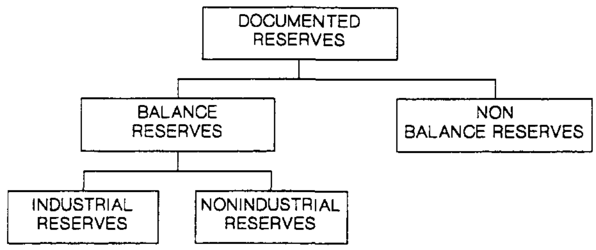


TABLE B-1. COMPARISON OF RESOURCE CLASSIFICATION SYSTEMS

FORMER USSR RESERVE CLASSIFICATION SYSTEM					WESTERN RESOURCE CLASSIFICATION SYSTEM
	CATEGORIZED BY EXTENT OF STUDY		GROUPED ACCORDING TO ECONOMIC SIGNIFICANCE		
RESERVES	EXPLORED	A	BALANCE	NON-BALANCE	PROVEN
		B			
		C_1 (30 percent)			
	PRELIMINARILY ESTIMATED	C_1 (70 percent) & C_2			PROBABLE
RESOURCES	PREDICTED	P_1			POSSIBLE
		P_2			
		P_3			

In Russia, documented reserves are further subdivided as shown in Figure B-1. The terms used are defined below.

Balance coal reserves: documented reserves that meet criteria related to quantity, quality, technology, geologic conditions, and mining conditions. Criteria vary according to basin.

Non-balance coal reserves: documented reserves that do not meet the balance criteria for one or more reasons.

Industrial coal reserves: that portion of the balance reserves that is designated for extraction according to the mine plans and using available technology.

Non-industrial coal reserves: balance reserves which are not intended for production using available technology and production systems.

COAL RANK

In Russia, as in other countries, coal is ranked according to various parameters, including its carbon content, volatile matter content, and heating value. Table B-2 shows the approximate correlating descriptive terminology used in U.S. and Russia. The U.S. rank equivalents are approximate in that the ranges of the parameters used in the former USSR (shown here) are not identical to those used in the U.S.

TABLE B-2: COMPARISON OF U.S. & FORMER USSR COAL CLASSIFICATION SYSTEMS

RANK	VOLATILE MATTER $V^{as\ received}$ percent	HEATING VALUE Q kcal/kg	CARBON CONTENT C percent	APPROXIMATE U.S. EQUIVALENT
LONG-FLAME	$\geq$ 35	7300-8100	77-83	HIGH VOLATILE BITUMINOUS C
GAS	$\geq$ 35	7000-8600	81-87	HIGH VOLATILE BITUMINOUS B
GAS-FAT	27-35	8300-8750	81-87	
FAT	27-35	8300-8750	85-88	
COKING	18-27	8500-8800	88-91	HIGH VOLATILE BITUMINOUS A
LEAN-CAKING	14-22	8500-8800	90-93	MEDIUM VOLATILE BITUMINOUS
LEAN	8-17	> 8400	91-94	LOW VOLATILE BITUMINOUS
ANTHRACITE	> 8	< 8400	94-97	ANTHRACITE