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ANALYSIS OF ENERGY RESOURCES AND PROGRAMS OF THE SOVIET UNION AND EASTERN EUROPE

SUMMARY

Stanford Research Institute

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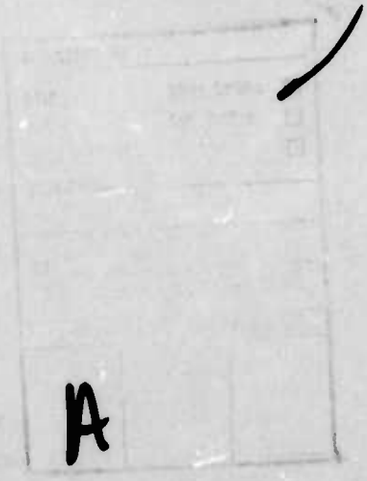

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CONTENTS

ILLUSTRATIONS

TABLES

TABLES (Concluded)

PREFACE

The analysis reported herein was conducted by an interdisciplinary team from the Operations Evaluation, Energy Technology, Energy Economics, and Mineral Resources and Materials Departments at Stanford Research Institute. We are grateful for the cooperation of interested agencies and individuals who were contacted for their knowledge, data, and opinions regarding various aspects of energy programs in the USSR and Eastern Europe.

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1 INTRODUCTION

The energy shortage faced by the United States during the coming decade has global analogs. Many other industrialized nations face similar energy shortages that could impair their ability to meet expanding needs. The rapid conversion of the industrialized nations from a coal based economy to an oil and gas based economy is producing especially acute problems for nations such as those in Western Europe and Japan which are lacking adequate resources of oil and gas. These countries are becoming increasingly dependent upon the OPEC countries in general and on North Africa and the Middle East in particular to meet their expanding fuel needs.

On the other hand, the USSR is known to have vast energy resources. Like other European countries, most of the USSR's client states in Eastern Europe are short of energy resources. The Eastern European countries rely on the USSR to meet their energy needs. If the latter is unwilling or unable to meet these needs, many of these countries will undoubtedly turn to the North African and Middle Eastern suppliers to fulfill their requirements.

In the meantime, the political/military situation in North Africa and the Middle East can best be described as unstable. In addition to the Arab-Israeli confrontation, the OPEC nations have developed an awareness (in some cases exaggerated) of their strong economic position vis-a-vis the oil hungry nations, and are exhibiting an increasing degree of independence in dealing with those nations.

In view of the many historical cases of military confrontation occurring over prized resources, it is obvious that the Department of

Defense needs a sound assessment of the potential role of the USSR in the world energy economy. On the one hand, the Soviets represent a potential competitor for the resources of the OPEC; on the other hand, they may well provide an alternative source of oil and gas to relieve the dependence of energy hungry nations on OPEC. The actual role of the USSR may well lie between these two poles.

The objective of this study is to provide a sound assessment of the energy economy of the USSR and six Eastern European nations (Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania) from now through 1990. The elements of this assessment include:

- Survey of energy resources by type, locations, quantities, and development potential, including coal, oil, gas, other solid fuels, and electric power generation.
- Review of technology employed for energy exploitation, including exploration, development, production, distribution, storage, and utilization.
- Appraisal of recent R&D in resource recovery, fuel and energy conversion, distribution, and utilization, including new forms of energy.
- Trends in energy production and consumption.
- Estimation of overall energy supply-demand balance for 1970, with projections at five-year intervals to 1990.
- Review of Soviet trade policies with Eastern Europe, Western Europe, and the rest of the world.
- Analysis of the implication of Soviet energy policies vis-a-vis the United States, Western Europe, and the rest of the world.

Although a great deal of classified literature was available for this study, the results are based entirely on unclassified literature. The authors were pleasantly surprised by the amount of information available for this study, but were disappointed by its unevenness and the lack of consistency in both the numbers and the definitions. Although the classified and unclassified literature were not always consistent, and the classified literature contained more detail in certain areas, use of classified data would not change the findings and conclusions.

The results of this study are contained in seven volumes. In addition to this summary volume, the following six detailed studies are available:

Appendix A	Framework of Energy Supply and Demand
Appendix B	Coal
Appendix C	Petroleum
Appendix D	Gas
Appendix E	Other Hydrocarbons and Energy Sources
Appendix F	Electric Power

II ENERGY RESOURCES

In discussing the potential development of energy resources, one must distinguish between resources, which are the total amount of materials occurring in nature, and recoverable reserves, which are the known identified deposits that can be developed economically with existing technology. Seven categories of reserves are described in the Soviet literature:

Category	Approximate Equivalent to US Nomenclature
A	Proved reserves
B	Probable reserves
C	Inferred reserves
C_1	Initial development done
C_2	Preliminary exploration done
D	Speculative reserves
D_1	Reconnaissance data only
D_2	Predicted on geological principles

These descriptions give the closest U.S. equivalent definitions, but they are still only very rough equivalents. Category A Soviet reserves are much less certain than U.S. proved reserves.

The USSR is known to have very large energy resources, but no one (including the USSR) has a very good estimate of the magnitude of the recoverable reserves. This is primarily because relatively little exploratory work has been carried out in the vast reaches of Siberia and Eastern USSR. Table 1 shows an estimate of the principal recoverable energy reserves of the USSR and Eastern European countries--reserves that are economically recoverable through the use of currently available

Table 1

SUMMARY OF RECOVERABLE ENERGY RESERVES IN USSR AND EASTERN EUROPE

	Hard Coal*	Brown Coal*	Peat*	Oil Shale*	Oil+	Gas‡	Hydro§	Uranium**
Bulgaria	Neg.	1.7	Neg.	Neg.	7.2	29	10.2	17.7
Czechoslovakia	6.0	4.6	Neg.	Neg.	1.6	15	8.2	29.5
GDR	Neg.	18.0	Neg.	n.a.	1.5	15(a)	1.0	117.9
Hungary	0.1	1.8	Neg.	n.a.	138.0	85	2.4	17.7
Poland	11.8	3.8	2.0	n.a.	8.3	142	6.0	1.2
Romania	Neg.	Neg.	Neg.	n.a.	330.0	170(b)	17.0	17.7
USSR	181.1	78.7	9.8	14.0	10,000.0	22,000	1,100.0	318.4
Total	199.0	108.6	11.8	14.0	10,486.5	22,456	1,144.8	520.1

Neg. - negligible.

* Billion metric tons.

\+ Million metric tons.

‡ Billion cubic meters

§ Billion KWHR

** Thousand metric tons U_3O_8.

n.a. = not applicable; no oil shale deposits.

(a) If sources of low BTU gas were included, total GDR gas would be 400 billion cubic meters.

(b) If all apparent reserves were recoverable, total Romanian gas would be 285 billion cubic meters.

technology. Although the reserves of the fossil fuels in the Eastern European countries are locally significant in several cases, they are small compared with those of the USSR. Further, these estimates of recoverable reserves are small in comparison with the total resources that exist in these countries. Uranium reserves of the GDR represent an exception to this general situation.

To place the USSR and Eastern European energy reserves in perspective, Table 2 shows a comparison of selected estimated recoverable reserves with the proven reserves of the United States. The comparison is not performed using strictly identical units, because of differences in definition of reserves. The estimate for the USSR in particular is much less certain than the estimate of U.S. proven reserves.

As the demand for energy rises in the USSR, the center of energy production is shifting toward Siberia. Table 3 shows the declining percentage of production of crude oil, natural gas, coal, and electric power in the European part of the USSR from 1940 through 1975. It is clear that the USSR is becoming increasingly dependent upon new resource developments east of the Urals.

To summarize, the USSR has enormous deposits of all fossil fuels, and great potential for hydroelectric and nuclear power. A large portion of these resources are located in Siberia and the Soviet Far East, far from their centers of consumption, so that their recovery is hampered by geography and geology. The bulk of Soviet energy resources is essentially underdeveloped. Meanwhile, the resources of fossil fuels in Eastern Europe and European USSR are becoming depleted through increased production.

With some exceptions, the resources of the Eastern European countries are small in comparison with their present and projected energy requirements.

Table 2

COMPARISON OF ENERGY RESERVES

	Hard Coal (Billion Metric Tons)	Oil (Million Metric Tons)	Gas (Billion Cubic Meters)
Eastern Europe	17.9	487	956
USSR	157.6	10,000	22,000
United States	79.5	5,290	7,900
United States as percent of USSR	51%	53%	36%

Table 3

REGIONAL DISTRIBUTION OF PRIMARY ENERGY PRODUCTION IN THE USSR
(Percent of Total in European Part, Including the Urals)

Production	1940	1960	1970	1975 (Plan)
Crude oil	93.7	92.8	81.8	63.4
Natural gas	99.5	97.6	70.2	51.3
Coal	71.3	64.1	56.8	n.a.
Electric power	90.8	78.4	73.8	72.0

n.a. - not available

Moreover, these reserves are generally in small deposits, leading to relatively inefficient recovery and high recovery costs. Eastern European fuels are frequently of low quality, requiring processing before use, which leads to further losses. Thus, the Eastern European countries are becoming increasingly dependent upon imports of fuels to meet their internal deficits of fossil fuels. Notable exceptions include East German and Polish coal and Romanian oil, but even these deposits are becoming rapidly depleted through development.

III SOLID FUEL DEVELOPMENT

The general trends in coal production in the USSR and Eastern Europe are shown in Figure 1. Overall coal production is rising rapidly in both the USSR and the other Eastern European countries, although the rate of increase is declining. While the USSR dominates the coal reserves of the area, it produces only about one-half of the total coal produced in Eastern Europe.

The USSR, like the United States, experienced a strong trend toward surface mining of coal in recent years, as shown in Figure 2. Most of the current production increase can be attributed to surface mining, and much of it is in the Kuzbas* and Kazakhstan.

The comparison of coal mining technology in the USSR and the United States is shown in Tables 4 and 5. The USSR tends to use much larger machinery than the United States does, and to operate in much larger mines. In deep mining, the USSR tends to use mechanized longwall mining equipment, but the remaining need for manual workover tends to offset the higher productivity that ordinarily would be expected with longwall machines. In surface mining, the USSR relies heavily on large, complex bucket-wheel excavators, whereas the United States relies on intermediate size shovels and loaders that have greater flexibility. The use of larger and highly mechanized machines results in the introduction of waste matter to the coal, and leads to cleaning losses and production losses. Also, the need for equipment maintenance of large machines could affect overall production.

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* Kuznetsk Basin. A similar short form is Donbass, for Donets Basin.

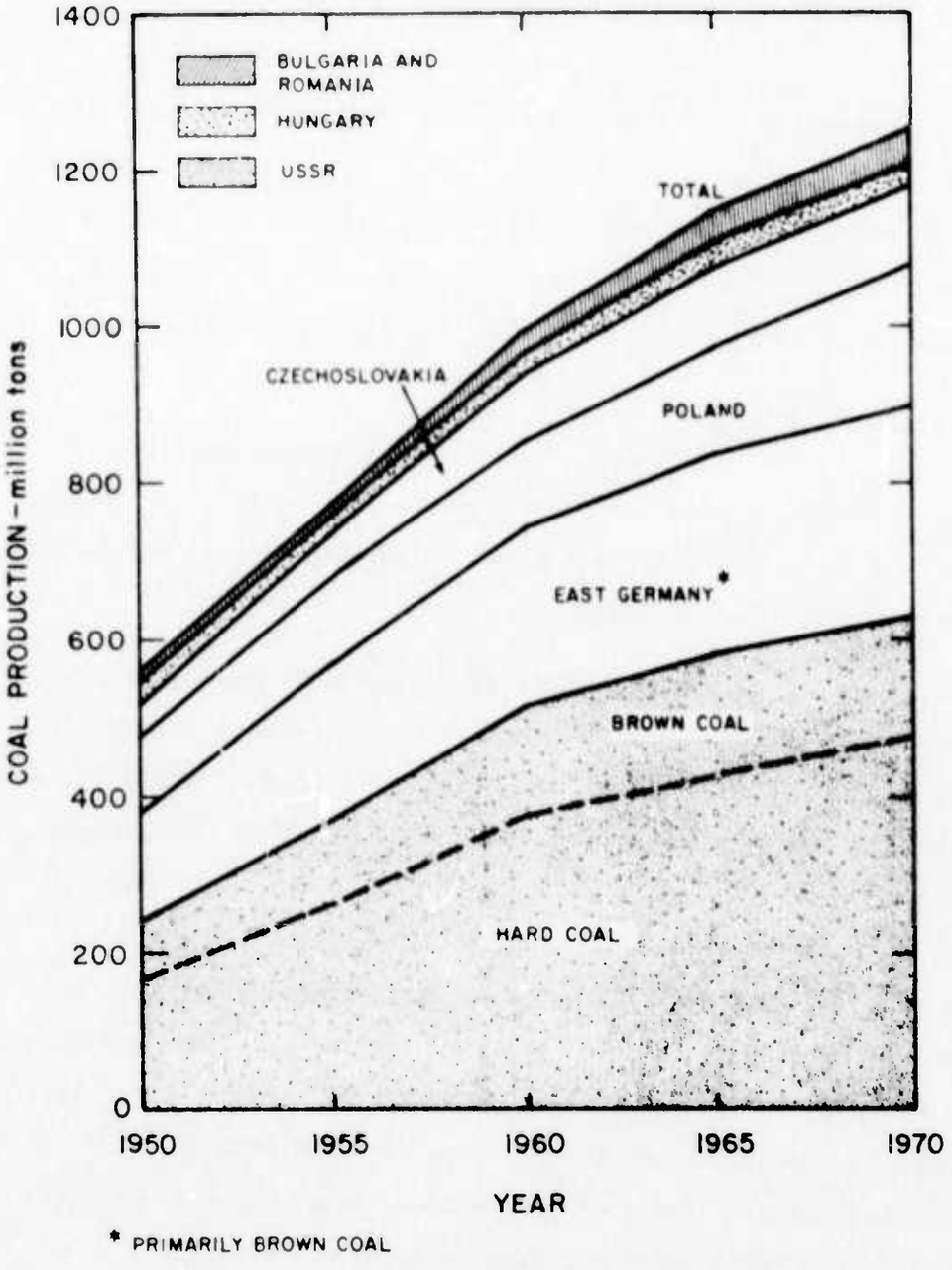


Figure 1

TRENDS IN COAL PRODUCTION IN EASTERN EUROPE AND USSR

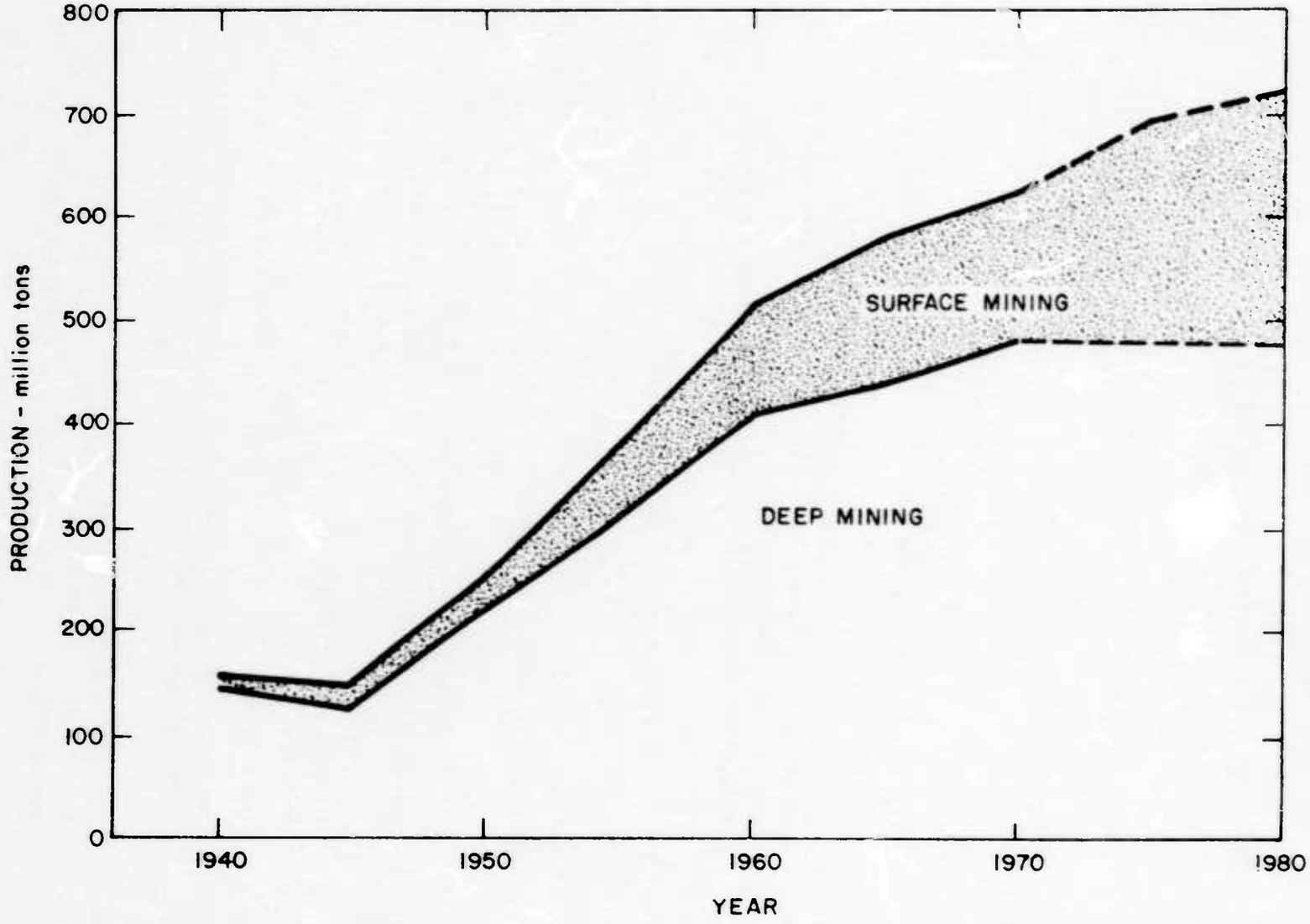


Figure 2

TRENDS IN COAL PRODUCTION BY MINING METHOD IN THE USSR

Table 4

COMPARISON OF DEEP COAL MINING TECHNOLOGY

	USSR and Eastern Europe	United States
Mining	Mainly longwall; some continuous	Mainly continuous; some longwall
Initial haulage	Scraper chains	Shuttle cars
Main haulage	Belts and rail	Belts and rail
Trends	Increasing mechanization; reduction working forces	Increasing mechanization; reduction work force
Problems	Excessive manual work; limiting benefits from mechanization; inefficient mining of thick/thin seams	Lack of short-haul capability to use capacity of mining machines

Table 5

COMPARISON OF SURFACE COAL MINING TECHNOLOGY

	USSR and Eastern Europe	United States
Overburden	Bucket wheel excavators	Draglines/power shovels
Mining	Bucket wheel excavators/ shovels	Shovels/loaders
Haulage	Large trucks	Large trucks
Trends	Increasing equipment size; increasing mine size	Moderate equipment size; modular operations
Problems	Successful application of giant, high capacity equipment	Improvement of technology application; control of environmental effects

Figure 3 gives a gross impression of the inter-regional coal movements from the main coal basins of the USSR. Large quantities of coal move long distances in the USSR, with most of the movement being rail movements into the Central European regions. In fact, 88 percent of the coal moved by rail in 1970 and these coal shipments constituted 22 percent of the total rail freight in the USSR.

Coal production, consumption, and exports in the USSR are summarized in Figure 4. The difference between raw production and net internal consumption curves is represented by losses in the case of brown coal and by exports and losses in the case of hard coal. The production and consumption of hard coals is expected to remain relatively constant in coming years, while consumption of brown coal is expected to increase significantly. The use of hard coals is expected to shift primarily to coking, while the increased use of brown coal will be for electric power generation.

Figure 5 shows the utilization of other solid fuels in the USSR. Peat and oil shale, most of which become boiler fuel for electric power stations where they are locally plentiful, are expected to level off in the coming years at about one order of magnitude lower than either brown or hard coal. The use of fuel wood is expected to decline and be used mainly for domestic purposes.

Figure 6 shows an overview of end use for all solid fuels in the USSR. The primary use of solid fuels (mainly coal) is for industry and electric power generation where its utilization is projected to continue to increase out to 1990. Commercial, residential, agricultural, and transportation uses of solid fuels are about one-tenth that of electrical generation, and these are expected to decrease rapidly as they are replaced by oil and gas.

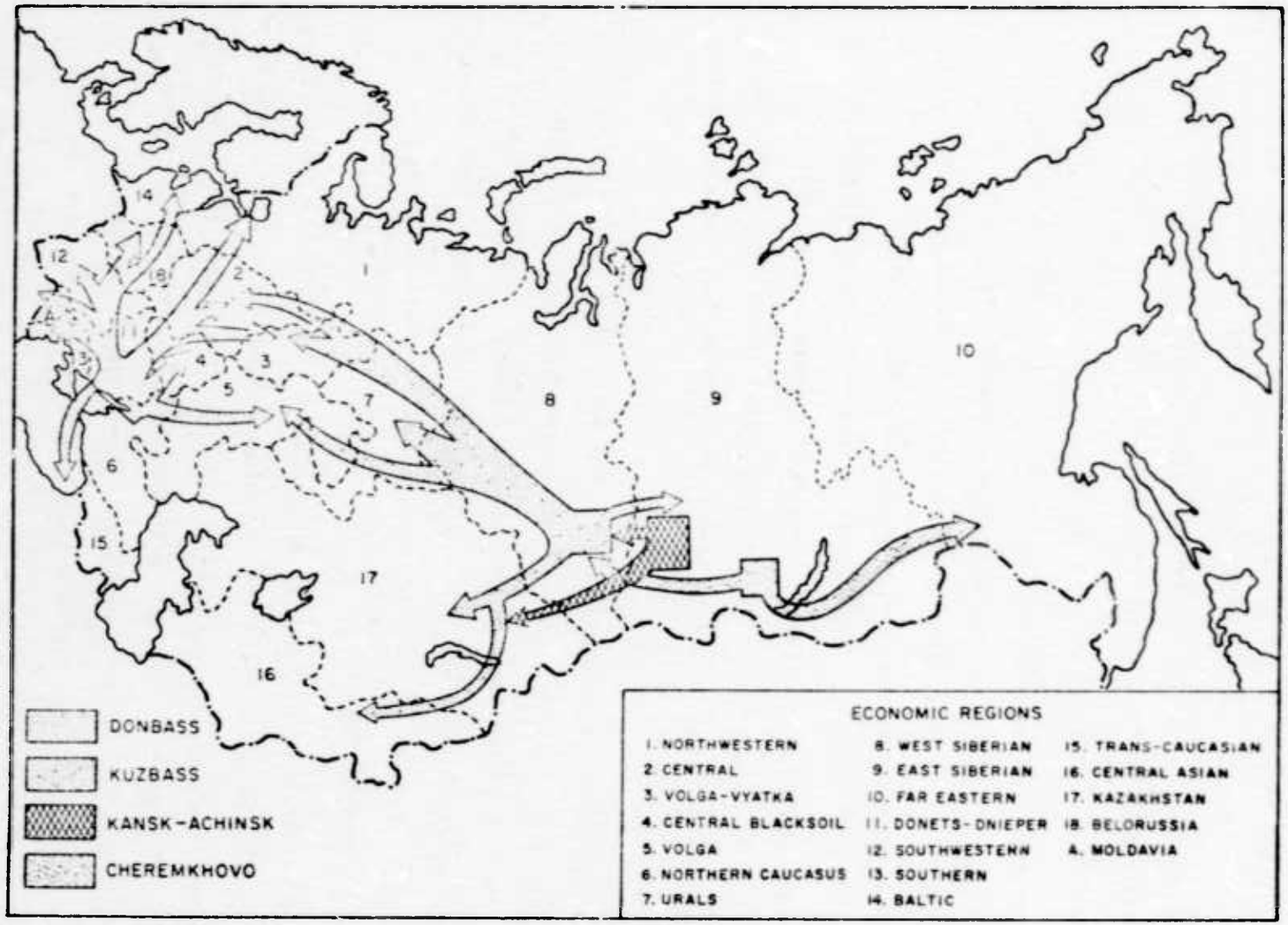


Figure 3
INTER-REGIONAL COAL MOVEMENTS

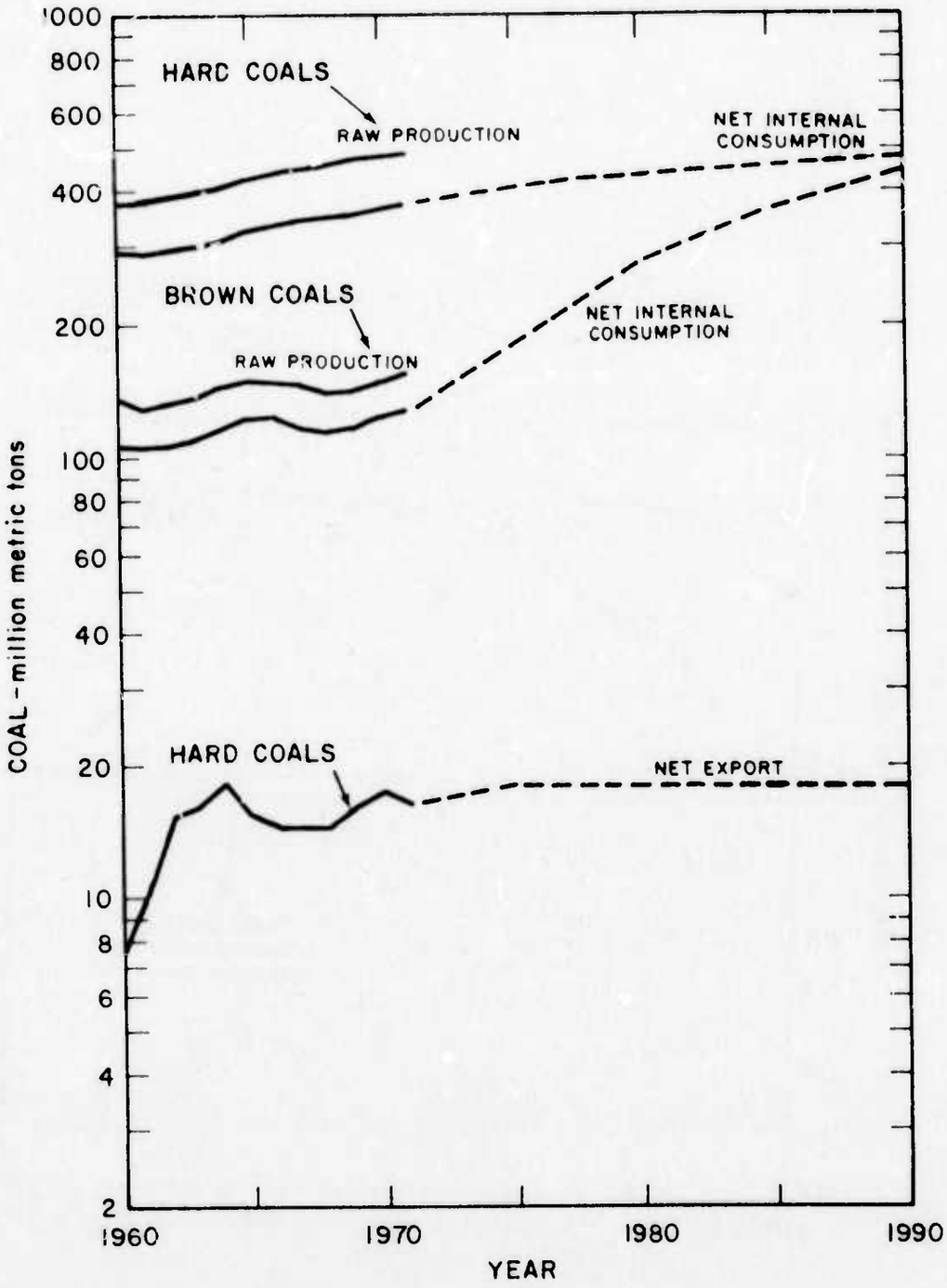


Figure 4

USSR COAL PRODUCTION, CONSUMPTION, AND EXPORT

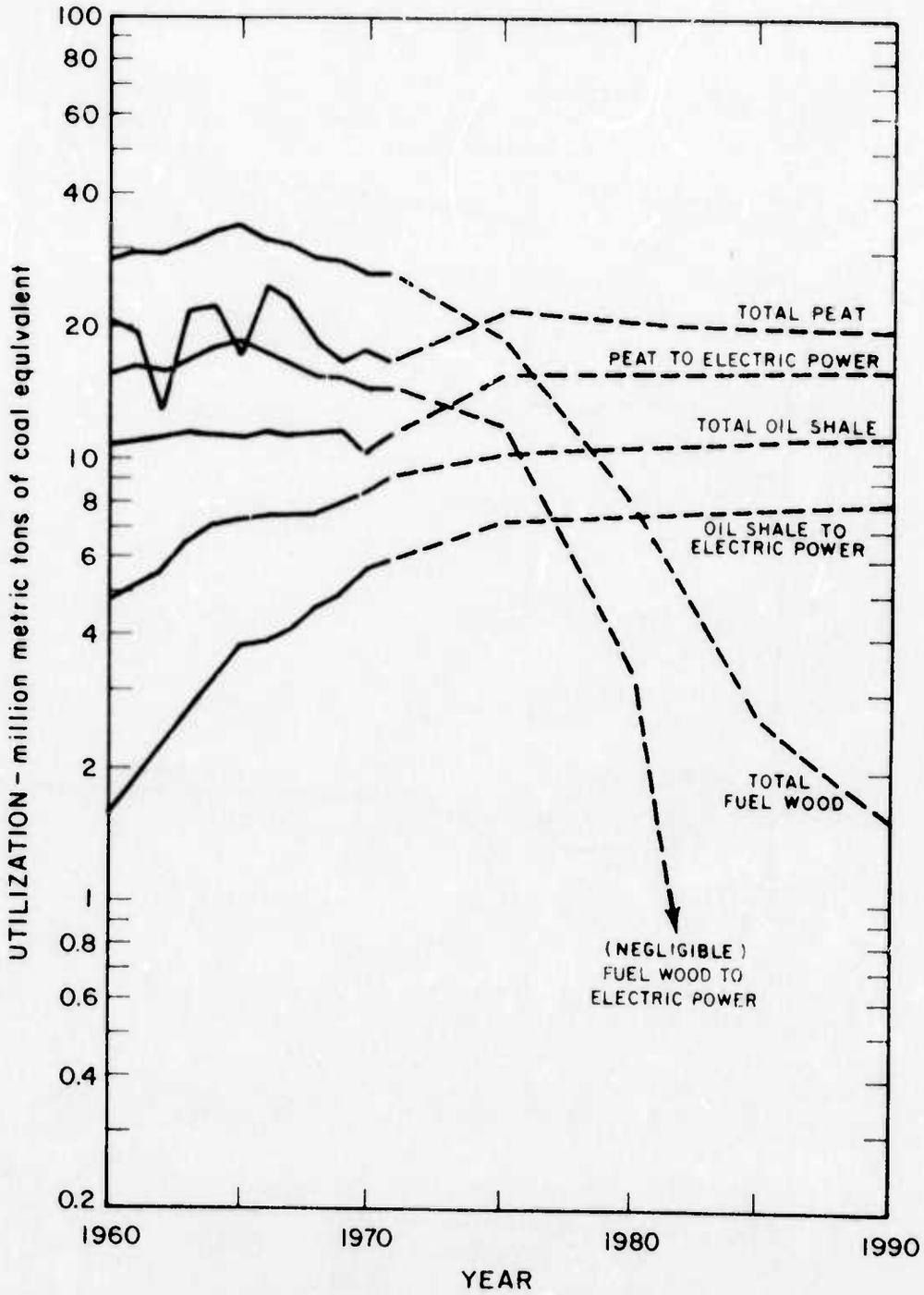


Figure 5
USSR UTILIZATION OF OTHER SOLID FUELS

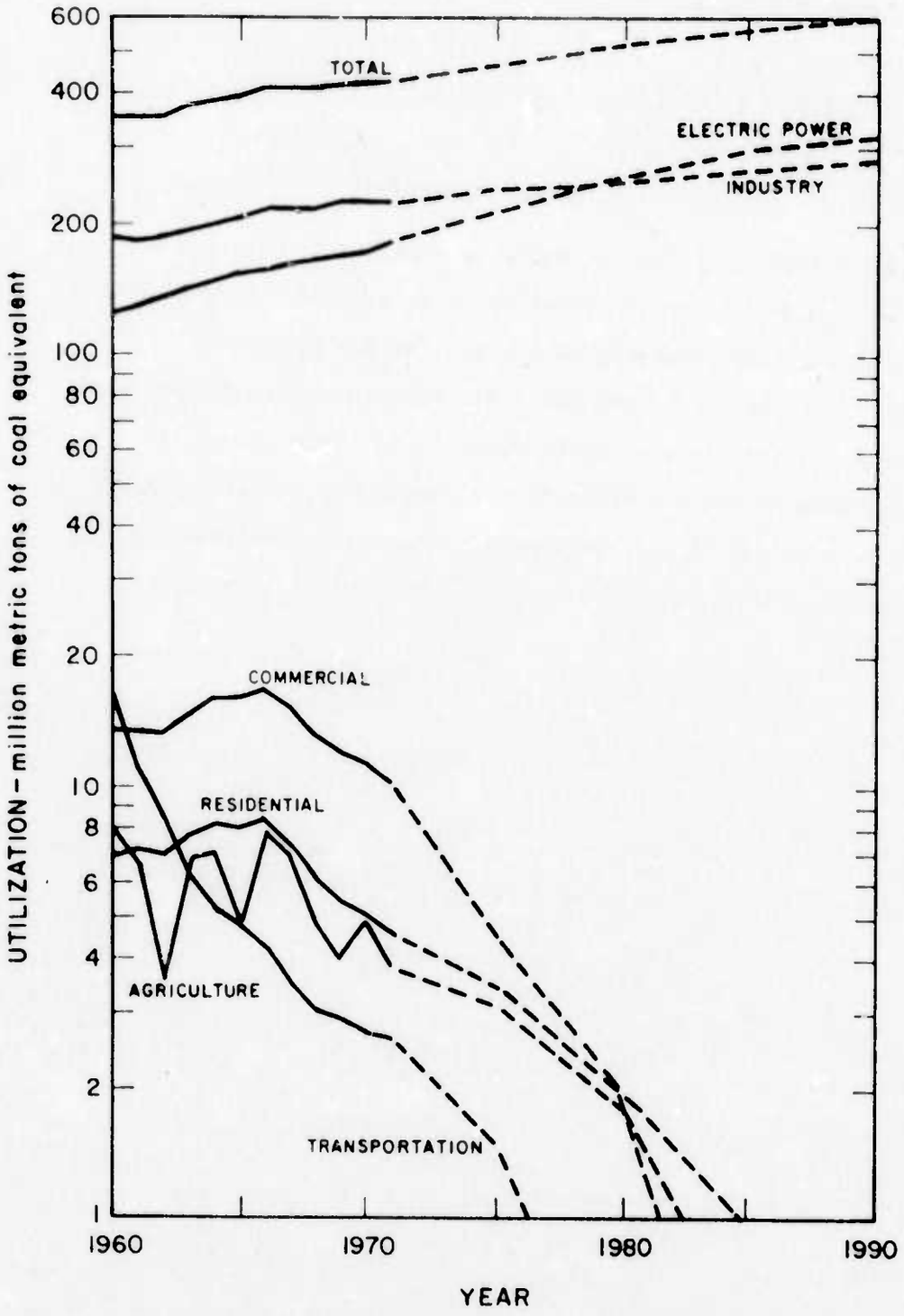


Figure 6

USSR UTILIZATION OF ALL SOLID FUELS

Solid fuel consumption in the other Eastern European countries is shown in Figure 7, where it is seen that modest growth is expected in Poland, Czechoslovakia, Bulgaria, and Romania, and little or no growth of solid fuel use is expected in East Germany and Hungary, where oil and gas are projected to become increasingly important.

In summary, the use of solid fuels is expected to have a continuing modest growth, primarily for electric power generation. Hard coal will probably be restricted primarily to coking, and for other purposes will be replaced by brown coal, oil, and gas. Surface mining is expected to provide an increasing share of solid fuels as new large mines in Southwestern Siberia and Central Asia are developed. Although oil shale and peat will continue to be used locally, they will provide a rapidly declining share of the energy balance.

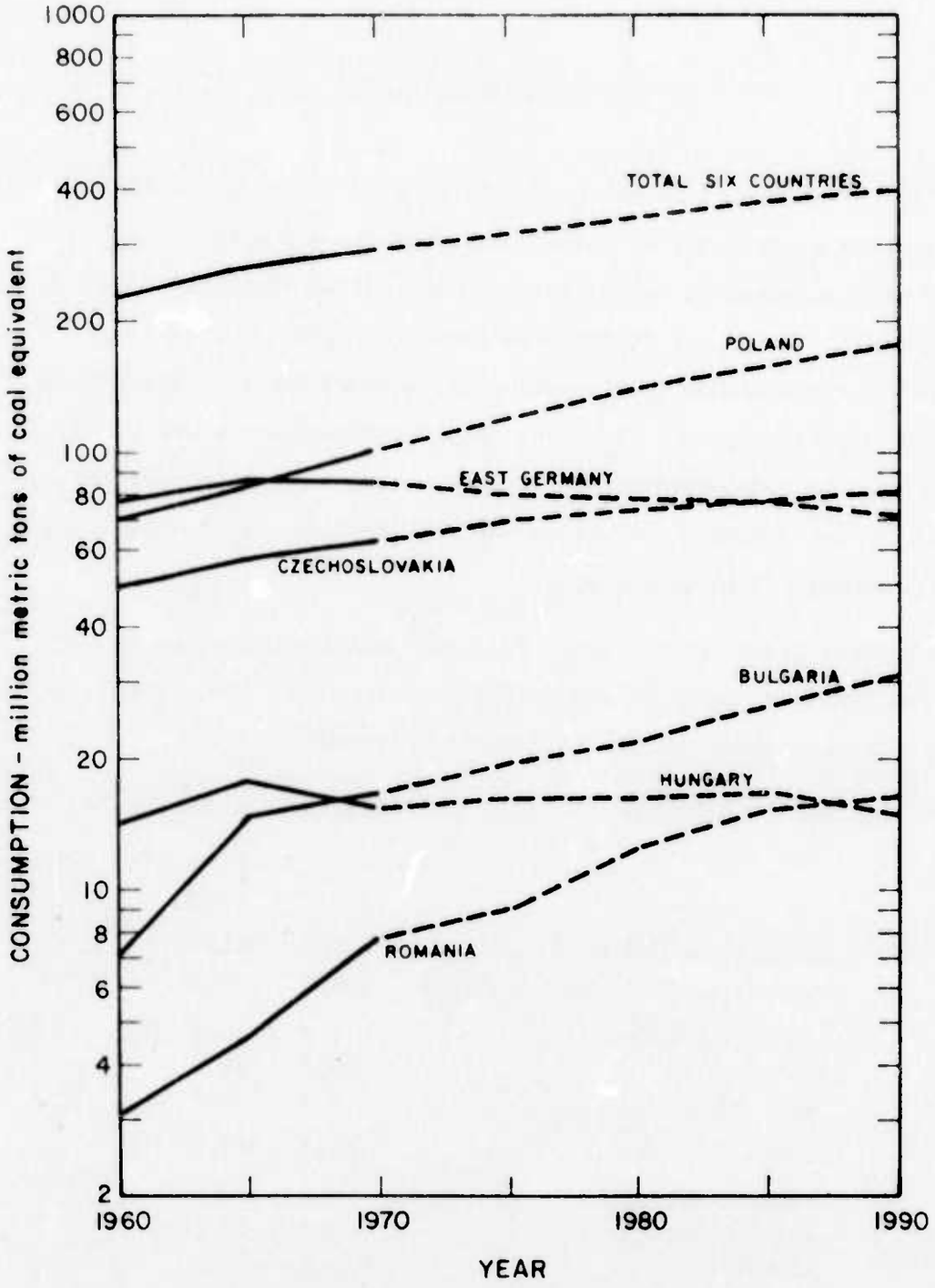


Figure 7

SOLID FUEL CONSUMPTION IN EASTERN EUROPE

IV PETROLEUM DEVELOPMENT

Except for periods of war and civil strife, the USSR has been a major producer and net exporter of oil and oil products since 1873. However, the dramatic increase in production and consumption (shown in Figure 8) has taken place since the decision in the early 1950s to shift from a coal to an oil and gas economy. Oil production reached the U.S. level in 1971 and is likely to surpass it by 1975. Exports of crude oil and products account for about one-quarter of oil production, and may be expected to continue in the future. The shaded portions of Figure 8 indicate losses in crude transport and refining.

Continued growth of the oil industry is heavily dependent upon the development of new fields, and especially those in Siberia. The major growth areas are shown in the following tabulation:

REGIONAL DISTRIBUTION OF CRUDE OIL PRODUCTION IN THE USSR*
(Million Metric Tons)

Region	1970	1975 (Plan)
European part (including Urals)	285.2	314.5
Orenburg Region	7.4	14.0
Perm Region	16.1	21.5
Komi ASSR	5.6	10.0
Asiatic Part (east of Urals)	63.6	181.5
Western Siberia	31.4	125
Turkmen SSR	14.4	22
Kazakh SSR	13.1	30
Total	348.8	496.0

* Not including gas condensate.

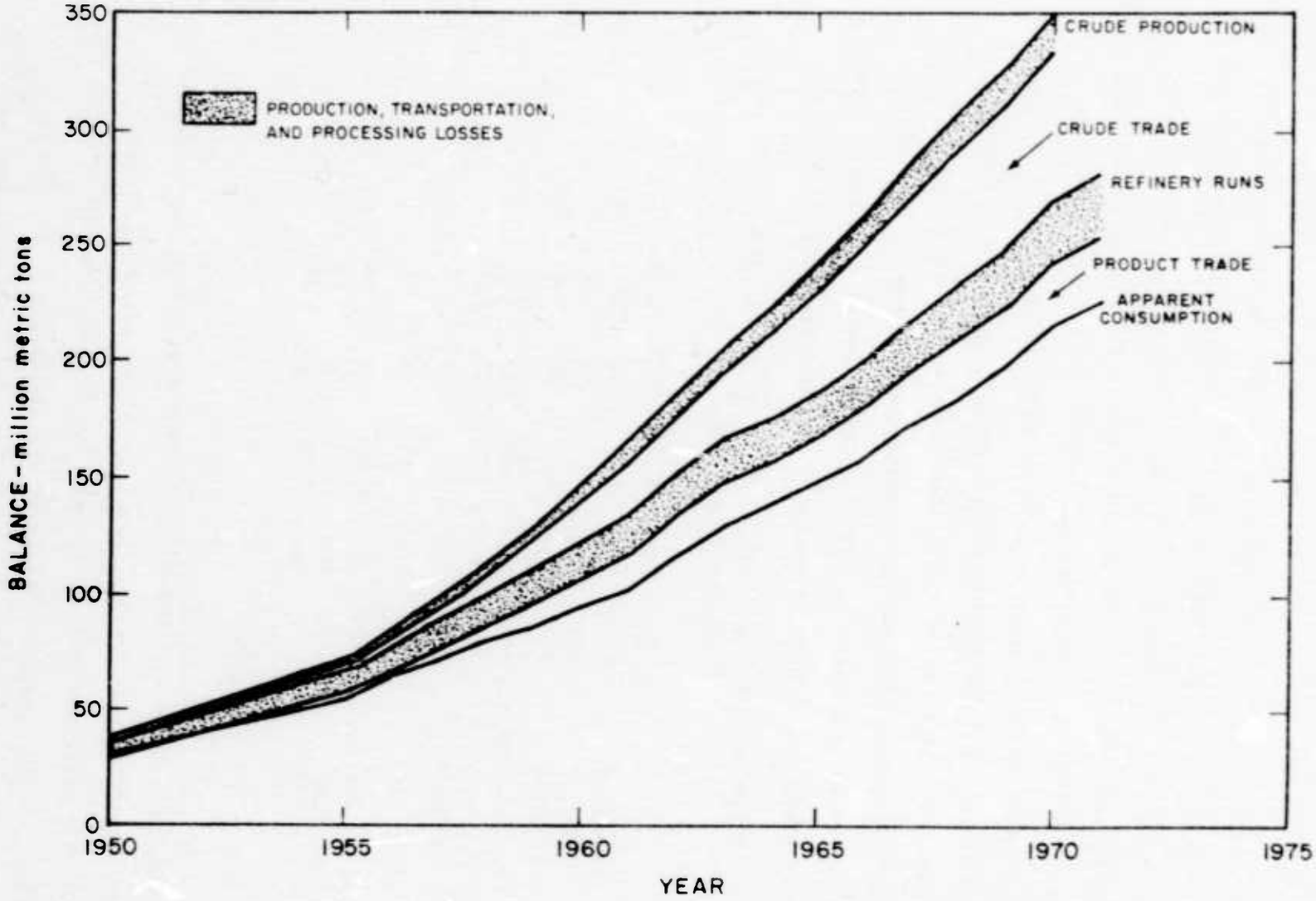


Figure 8

OIL AND OIL PRODUCTS BALANCE IN THE USSR

About four-fifths of the added production during the current five-year plan is expected to occur east of the Urals, especially in Western Siberia. Some doubts have been expressed about the Soviet ability to exploit the Western Siberian deposits in a timely fashion. Although Soviet technology may not be as sophisticated as that of the United States, over 30 million tons of crude oilwwere produced in Western Siberia in 1970, just ten years after oil was discovered at Shaim 63 million tons were produced in 1972, when Samotlor alone overfullfilled the plan by 5 Mt. A problem that resulted from this shift of oil production to the east is the extra burden placed onthe transportation system. The following tabulation shows the means of crude and product transport in the USSR from 1950 to 1975.

MEANS OF CRUDE AND PRODUCTS TRANSPORT IN THE USSR
(Million Metric Tons)

	1950	1955	1960	1965	1970	1975
Railroad Total	43.2	77.6	150	221	302	410
Crude	14.1	15.6	37	53	84	105
Products	19.1	62.0	113	168	218	305
Pipelines Total	15.3	51.7	130	226	340	
Crude	12.6	45.3	115	205	315	
Products	2.7	6.4	15	21	25	
River Total	11.9	14.4	19	25	34	
Ocean Total	15.8	23.0	34	54	93	
Foreign	n.a.	n.a.	8	23	58	
Internal	n.a.	n.a.	26	31	35	

n.a. - not available.

Although pipelines have had a rapid growth over the period shown, they have not effectively met the demand for either crude or product transport; the railroads continue to carry an increasing amount of crude and the bulk of the products. The following tabulation of the average length of oil pipeline haul shows that the length of the crude haul has grown dramatically, while the length of product haul has remained essentially constant.

AVERAGE LENGTH OF OIL PIPELINE HAUL IN THE USSR
(Kilometers)

	1950	1955	1960	1965	1970	1971
Crude oil	230	234	350	629	826	939
Products	739	648	745	857	864	840

This trend is expected to continue as the center of crude production moves away from the markets and new refineries are built nearer to the consumers. This will, of course, increase the cost of delivered product. The cost of pipelining crude oil from Western Siberia fields to Moscow would be about 2 rubles per ton.

In addition to a shortage of product pipelines, the supply of oil products has been limited by refining capacity. As shown in the following tabulation, the USSR has consistently fallen short of its planned refinery growth, although its current five-year projection seems more realistic.

GROWTH INDICES OF PRIMARY REFINING CAPACITY IN
THE USSR, PLANNED AND ACTUAL
(Growth Over Planning Period)

Planning Period	Planned Growth Index	Actual Growth Index
1959-1965	2.0 Plus	1.9
1966-1970	1.7	1.44
1971-1975	1.4	1.3*

* SRI projection.

The apparent refinery runs in the USSR are seen in Figure 9 to be slanted heavily to fuel oil, with a substantial increase in diesel fuel production to match the mechanization of agriculture in the late 1950s. This breakdown is similar to that of Western Europe and is expected to

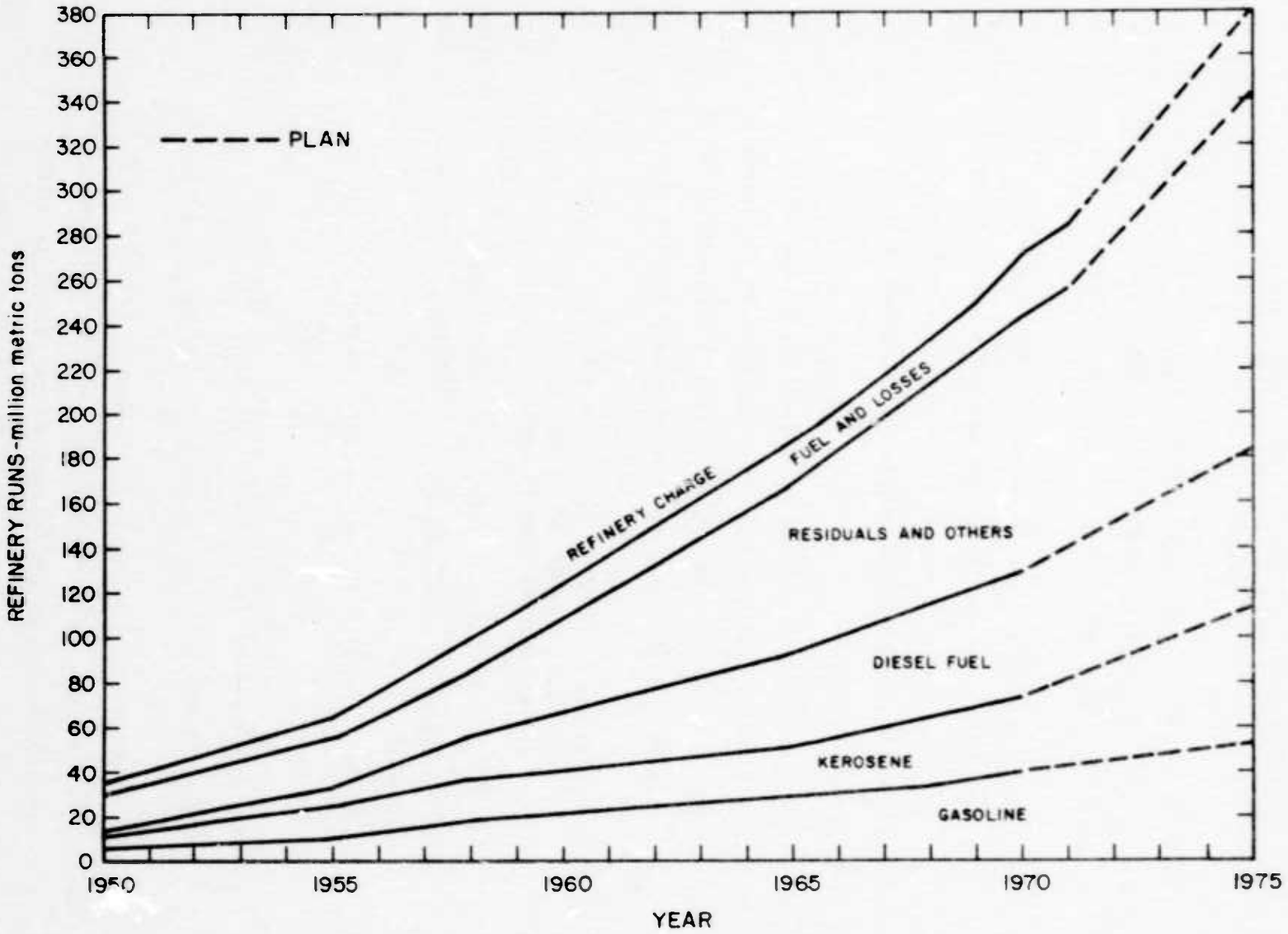


Figure 9

APPARENT REFINERY RUNS IN THE USSR

remain so, with emphasis on fuel oil. The quality of these products is dependent upon the relatively high sulfur content of Soviet crudes, which is shown in the following tabulation.

SULFUR CONTENT OF CRUDES DELIVERED TO SOVIET REFINERIES
(Percent of Total)

	Less than 0.5 WT%	0.5 WT% to 2.0 WT%	Over 2 WT%
1965	25.8	64.6	9.6
1966	25.4	64.4	10.2
1967	24.3	64.9	10.8

The quality of Soviet oil products also suffers from a lack of sophisticated secondary processing capability at Soviet refineries relative to the United States, as shown below.

SECONDARY PROCESSING USSR REFINERIES
(Percent of Primary Distillation)

	USSR			1970		U.S.
	1955	1960	1965	Plan	Actual	1970
Thermal cracking	48.1	36.4	26.7		18.5	10.3
Catalytic cracking	0.9	n.a.	5.2	6.5	5.7	39.7
Catalytic reforming	-	-	4.4	10.9	6.1	23.4
Hydrotreating	-	-	3.0	4.5	4.1	31.4
Hydrocracking	-	-	-	0.9	-	6.2

n.a. - not available.

This shortage of secondary processing capability is especially important to the petrochemical industry, which is faced with importing feedstocks. Continuing improvements in secondary processing should alleviate this difficulty.

The Eastern European countries can be seen from the following tabulation to be increasingly dependent upon imports of crude oil from the USSR.

OIL PRODUCTION AND IMPORTS, IN EASTERN EUROPE
(Million Metric Tons)

	1960	1965	1970
Production			
USSR	147.9	242.9	352.6
Eastern Bloc	13.3	15.2	16.6
Eastern Bloc Imports			
Crude	6.4	16.9	34.1
Products	4.0	5.6	7.5
Total	10.4	22.5	41.6

Petroleum products account for a decreasing share of the imports as the Eastern European countries increase their refining capacity.

In summary, oil production in the USSR has started to shift toward Western Siberia, increasing the cost of oil products to the consumers. Still, important production from European USSR fields is projected. Increasing domestic consumption of oil products will strain refinery capacity and construction schedules. Refinery product slates will change only slowly, continuing to stress fuel oil production to gain the economy of scale; the capacity of individual refineries will increase to about 240,000 barrels per day. There will be an increasing need for secondary processing to handle new high sulfur crudes and to meet the needs of the petrochemical industry and the new demands of the transportation sector. New refineries will tend to be located near centers of consumption. The Eastern European countries will continue to be dependent upon the USSR for crude oil, but will approach self-sufficiency in refined products.

V NATURAL GAS DEVELOPMENT

In contrast with the petroleum industry, the natural gas industry in the USSR is a relatively recent development, becoming significant less than 20 years ago. Before 1955 most natural gas was associated gas that was a byproduct of the petroleum industry. The gas industry has consistently fallen short of Soviet plans (as seen in Figure 10) and not kept pace with demands. This shortfall is due mainly to lack of gas processing plants and to delays in the pipeline construction industry. This is recognized by the Soviet leaders who have scheduled the laying of 33,000 kilometers of large diameter (40-inch to 56-inch) main gas pipoline in the ninth five-year plan.

As with coal and oil, the production of natural gas projected to shift toward the east, although the European fields will continue to bo important. The following tabulation, which shows the main growth areas, indicates that 80 percent of the increased gas production from 1970 to 1975 is expected to occur east of the Urals.

REGIONAL DISTRIBUTION OF NATURAL GAS
PRODUCTION IN THE USSR
(Billion Cubic Meters)

	1970	1975 (Plan)
European part (including Urals)	139	164.1
Orenburg Region	1.3	26
Komi ASSR	6.9	16.1
Asiatic part (east of Urals)	59	155.9
Western Siberia	9.3	44
Turkmen SSSR	13.1	65.1

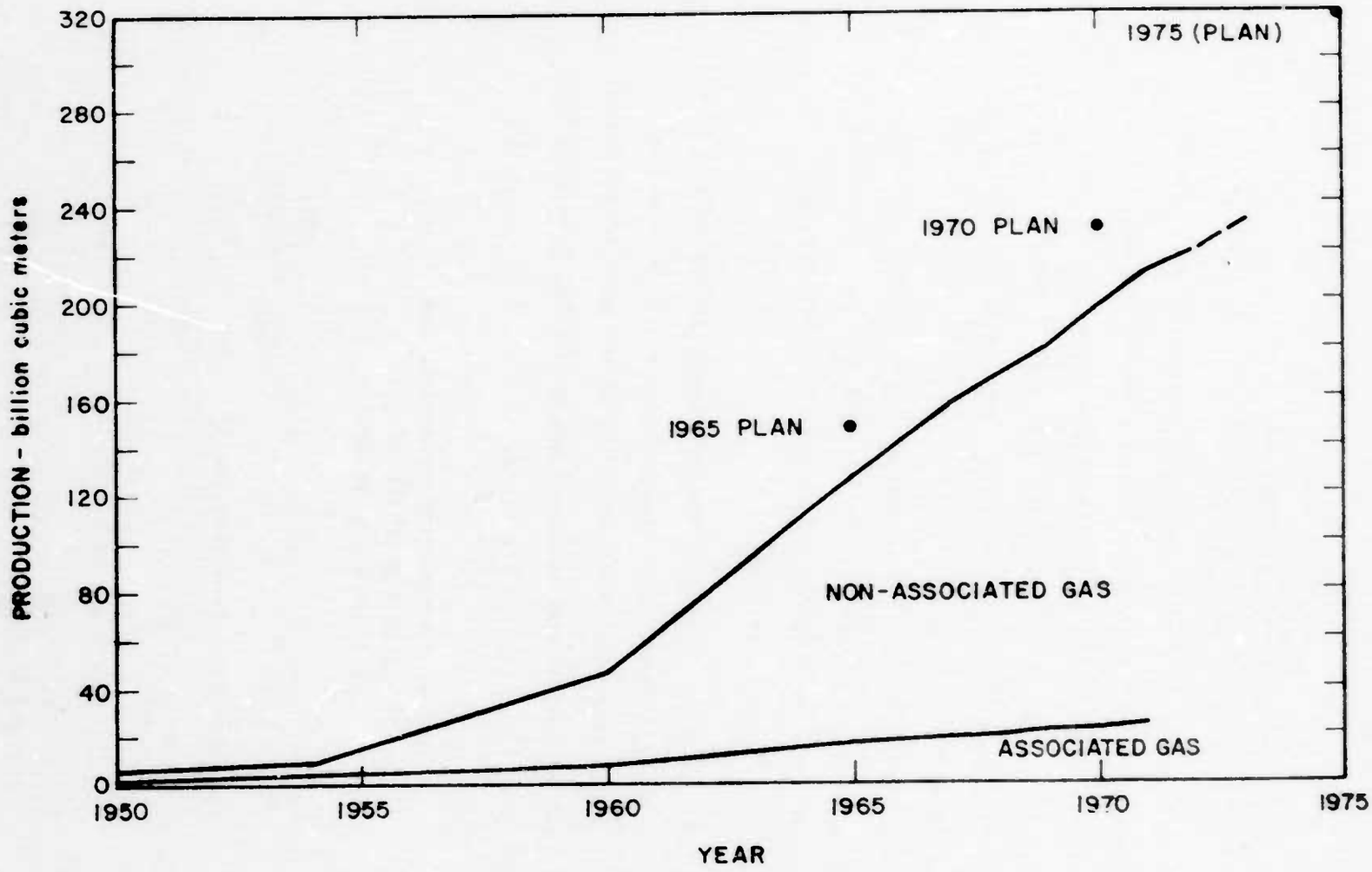


Figure 10

USSR NATURAL GAS PRODUCTION

Since the increased production in the four areas shown exceeds the total increase in production during the period, other fields must have a decreasing production.

This will, of course, greatly increase the average distance transported beyond that shown in the following tabulation. For example, the transport of gas from Urengoi, 3,000 kilometers, through the Northern Lights Pipeline to Leningrad would cost about 9 rubles per 1,000 cubic meters.

NATURAL GAS TRANSPORT IN THE USSR

	1950	1955	1960	1965	1968	1970
Gas production (billion cubic meters)	5.8	9.0	45.3	127.7	169.1	197.[illegible]
Gas pipelined (billion cubic meters)	1.5	3.5	32.8	112.1	145.7	181.5
Average distance of transport (kilometers)			607	680	900	

The substantial difference between gas produced and gas pipelined represents losses and usage in the field.

In addition to the losses of natural gas, there is a substantial loss of associated gas in the oil fields, as shown in Table 6. The degree of gas utilization has dropped from 70 percent in 1965 to 61 percent in 1970, which was 6 percent less than the planned level of utilization in that year. This is a further result of the shift of production to the east and the resultant shortage of gas processing equipment and pipelines. (In comparison, over 90 percent of the associated gas is used in the United States.) The large diameter pipe (42, 48, and 56 inches) being introduced in the USSR is more efficient than the relatively smaller diameter pipe in widespread use in the United States, but there is a shortage in this larger pipe that limits gas transport capabilities.

In gas consumption, there is inadequate storage capacity to meet peak demands. As shown in Table 7, there was only enough storage capacity

Table 6

EXTRACTION AND LOSSES, AND UTILIZATION OF ASSOCIATED GASES

Indicator	1965	1966	1967	1968	1969	1970 (Plan)	1970 (Actual)
Extraction (Million cubic meters)	16,482.9	17,789.9	18,857.9	19,581.2	21,571.6	22,720.0	
Losses (Million cubic meters)	7,064.1	7,816.1	8,829.7	10,913.1	12,364.9	11,079.0	
Utilization (Percent)	70.0	69.5	68.1	64.2	63.6	67.2	61.1

Table 7

UNDERGROUND STORAGE OF GAS IN THE USSR

Indicator	1965	1966	1967	1968	1969	1970	1971	1975 (Plan)
Injection of gas (Million cubic meters)	1,777.9	2,240.5	3,244.1	3,762.9	4,103.6	5,473.0	5,500.0	
Withdrawal (Million cubic meters)								
Annual	1,012.3	1,442.4	1,776.2	2,668.7	3,395.9	3,643.0	3,700.0	
Daily (max.)	17.5	20.7	31.3	38.9	33.0	52.1	53.0	
Number of facilities	10	10	11	12	15	15	15	
Capacity, as percent of required for peak demand	36					60		66

to meet 36 percent of peak demands in 1965. This increased to 60 percent in 1970, with plans to reach 66 percent by 1975.

The production of natural gas in Eastern Europe (Table 8) is small compared to USSR production, with only Romania being self-sufficient in this regard.

In summary, natural gas production is projected to move toward the east, as with other fuels. There continue to be shortfalls in gas production and under-utilization of associated gas because of lack of pipeline and processing facilities. Supply dislocations continue because of shortage of storage facilities. Increased exports of natural gas from the USSR to the other Eastern European countries will be partly offset by increasing imports of gas to the USSR from Iran and Afghanistan.

Table 8

PRODUCTION OF NATURAL GAS IN EASTERN EUROPE
(Million Cubic Meters)

	1960	1965	1966	1967	1968	1969	1970
Bulgaria	-	73.2	109	329	508	525	474
Czechoslovakia	1,443	965	1,070	1,017	1,108	1,185	1,204
GDR	-	133	116	107	143	370	1,233
Hungary	342	1,108	1,552	2,045	2,687	3,235	3,469
Poland	541	1,312	1,290	1,463	2,402	3,872	4,975
Romania	9,980	16,773	18,046	19,857	21,036	23,093	23,990
Total Eastern Europe	12,306	20,364	22,183	24,818	27,882	32,280	35,345
USSR	42,221	118,981	133,236	146,734	157,597	168,798	184,478
Eastern Europe as Percent of USSR	29.1	17.1	16.6	16.9	17.7	19.1	19.2

VI ELECTRIC POWER DEVELOPMENT

Since Lenin first recognized the electric power industry as basic to the growth of the Soviet economy, electric power developments have enjoyed a relatively privileged position and have acquired an ability to produce equipment as technologically advanced as any in the United States or Western Europe. From its earliest development, this equipment has been installed in an integrated grid in European USSR that is being extended both beyond the Urals and into Eastern Europe.

The trends in installed electric power capacity in the USSR are shown in Figure 11. Although most of the installed capacity is derived from thermal power plants, hydroelectric power contributes over 20 percent of the total, and nuclear power is expected to do so by 1990. Many of these nuclear stations are located where hydro power is unavailable and where it is uneconomical to transport fossil fuel.

The following tabulation shows that (as with other energy resources) the greatest opportunity for expanding hydroelectric power lies east of the Urals, where the hydroelectric potential is under-utilized.

HYDROELECTRIC POWER UTILIZATION IN THE USSR
BY REGION IN 1970

	Production of Hydro-power (Million kwh)	Percent of Economic Potential
European Region	68,839	34.3%
Asiatic Region	63,281	7.1
Western Siberia	1,760	3.2
Eastern Siberia	49,356	14.1
Total USSR	132,120	12.1

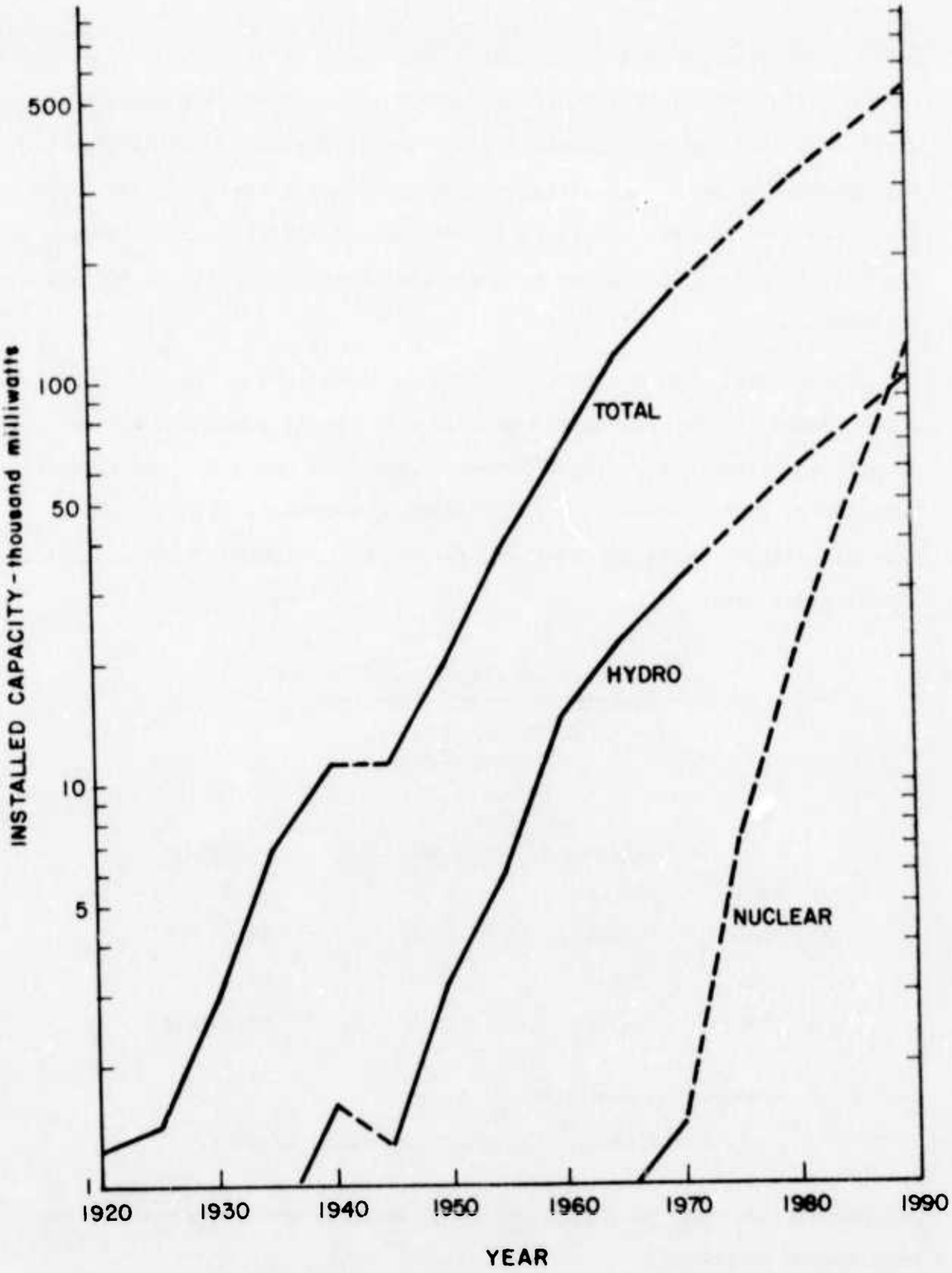


Figure 11

INSTALLED ELECTRIC POWER CAPACITY IN THE USSR

Most of the hydroelectric development will occur in Western Siberia, where the existing economic potential is currently only about 2.3 percent utilized. Although some pumped storage plants are being built, they are not expected to be a significant source of electric energy in the USSR. Other Eastern European countries do not have significant unused hydroelectric potential, and major projects are being built only in Romania and Bulgaria.

In contrast with the United States, a large portion of the thermal power plants in the USSR supply heat in the form of steam and hot water as well as electricity. The following tabulation shows the installed capacity by type of station. The condensing turbine stations provide only electricity while the heat and power turbine provide both electricity and district heat.

INSTALLED CAPACITY OF ELECTRIC POWER
THERMAL STATIONS IN THE USSR,
BY TYPE OF STATION
(Thousand MW)

	Steam Turbines		
	Condensing	Heat and Power	Others*
1958	20.9	13.0	8.7
1965	48.2	32.7	11.0
1970	76.2	47.0	10.2
1975	99.5	65.0	12.5-14.5

* Gas Turbines and Internal Combustion Engines.

The gas turbines and internal combustion engines are used primarily for peak-demand operation.

There have been dramatic increases in the sizes of individual turbines and station sizes since World War II, and further increases in unit sizes are planned for the future, as shown in Table 9. Eight hundred MW power turbines were installed in stations having 2,000 MW total capacity in 1970. At present, 1,200 MW single shaft turbines are being built for introduction in 3,000 MW stations by 1975.

In conjunction with the technological changes in thermal power generation, a basic change in the type of fuel used in power stations also occurred in recent years. Table 10 shows that coal's share of the fuel balance has dropped from 71 percent in 1960 to 46 percent in 1970 and is expected to drop another 3.5 percent by 1975. In the meantime, the share of gas and oil is expected to increase from about 20 percent to about 52 percent. It can be observed that thermal stations consume over one-third of the fuel used in the USSR and are still growing.

The efficiency in fuel consumption of thermal power stations is improving dramatically, as a result of the increasing size of thermal power stations which lead to economies of scale; the change of fuel type; and the phasing out of older, loss efficient generating capacity. This increase in efficiency is shown by the following comparison of decreasing heat rates:

NET HEAT RATES OF THERMAL POWER STATIONS IN THE USSR
(Btu/kWh)

	USSR (Net) Btu/kWh	United States (Net) Btu/kWh
1960	14,157	10,701
1965	12,096	10,384
1970	10,459	10,508
1975 (Plan)	9,444	

Table 9

MAXIMUM POWER STATION SIZES AND STEAM PARAMETERS IN USSR

Type of Station	Condensing Turbines			Electric Power and Heat Turbines		
	1950	1970	1975	1950	1970	1975
Maximum Station Capacity (MW)	510	2,440	3,000	150	600	1,000
Maximum Individual Turbo-Generator Size (MW)	100	800	1,200	25	100	250
Maximum Boiler Capacity (Metric Tons/Hour)	230	1,250	3,600	230	480	950
Initial Steam Parameters at Turbine Inlet						
Pressure, (Kilogram/ sq. cubic meter)	90	240	240	90	130	240
Temperature, °C	500	565	565	500	565	565
Second Reheat, °C	--	565	565	--	--	565

Table 10

STRUCTURE OF FUEL COMSUMPTION IN USSR
THERMAL ELECTRIC POWER STATIONS
(Percent of Total Fuel on Coal Equivalent Fuel Basis)

	1960	1965	1970	1975 (Plan)
Gas	12.3%	25.6	26	26.8%
Liquid Fuel	7.5	12.8	22.5	25.1
Coal	70.9	54.6	46.1	42.6
Peat	7	4.5	3.1	3.5
Oil Shale	1	1.5	1.7	1.6
Other	1.3	1	0.6	0.4
Percent of Total Fuel Consumed in USSR	29.3	32.6	35.6	36.5

Within ten years, the heat input per kilowatt of electrical output has decreased by 25 percent to equal that of the United States, with further improvements projected for 1975.

The rapid introduction of nuclear power into the USSR and Eastern Europe is shown in Table 11. The USSR, East Germany, and Czechoslovakia are the clear leaders in this program. Poland and Romania have less requirement for nuclear power because of their apparent self-sufficiency in coal, and oil and gas, respectively.

Table 12 shows that the standardized 440 MW pressurized water reactor will take the lead, followed by the light water cooled, graphite moderated reactor. The fast breeder reactor is not expected to be significant until after 1980.

Table 11

NUCLEAR POWER PROJECTIONS FOR EASTERN EUROPE
INSTALLED CAPACITY
(Thousand MW)

	1970	1975	1980	1985	1995
USSR	1.4	7.1	21.1	53	118
Bulgaria	--	.44	.88	1.76	3.5
Czechoslovakia	--	--	1.76	3.6	6.0
GDR	0.07	0.51	2.0	4.0	7.0
Hungary	--	--	0.44	0.88	1.76
Poland	--	--	--	0.44	0.88
Romania	--	--	--	0.44	0.88

Table 12

INSTALLED CAPACITY OF USSR NUCLEAR POWER REACTORS
BY TYPE
(Thousand MW)

	1966	1970	1973	1975	1980
BWR	0.05	0.05	0.05	0.05	0.05
PWR	0.21	0.58	1.46	4.22	10.22
LWGR	0.69	0.89	0.89	1.89	8.87
FBR	--	0.01	0.36	0.96	1.96
Total	0.95	1.53	2.76	7.12	21.1

BWR - Boiling Water Reactor.
PWR - Pressurized Water Reactor.
LWGR - Light Water Cooled, Graphite Moderated Reactor.
FBR - Fast Breeder Reactor.

In summary, electric power generation is expected to continue its rapid growth, with thermal power stations leading the way and nuclear power becoming significant after 1985; the expansion in Eastern Europe will be based on standard Soviet 440 MW reactors. No significant hydro power programs are expected except possibly in Siberia, with transmission of power to the Urals and continued integration of the USSR and Eastern European power grids. Spot shortages of power because of inadequate reserve capacity will continue. The USSR will continue to develop large supercritical single shaft turbines, each having capacities on the order of 1,000 MW. Expansion of the use of strip mined, low-grade coal can be expected for thermal power stations.

VII SUPPLY-DEMAND BALANCE

In order to project the demand for basic energy in the USSR and the six Eastern European countries, the economic framework shown in Table 13 was developed from United Nations statistical abstracts and from statistical handbooks of the individual countries. It is seen that the total population, GNP, and energy consumption of the six Eastern European countries are only about 40 percent of the USSR levels.

Table 13

ECONOMIC FRAMEWORK FOR USSR AND EASTERN EUROPE

	USSR	Eastern Europe
1970 Population (million)	242.8	103.1
Growth rate 1960-1970	1.3%	0.6%
1970-1980	1.1	0.8
1980-1990	1.1	0.7
1970 GNP (billion U.S. dollars)	314.2*	137.0
Growth rate 1960-1970	6.7%	5.6%
1970-1980	6.6	5.9
1980-1990	5.5	5.1
1970 Primary energy (million tons of coal equivalent)	994.1	403.2
Growth rate 1960-1970	5.7%	4.5%
1970-1980	5.5	4.5
1980-1990	5.0	3.9

* The absolute value of Soviet GNP is subject to definition, but it does not affect results of this study because it was used only as an index.

The Eastern European countries are expected to grow in populations, GNP, and energy consumption at a slightly slower rate than the USSR.

Figure 12 shows the estimated demand for primary energy in the USSR during the 1960 to 1990 period. It is seen that the total demand for primary energy will nearly triple between 1970 and 1990. Since the demand for solid fuels is projected to increase only about 40 percent during this period, other sources must nearly quadruple to fill the gap. The changing energy balance is shown in Table 14. Whereas solid fuels supplied 42 percent and oil and gas a little over 50 percent of the energy in 1970, solid fuel's share will drop to about 21 percent and oil and gas will increase to two-thirds by 1990, with nuclear power approaching 10 percent and hydropower remaining constant at just over 4 percent.

The statistics shown on Figure 12 and Table 14 were derived by projecting the growth of the various sectors of the economy, and the amount of energy required for each end use. The breakdown of total primary energy by end use is given in Table 15, where it is seen that the combined demand for industry and electric power is a fairly constant 77 percent of the total from 1970 through 1990, even though industry and electric power reverse positions. The shares of the residential, commercial, and transportation sectors are projected to increase slightly through the period, while the share of agriculture and "other" decline slightly.

In addition to the demand for primary energy, the flow of secondary energy among the various economic sectors is important. Typical flows of secondary energy (electricity, steam, coke, manufactured gas) between the industrial and electric power sectors are shown in Figures 13 and 14. Even with the waste heat of much of the electric power industry being used as district heat, the total efficiency of the industry is only about 35 percent.

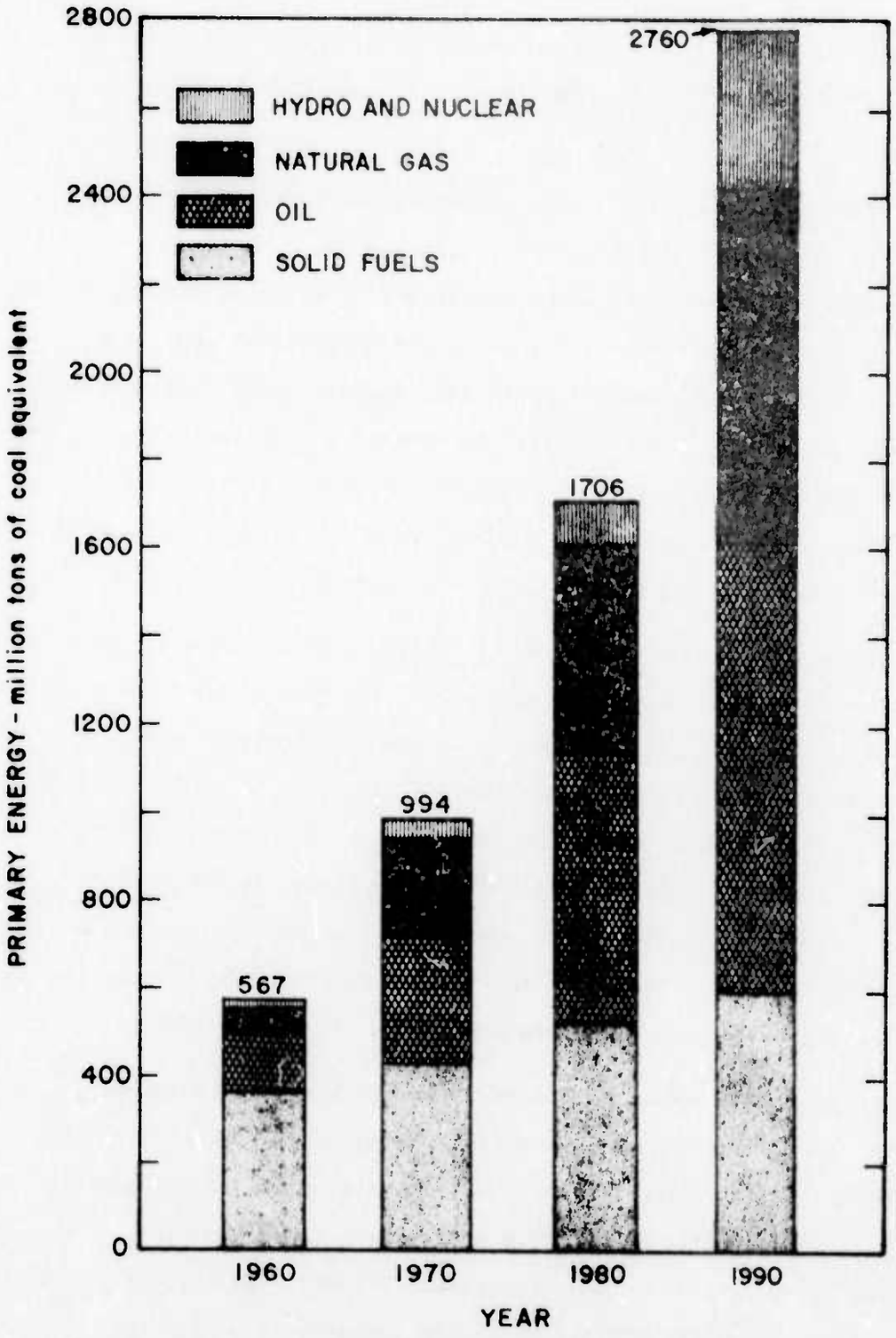


Figure 12
USSR DEMAND FOR PRIMARY ENERGY

Table 14

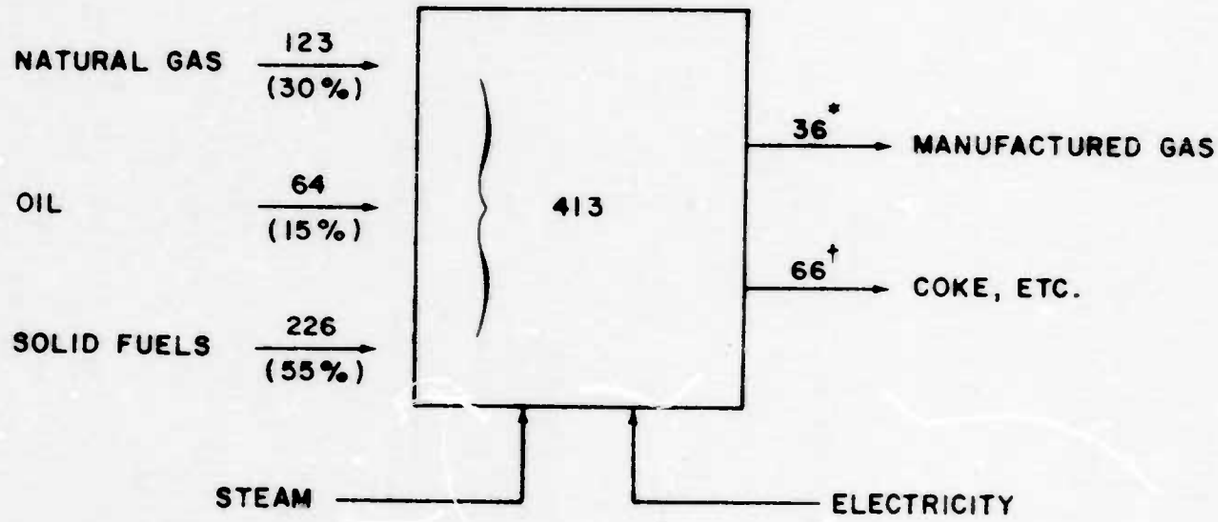
USSR DEMAND FOR PRIMARY ENERGY
BY SOURCE OF ENERGY

	1960	1970	1980	1990
Natural gas	9.2%	21.9%	27.9%	29.2%
Oil	23.5	31.1	35.9	36.2
Solid fuels	63.1	42.3	30.0	21.5
Hydro	4.2	4.6	4.3	4.3
Nuclear	-	0.1	1.9	8.8
	100.0%	100.0%	100.0%	100.0%

Table 15

DEMAND FOR PRIMARY ENERGY
BY END USE IN THE USSR
(Million Tons Coal Equivalent)

	1970	1980	1990
Residential and commercial	73	134	241
Industry	413 (41.5%)	630 (36.9%)	948 (34.2%)
Electric power	354 (35.6%)	691 (40.5%)	1174 (42.4%)
Transportation	72	130	234
Agriculture	53	82	123
Other	29	39	49
Total	994	1706	2769



* 26 Used by industry.

† 44 Used by industry.

Figure 13

ENERGY DEMAND OF USSR INDUSTRIAL SECTOR

(Million Tons of Coal Equivalent)

1970

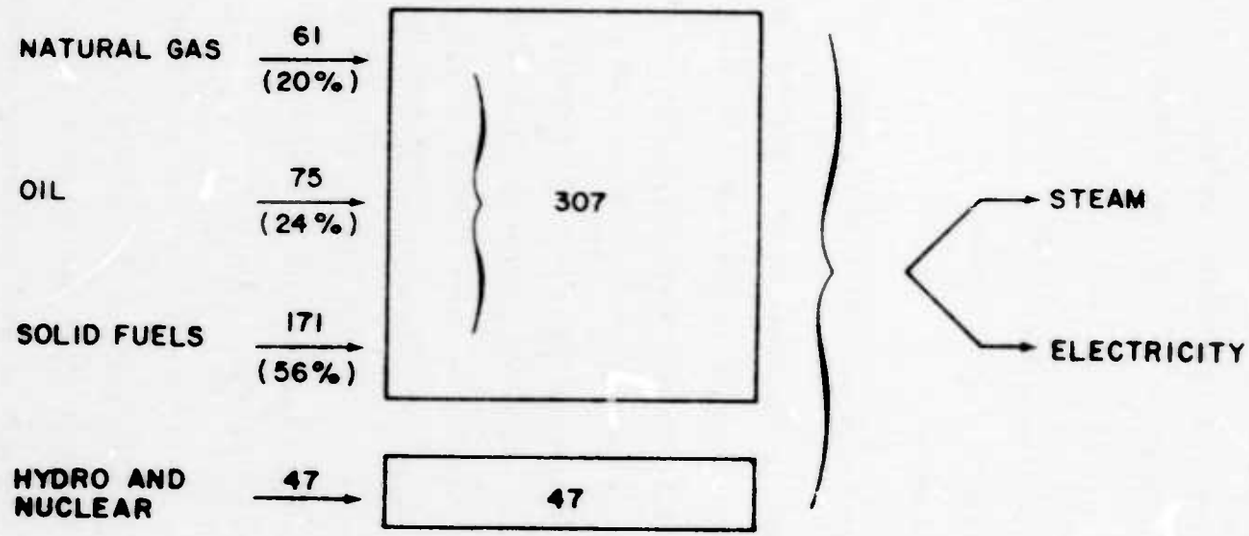


Figure 14

ENERGY DEMAND OF USSR ELECTRIC POWER INDUSTRY

(Million Tons of Coal Equivalent)

1970

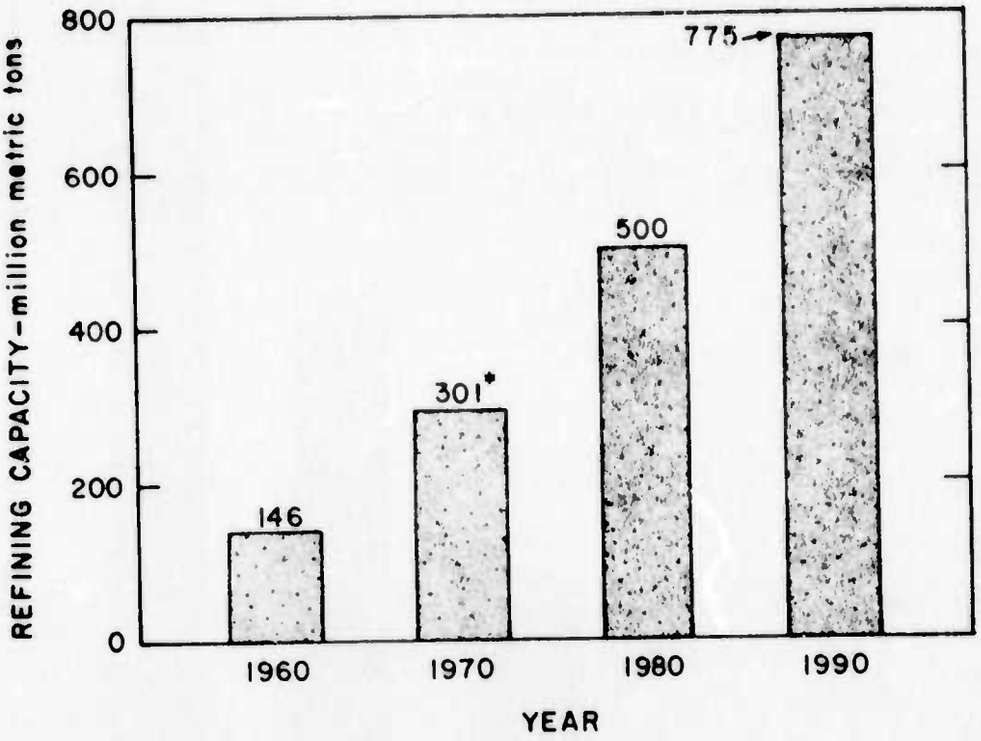
In order to meet the petroleum product demands through 1990, the very substantial buildup of refining capacity shown in Figure 15 will be required. This conclusion is based on the assumption that USSR will attempt not only to be self-sufficient in refined products, but also to continue exporting about 10 percent of its refined products, as in the recent past. The following growth rates in refining capacity would be required to meet these goals:

1960-1970 (actual)	7.5%
1970-1980	5.2%
1980-1990	4.5%

These would appear to be achievable in an expanding economy.

The growth in energy demand in the other Eastern European countries is expected to be significantly less than in the USSR. The increase in enemy demand shown in Figure 16 is significantly less than the increase in demand in the USSR during this period. Solid fuels (primarily coal) are expected to continue to provide a great share in the energy economies of these countries (except these countries will not support this expansion, they will probably rely on either increased coal imports from the USSR or a greater shift to oil and gas imports from the USSR or the OPEC countries. The expected shift in the fuel balance in Eastern Europe is shown in Table 16. By 1990 oil and gas will provide half of the energy, and nuclear power should begin to be significant.

The expected dependence of the Eastern European countries on omports to meet their energy requirements is shown in Table 17 and illustrated in Figures 17 and 18. Total production of coal in the six Eastern European countries should be adequate to meet their total demand for coal, although there are great differences between supply and demand in



1960 - 70	155	(3.1×10^6 bbl/day; 300 million bbl/day)
1970 - 80	199	(4.0×10^6 bbl/day; 400 million bbl/day)
1980 - 90	275	(5.5×10^6 bbl/day; 550 million bbl/day)

* Equivalent to 6.0×10^6 bbl/day of crude oil input.

Figure 15

USSR REFINING CAPACITY BUILDUP

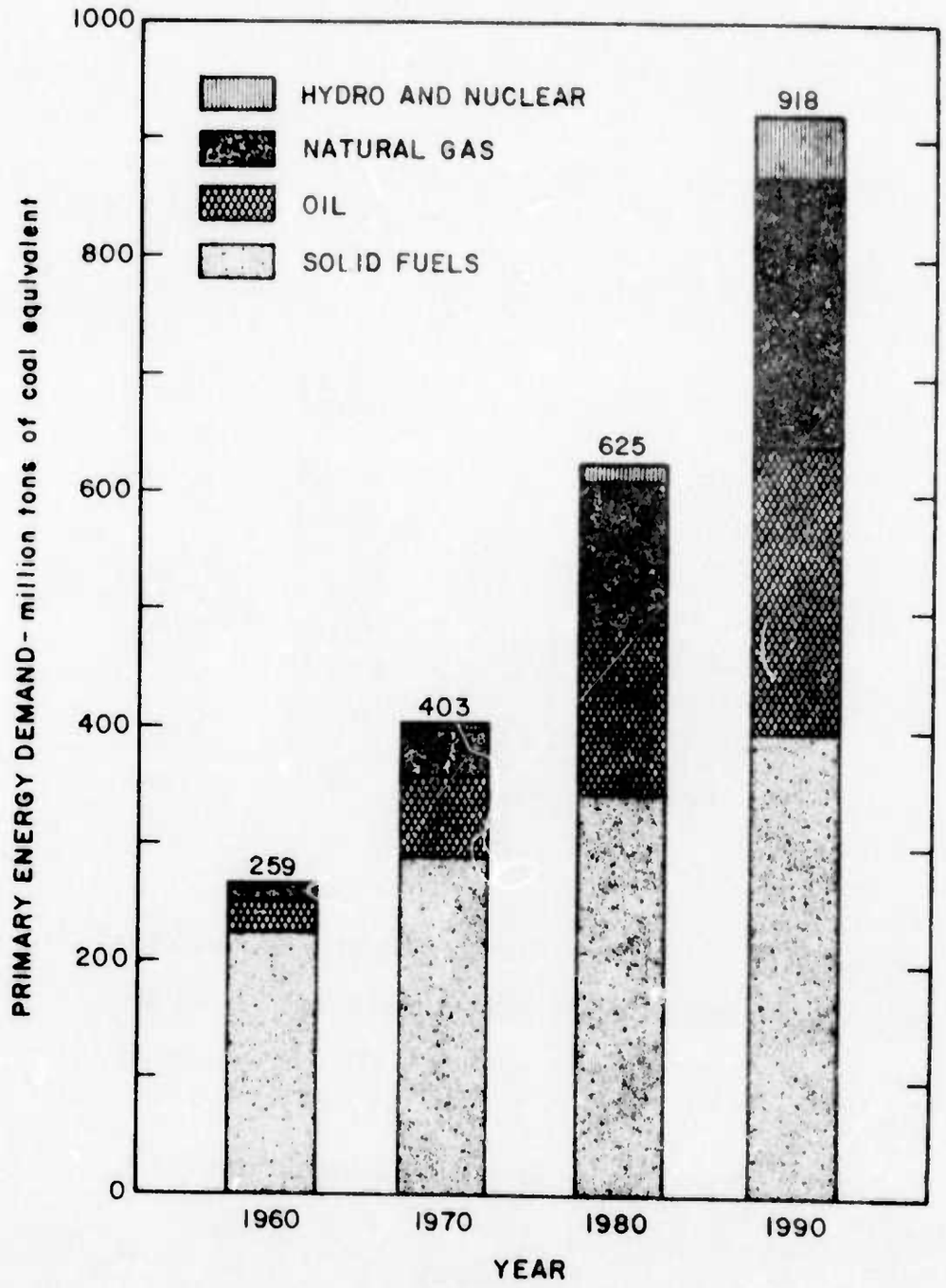


Figure 16

DEMAND FOR PRIMARY ENERGY IN EASTERN EUROPEAN COUNTRIES

Table 16

DEMAND FOR PRIMARY ENERGY BY SOURCE OF ENERGY IN EASTERN EUROPE

	1960	1970	1980	1990
Natural gas	5.0%	10.4%	19.9%	24.8%
Oil	8.0	16.8	22.2	26.1
Solid fuels	86.1	71.6	55.1	43.0
Hydro	0.9	1.1	1.6	1.6
Nuclear	-	0.1	1.2	4.5
	100.0%	100.0%	100.0%	100.0%

Table 17

DEPENDENCE OF EASTERN EUROPE ON IMPORTS FOR ENERGY SUPPLIES

	1970	1980
Oil (million metric tons/year		
Requirements	56	106
Production	17	18
Imports	39	88
Gas (billion cubic meters/year)		
Requirements	37	110
Production	34	74
Imports	3	36
Coal* (million metric tons/year)		
Requirements	596	685
Production	622	700-725
Imports/exports	21/32	30/40

* Hard coal and brown coal.

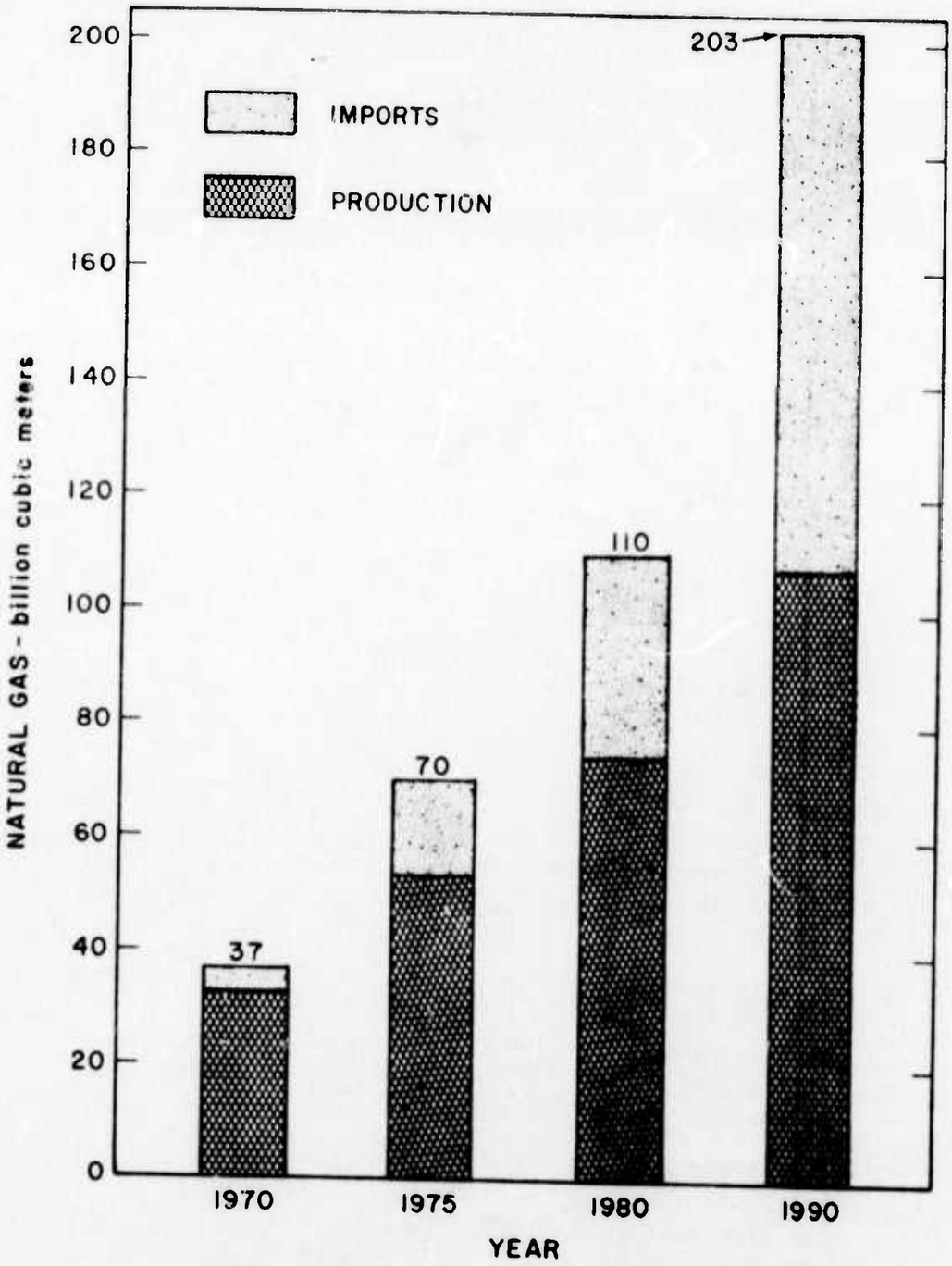


Figure 17
ESTIMATED PRODUCTION, IMPORTS, AND DEMAND OF NATURAL GAS IN EASTERN EUROPE

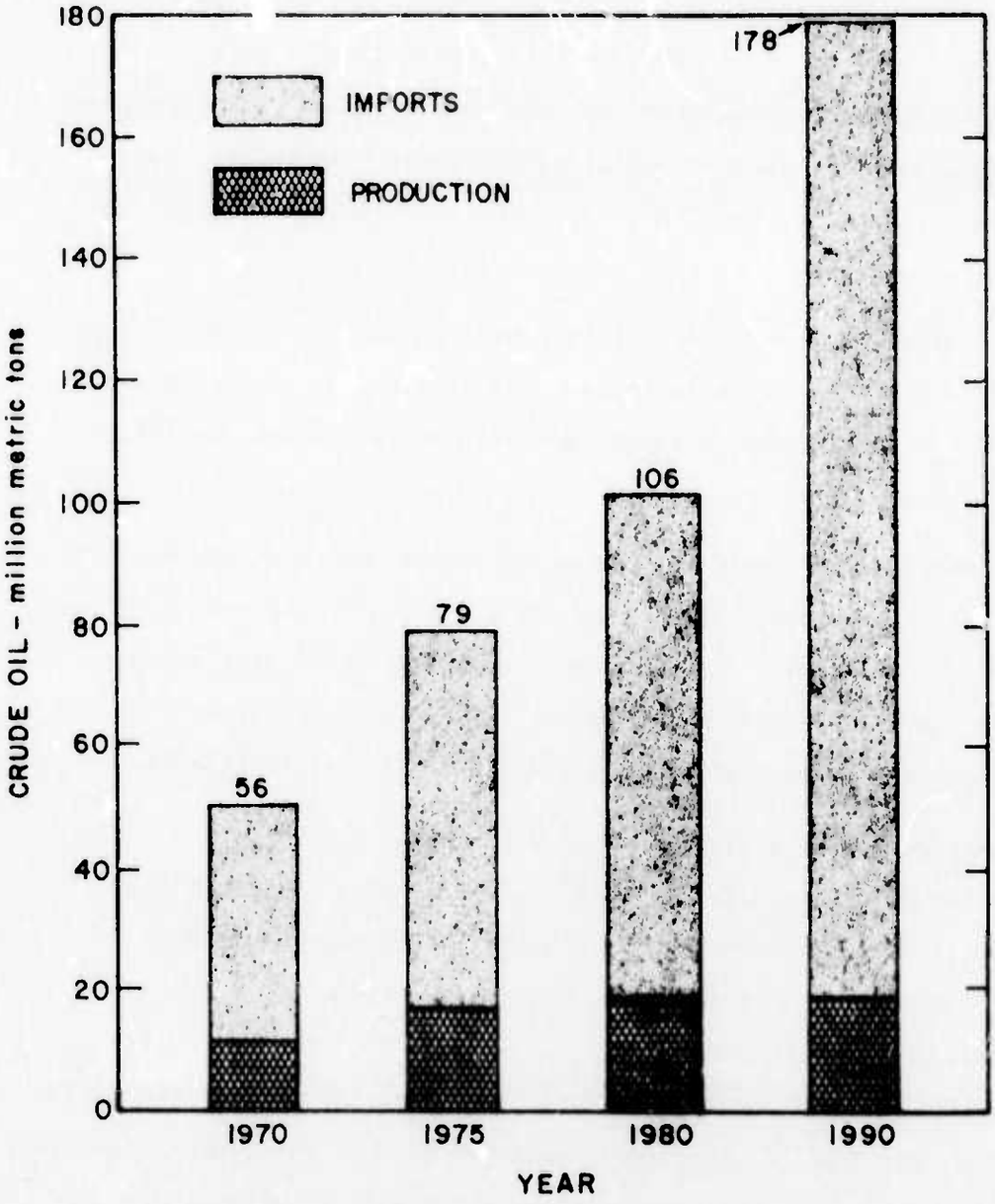


Figure 18

ESTIMATED PRODUCTION, IMPORTS, AND DEMAND OF CRUDE OIL IN EASTERN EUROPE

the individual countries. The total supply of gas in the six countries should be only about 10 percent short of their demand in 1970, but they will have to import about one-third of their natural gas from the USSR by 1980, and nearly half of it in 1990. A much more serious deficit in crude oil is expected throughout the study period, with a corresponding large demand for imports. The USSR currently fills almost all of this demand, but has recently suggested that their Eastern European clients begin to develop alternative sources of supply, i.e., the OPEC nations.

A major increase in refining capacity will be required in Eastern Europe and countries as they move toward self-sufficiency in refined products. The buildup shown in Table 18 should be within the capability of these nations.

The production and demand for crude oil in the USSR and potential for crude oil exports are shown in Table 19. The production figures shown are based on annual increases of 6.4 percent from 1970 to 1975, 5.4 percent from 1975 to 1980, and 4.6 percent from 1980 to 1990. Such increases will require a rapid development of oil reserves, particularly in Siberia.

If these production estimates are achieved, the USSR should be able to meet the domestic demand for petroleum products plus the crude oil requirements of Eastern Europe with a substantial balance for export to the rest of the world. To the extent that the requirements of the Eastern European countries are met through imports from the OPEC nations, additional crude oil will be available for export to the rest of the world. Alternatively, these potential exports could be used to relieve the expected short term problems resulting from expected shortfalls in natural gas production. As a swing fuel, oil could provide a cushion against possible shortfalls in the production of other energy sources.

Table 18

REFINING CAPACITY BUILDUP IN EASTERN EUROPE'
(Million Metric Tons per Year)

	1960-70	1970-80
Bulgaria	5.9	8.0
Czechoslovakia	8.0	8.0
GDR	8.7	13.8
Hungary	3.7	6.8
Poland	6.5	12.0
Romania	4.0	8.0
Total	36.8	56.6

Table 19

CRUDE OIL SUPPLY/DEMAND BALANCE
(Million Metric Tons)

	1970	1975	1980	1990
USSR				
Production**	353	480*	625	980
Demand†	289	368	470	768
Potential surplus	64‡	112	155	212
Eastern European requirements	39§	61	88	161
Potential export to rest of world	28§	51	67	51

---

* Five-year plan goal--496.

† Includes losses and refinery charge for product exports.

‡ Difference between production and demand; with imports of 2 million metric tons added, surplus is 66.

§ Actual deliveries.

** Including condensate production.

The expected refinery production, demand and potential exports of petroleum products from the USSR are shown in Table 20. The share of petroleum products produced for export is expected to decline over the coming years as other industrialized countries become self-sufficient in refining capacity. This will again require a substantial buildup of refinery capacity, as indicated earlier.

The USSR is expected to face a short term problem with natural gas. They have regularly missed their production goals, and are expected to continue this trend at least through 1975. Even so, the production figures shown on Table 21 require annual production inceases of 6.4 percent from 1970 to 1975, 9.4 percent from 1975 to 1980, and 7.2 percent from 1980 to 1990. Table 21 shows a potential production shortfall of about 64 billion cubic meters in 1975 (including contractual commitments to Europe) and 56 billion cubic meters in 1980. These figures are about equivalent to 50 million barrels of crude oil or residual fuel oil. This deficit will probably be met by a combination of reduced demands; imports of gas from Iran and Afghanistan; shifts to petroleum; and perhaps reneging on contract commitments. Expansion of the pipeline system should alleviate this problem by 1990.

Except for times of war and civil strife, the USSR has been a significant exporter of petroleum and products for 100 years. The exponential buildup of these exports since World War II are shown in Figure 19, and their recent stability is shown in Figure 20. Since energy exports provide an important share of Soviet hard currencies, they are expected to continue at a high level, with natural gas adding to the opportunities.

In summary, both oil and natural gas represent large foreign exchange earnings for the USSR, and the Soviets will attempt to meet their contract commitments. Although they plan to supply a major share of the oil and

Table 20

REFINERY PRODUCTION AND PRODUCT EXPORTS
(Million Metric Tons)

	1970	1975	1980	1990
USSR				
Production	257	332	427	712
Less: Own requirements (includes losses)	230	305	422	690
Potential surplus (available for export)	27*	27	5	22

* Imports--1; exports--28 million metric tons.

Table 21

NATURAL GAS SUPPLY/DEMAND BALANCE
(Billion Cubic Meters)

	1970	1975	1980	1990
USSR				
Production	198	270*	400-500	800-900
Demand†	198	300	420	720
Potential surplus	3.3‡	(30)§	5**	130††
Eastern Europe requirements	2.5‡‡	17	36	109
Commitments§§	-	17	25	21

* Five-year plan goal--320.

† Including losses.

‡ Available for export based on imports from Iran and Afghanistan.

§ Deficit.

** Assumed production of 425.

†† Assumed production of 850.

‡‡ Actual deliveries.

§§ Contract commitments to Western Europe, including options.

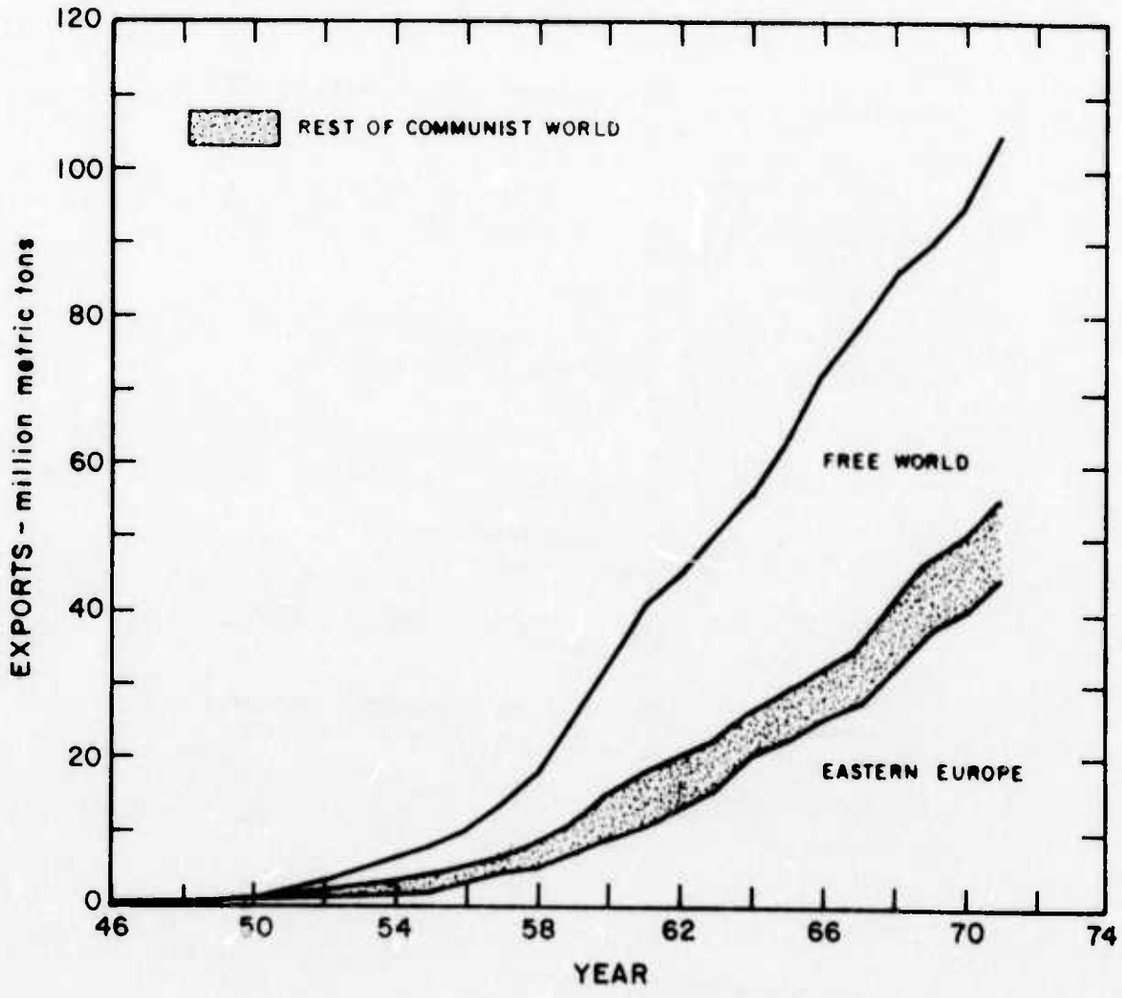


Figure 19
USSR OIL AND PRODUCT EXPORTS

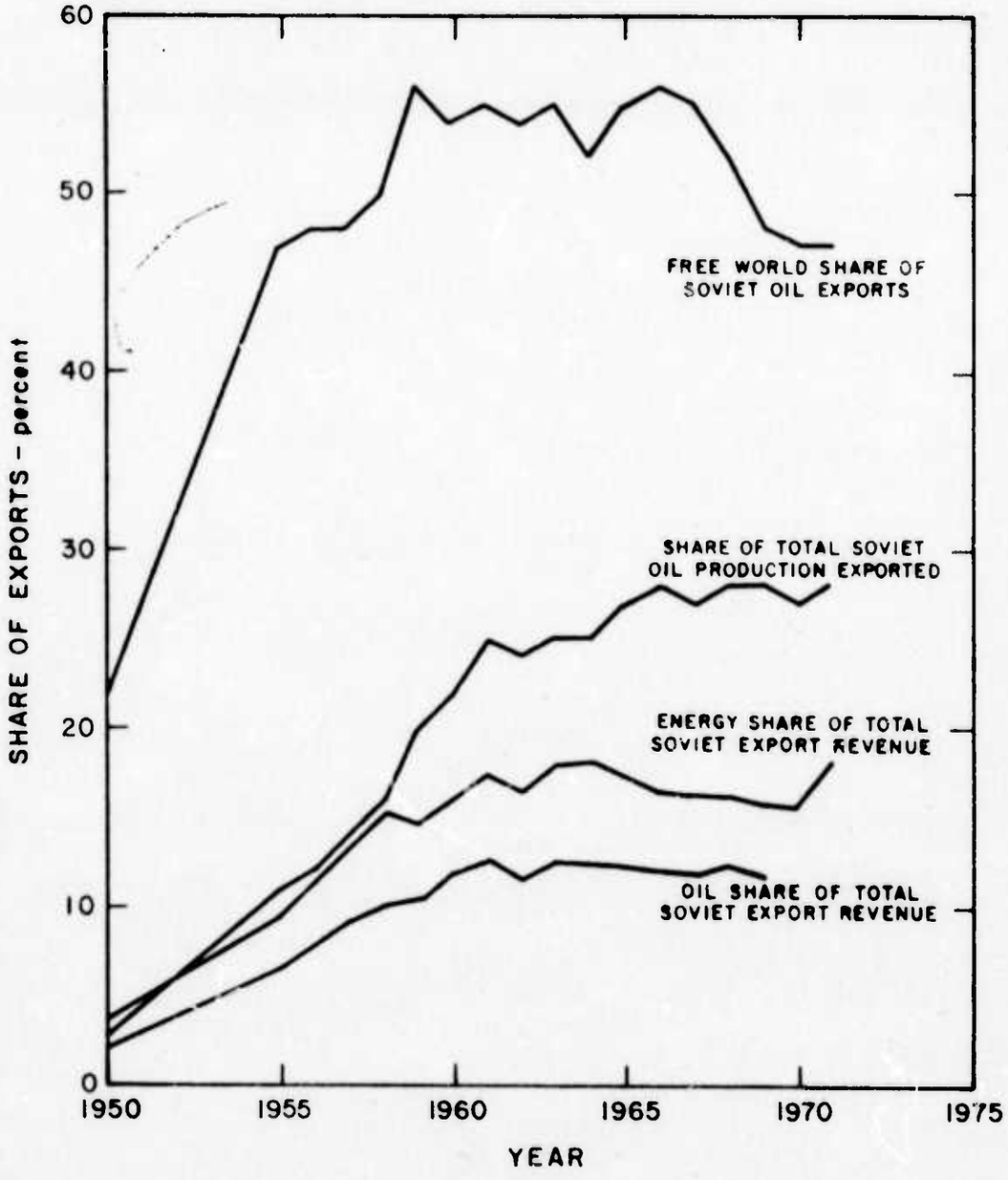


Figure 20

IMPORTANCE OF USSR ENERGY EXPORTS

gas requirements of Eastern Europe, they encourage these countries to develop alternative sources of energy. The Eastern European countries will strive for self-sufficiency in petroleum refining but are not projected to become major net petroleum product exporters.

VIII RESERVE-PRODUCTION COMPARISONS

Comparison of projected cumulative production of principal fuels with their estimated recoverable reserves is required to complete the supply-demand analysis presented in the preceeding section. Projections of fuel demand and production acquire full significance only in the context of their reserve base and the relative ease by which such reserves can be developed.

A comparison of hard coal reserves and projected cumulative production in the period from 1975 to 1990 is shown in Table 22. Reserves of hard coal in Bulgaria, German Democratic Republic, Hungary, and Romania are small, and it appears likely that these countries will continue to import hard coal. Czechoslovakia, Poland, and the USSR have hard coal reserves in excess of their domestic needs, and can probably supply the requirements of the other Eastern European countries. It is noted, however, that only about half of the USSR hard coal reserves are in the European and southwestern Siberian fields that are closest to consuming regions. Development of more remote hard coal deposits of the USSR will be both costly and time-consuming.

The reserve-production relationships for brown coal are shown in Table 23. Although there are relatively small reserves of brown coal in Bulgaria, Czechoslovakia, Hungary, and Poland, these appear adequate to satisfy projected demands until 1990. After that time, however, unless there are shifts in the energy fuel mix that substitute for brown coals, it may become necessary for some of these nations to import brown coals, as it appears necessary for Romania to do at an earlier date because of her small reserves. The German Democratic Republic and the USSR each have

Table 22

COMPARISON OF RESERVES AND PRODUCTION DATA--HARD COAL
(Billions of Metric Tons)

	(1) Estimated Coal Reserves	(2) Projected Cumulative Production Required 1975 to 1990	(3) Surplus or (Deficit)	(4) Remarks Regarding Differences
Bulgaria	< 0.2	0.165	*	Small reserves; deficit appears likely
Czechoslovakia	2.7	0.510	2.2	Small difference; short reserve lifetime likely
GDR	< 0.1	0.074	*	Small reserves; deficit appears likely
Hungary	< 0.1	0.098	*	Small reserves; deficit appears likely
Poland	11.8	2.370	9.43	Small difference; short reserve lifetime likely
Romania	< 0.5	0.135	*	Small reserves; deficit appears likely
USSR	102.4	6.518	95.9	Roughly half of reserves in European/Southwestern Siberian fields
Total	117.8	9.87	107.9	

* Projected production requirements roughly equivalent to known reserves.

Table 23

COMPARISON OF RESERVES AND PRODUCTION DATA--BROWN COAL
(Billions of Metric Tons)

	(1) Estimated Coal Reserves	(2) Projected Cumulative Production Required 1975 to 1990	(3) Surplus or (Deficit)	(4) Remarks Regarding Differences
Bulgaria	0.7	0.464	0.2	Small difference; short reserve lifetime likely
Czechoslovakia	4.6	1.495	3.1	Small difference; short reserve lifetime likely
GDR	18.0	3.630	14.4	Adequate reserves
Hungary	1.8	0.410	1.4	Small difference; short reserve lifetime likely
Poland	3.8	0.791	3.0	Small difference, short reserve lifetime likely
Romania	< 1.0	0.465	*	Small reserves, could be actual deficit condition
USSR	78.7	4.478	74.2	More than half of reserves in Siberian coal fields
Total	108.6	11.7	97.3	

* Projected production requirements roughly equivalent to known reserves.

ample brown coal reserves to support their own needs and to export to other Eastern European nations. However, it is noted that more than half of USSR brown coal reserves are in remote Siberian coal fields, presenting development problems and high transportation costs.

For crude oil, the reserve-production relationships in the Eastern European nations are as shown in Table 24. Estimated reserves of Czechoslovakia, German Democratic Republic, and Poland are less than projected requirements to 1990, and these nations will be forced to import most of their crude oil supplies. Bulgaria appears to have enough reserves for the short term, if new fields meet expectations; if not, then she, too, will be forced to rely almost exclusively on imported crude. Hungary, Romania, and the USSR have crude reserves significantly in excess of their domestic requirements, and could provide the relatively small amounts of exports needed to supply other Eastern European nations. Again, it must be noted that most of the USSR's crude reserves are located in remote, eastern regions; only about one-third of the total crude reserves are estimated to occur in European regions of the USSR. Projected cumulative crude production in the USSR to 1990 would be about equivalent to presently known European reserves, and it is conceivable that spot shortages could occur during this interval unless the large Western Siberian deposits were developed at an early date.

The reserve-production relationships for natural gas are shown in Table 25. The data suggest that Czechoslovakia, Poland, and somewhat surprisingly, Romania may experience deficiencies in gas supplies from their domestic sources by 1990 that will require offsetting gas imports to meet projected demand. Gas supplies of Bulgaria, Hungary, and the USSR appear adequate to meet projected requirements to 1990. The situation in the German Democratic Republic is unclear. The 1973 International Petroleum Encyclopedia gives GDR gas reserves at 15 billion cubic meters, equivalent to one year's production as projected for 1975. New gas

Table 24

COMPARISON OF RESERVES AND PRODUCTION DATA--CRUDE OIL
(Millions of Metric Tons)

	(1) Estimated Crude Reserves*	(2) Projected Cumulative Production Required 1975 to 1990	(3) Surplus or (Deficit)	(4) Remarks Regarding Differences
Bulgaria	2.2[a]	4.5	(2.3)	New fields not fully evaluated; could increase reserves
Czechoslovakia	1.6	3.0	(1.4)	Depletion of old fields; no significant new discoveries
GDR	1.5	4.5	(3.0)	No significant discoveries
Hungary	138.0	36.5	101.5	New discoveries have increased reserves
Poland	8.3	12.0	(3.7)	Depletion of old fields; no significant discoveries
Romania	330.0	207.5	122.5	New discoveries have increased reserves
USSR	10,417.0	3,308.8	7,108.2	Production about equal to European reserves @ 30% of total; could be short unless Siberian fields developed
Total	10,898.6	3,576.8	7,321.8	

* International Petroleum Encyclopedia, 1973.

(a) Overall Bulgarian oil reserves estimated at 40 million metric tons, of which 20 percent recoverable ultimately. Present estimate of recoverable reserves at 2.2 million metric tons is therefore a conservative figure.

Table 25

COMPARISON OF RESERVES AND PRODUCTION DATA--NATURAL GAS
(Billions of Cubic Meters)

	(1) Estimated Gas Reserves*	(2) Projected Cumulative Production Required 1975 to 1990	(3) Surplus or (Deficit)	(4) Remarks Regarding Differences
Bulgaria	29	26.25	3.25	New discoveries could further expand reserves
Czechoslovakia	15	20.25	(4.75)	Old fields being depleted; no significant discoveries
GDR	400(a)	301.13	101	Newly discovered major reserves; estimate quite uncertain
Hungary	85	64.13	20.87	New discoveries could expand reserves to ~112 x 10^9 M^3
Poland	142(b)	285.0	(143)	New discoveries have increased reserves; amount uncertain
Romania	285(c)	517.5	(232.5)	Deep drilling may expand reserves by unknown amount
USSR	22,000	7,518.75	14,481.25	European reserves are ≈5500 billion M^3, insufficient to cover projected production, indicating shortfall unless Siberian fields developed
Total	23,214	8,733.01	14,341.12	

* International Petroleum Encyclopedia (IPE), 1973, except as noted in lettered notes below.

(a) Table p. 261 of the IPE gives 15 billion M^3, equivalent to one year's production as projected for 1975 (p. 178). Value used here calculated by SRI, assuming average production of 200 billion M^3 per year and reserves/production ration of 20:1. Probably includes low-heating value gas.

(b) Figure does not include low-heating value gas. Reference: "Prospects for the Development of the Oil and Gas Industry of Poland," Neftyanaya i gazovaya promyshlennost, No. 4, July-August 1971, p. 52-53.

(c) Calculated from data in text p. 178, which disagrees with table p. 261.

discoveries in the GDR have been indicated, but the actual reserves are uncertain. If the reserves prove to be less than that estimated, then the GDR will also be in a position to import natural gas supplies. The USSR has ample gas reserves to supply its needs and to export to other CMEA countries However, only about one-fourth of USSR gas reserves are in the European part of the country, and these will be insufficient to meet projected demands unless augmented (and ultimately replaced) by gas from Siberian fields.

In summary, a comparison of fuel reserves and cumulative production requirements for the Eastern European countries indicates that many nations have very limited fuel reserves and that they will need to import much (if not all) of their supplies by 1990. In this group of nations, only the USSR has sufficient fuel reserves to meet her own requirements and export to her trading partners. However, the principal fuel reserves of the USSR are located in regions remote from consuming centers, and this together with problems in development technology, could constrain the pace of such development.

IX CONCLUSIONS

Throughout most of the last hundred years, the USSR has not only maintained energy self-sufficiency but has been a major exporter of fuels. It appears that the resource base and recoverable reserves are sufficient to continue exports into the foreseeable future. If successful in carrying out projected development programs for very large fuel resources in Siberia, the USSR not only should remain self-sufficient but also should be able to meet its commitments to Eastern European clients and to contribute even more significant energy exports to the rest of the world. Nevertheless, Soviet exports of fuels will not be sufficient to disrupt the overall world energy market. Although the USSR and Eastern European countries will continue to import relatively small amounts of oil and gas from the OPEC countries, they are not expected to become major competitors with the rest of the world for large quantities of Middle Eastern oil and gas.

The successful exploitation of Siberian energy resources in general, and natural gas deposits in particular, is by no means assured. Although much of the required technology and the development programs for these resources exist, and although recent oil production has been impressive, there are significant logistic difficulties in exploiting the Siberian resources. As a result, oil, and particularly natural gas, production may be less than planned levels.

In the event that the Soviets are unable to develop Siberian resources on the required time scale, they would appear to have the following five options:

	Option	Apparent Consequences
1.	Substitute other fuels	Alter planned consumption patterns
2.	Limit exports to Eastern Europe	Force reliance on non-USSR supplies
3.	Limit internal consumption	Limit non-essential activities
4.	Expand imports from OPEC	Compete with Western world for supplies, lose self-sufficiency
5.	Reduce exports to rest of world	Relinquish important source of hard currency.

The USSR could be expected to approach these alternatives in approximately the above order of priority (least desirable options have higher numbers). There is only a limited flexibility in substituting fuels (e.g., oil for gas) without cutting into foreign trade commitments, but substitution would be a relatively straightforward approach. Since our near term projections of natural gas production fall short of the potential demand, a combination of substitution of oil for gas, limitation of gas consumption, and increased imports of gas from Iran and Afghanistan should be expected.

There are already indications of limitation of commitments to Eastern Europe as the USSR encourages these countries to develop other sources of supply. As a result, these countries will, to some extent, compete for supplies. Fortunately, however, their requirements are small. Limitation of internal consumption is relatively easier in the Soviet economy than in the U.S. economy, but may be expected to have an adverse effect on any economy. Greatly expanded imports of crude oil from the OPEC to the USSR seem unlikely, as noted above. However, expanded imports of natural gas would appear advantageous to both the USSR and Iran/Afghanistan. Natural gas imports by the USSR from these countries should not have a significant impact on potential supplies to the United States or other Western nations.

Another alternative scenario could result in expanded Soviet trade in oil and gas with the West. This expanded trade could result from a deliberate attempt by the West to prevent Soviet programs from experiencing an impending shortfall that could force them to become competitive with the West for OPEC oil or that would prevent them from meeting natural gas commitments. Or, the expanded Soviet trade could result from a desire to develop Soviet resources as another alternative source of supply for the West. Some combination of these situations could also bring about such expansion of trade. In any case, the West would supply technological inputs in a barter arrangement for Soviet oil or gas. Typical items that the West might barter in return for oil and gas might include:

- Gas processing plants
- Pipeline compressors
- Pipeline pipe
- Secondary oil processing equipment
- Drill pipe, bits, and accessories
- Secondary recovery material
- Arctic and offshore drilling equipment.

Several Western nations have already been trading pipeline pipe to the USSR for future gas deliveries. The timely development of Siberian oil and gas is dependent upon these imports. Therefore, a mutual dependency situation would result from increased trade, at least initially.

Expanded trade of Western technology for Soviet oil and gas would have potential widespread consequences for the West. Establishment of trade relations in this vital sector could further the progress made in relaxing strained relations between the United States and the USSR, with resulting general, as well as mutual, benefit. The development of alternative sources of fuel supplies should certainly be of benefit to

the West, in view of the large levels of projected fuel requirements. To the extent that the United States can trade technology for needed resources, a reduction in our projected balance of payments deficit will be affected. On the other hand, increased reliance on the USSR for essential resources increases our vulnerability to potential coercion from that source. One can only speculate about many conflict scenarios in which the West would develop the Soviet resources, only to be cut off from the expected oil and gas supplies without compensation. However bizarre such scenarios may be, it would be useful to analyze them fully before becoming committed to a major course of action.

On balance, it would seem that expanded trade of Western technology for Soviet oil and gas would be advantageous to the West, since we desire both detente and trade for resources, but would be even more advantageous to the Soviets since they seek peaceful conditions, Western resource development technology, and long range foreign exchange.

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The objective of this study was to conduct an analysis of the energy resources and programs of the Soviet Union and Eastern Europe and their relationship to the rest of the world. A survey was made of energy development technology which included exploration, development, production, distribution, storage and utilization of energy and new forms of energy. Also, an appraisal was made of recent resource recovery and research and development of energy conversion technology, distribution, and utilization efficiency. The (Over)

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economic aspects of energy developments and use were discussed as related to patterns of consumption, trade, and the Gross National Product of the Soviet Union and Eastern European Countries. The overall energy supply and demands of these countries were projected to the 1980 and 1990 time frames. Finally an analysis was made of the Soviet political/military/energy strategy policies relative to the economic impact on Eastern and Western Europe.

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