AD-A012 971

ANALYSIS OF ENERGY RESOURCES AND PROGRAMS OF THE SOVIET UNION AND EASTERN EUROPE. APPENDIX D: GAS

George D. Hopkins, et al

Stanford Research Institute

Prepared for:

Rome Air Development Center
Defense Advanced Research Projects Agency

December 1973

NOV 1974

RADC-TR-74-204
~~Technical Report~~ FR, APPEN. D.
December 1973

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

Appendix D: Gas

Stanford Research Institute

AF 30602-73-C-0200

Sponsored By
Defense Advanced Research Projects Agency
ARPA Order No. 2339

Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

[redacted] be made by NSA (TDL).

This technical report has been reviewed and is approved.

N.R. appendix B or C

See AD-A012970
appendix A.
Dec 7 AD A012971

If this copy is not needed, return to RADC (IRRO/Capt Trossbach, Jr.)
GAFB NY 13441.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD-A012 971

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: RADC-TR-74-204, Appendix D
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): Analysis of Energy Resources and Programs of the Soviet Union and Eastern Europe; Appendix D: Gas
5. TYPE OF REPORT & PERIOD COVERED: Final Report, February-December 1973
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s):

Mr. George D. Hopkins
Mr. Nick Korens
Dr. Richard A. Schmidt
Mr. Carl A. Trexel, Jr.

8. CONTRACT OR GRANT NUMBER(s): F30602-73-C-0200
9. PERFORMING ORGANIZATION NAME AND ADDRESS:

Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, California 94025

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62701D, 23390002
11. CONTROLLING OFFICE NAME AND ADDRESS: Defense Advanced Research Projects Agency, 1400 Wilson Boulevard, Arlington, Virginia 22209
12. REPORT DATE: December 1973
13. NUMBER OF PAGES: 525
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Rome Air Development Center/IRRO, Griffiss AFB NY 13441
15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report): None
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number): SOVIET UNION; ENERGY; COAL; PETROLEUM; GAS; ELECTRIC POWER; ENERGY CONSUMPTION; ENERGY RESOURCES; ENERGY TRANSFER; CMEA COUNTRIES; NUCLEAR ENERGY
20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

Objective
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 (Over)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

BLOCK 20. Abstract (Continued)

efficiency. The 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.

This appendix assesses the capability of the Soviet Union to satisfy its own demands for natural gas as well as its potential for supplying gas from their huge domestic reserves to the West.

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

Appendix D: Gas

George D. Hopkins
Nick Korens
Dr. Richard A. Schmidt
Carl A. Trexel, Jr.

Contractor: Stanford Research Institute
Contract Number: F30602-73-C-0200
Effective Date of Contract: 28 February 1973
Contract Expiration Date: 15 December 1973
Amount of Contract: $174,950.00
Program Code Number: 3F10

Principal Investigator: George Hopkins
Phone: 415 326-6200, X-2685

Project Engineer: John M. Trossbach, Jr., Capt
Phone: 315 330-2344

Contract Engineer: Francis L. Karlin, Capt
Phone: 315 330-2719

This research was supported by the Defense Advanced Research Projects Agency of the Department of Defense and was monitored by Capt Trossbach, Jr., RADC (IRRO) GAFB NY 13441 under Contract F30602-73-C-0200, Job Order No. 23390002.

CONTENTS

ILLUSTRATIONS

LIST OF TABLES

I NATURAL GAS IN THE USSR

A. Introduction

The almost accidental discovery of huge domestic reserves of natural gas* has led to a dramatic restructuring of the fuels economy of the USSR. This discovery has also significantly affected the fuels economies of its Eastern European satellites, as well as raised questions about the possibility of the USSR emerging as an important supplier of natural gas to the West.

In order to assess the capability of the USSR to satisfy its own demands as well as its potential for supplying natural gas to the West, it is important to look at the following:

- Natural gas resource base.
- Internal demands for natural gas in relation to the fuels/ energy economy of the country.
- Exploration, development, and production capabilities.
- Pipeline construction and storage.
- Gas processing.

---

* Natural gas will refer to both the associated gas extracted with oil as well as gas obtained from primarily gas fields. (For further elucidation on differences between the Western and USSR definitions of associated and nonassociated gas, see the Resource section.)

B. Natural Gas Resources

1. General

Natural gas is defined as the low-boiling-point hydrocarbon gases that occur in subsurface rock reservoirs, often associated with liquid hydrocarbons (petroleum).[1] Natural gas is largely methane, although smaller and variable amounts of other paraffin hydrocarbons such as ethane, butane, pentane, and hexane may also be present. Methane is always present as a gas, but some of the other hydrocarbon compounds may occur in condensed form. As it comes from the well, natural gas may be classified according to the amount of natural gas liquids it contains: dry gas has less than 0.1 gallon per 1000 cubic foot, whereas wet gas has more than 0.3 gallon per 1000 cubic foot. These liquids and water must be removed from natural gas prior to its use. Natural gas also contains minor amounts of impurities of several types, among which is hydrogen sulfide; the terms sweet gas and sour gas are used to denote natural gases that are low and high, respectively, in hydrogen sulfide content.

Natural gas may be broadly classified according to its occurrence, especially regarding its relationship to other fluids occurring in the reservoir.

- Free gas occurs in the upper parts of reservoirs. It may be underlain by petroleum (in which case it is known as associated gas because of its relations to crude oil), or it may be underlain by water (in which case it is known as nonassociated gas, as its occurrence is apparently independent of crude oil.)
- Dissolved gas may be present in either associated or nonassociated deposits. Where natural gas is associated with oil, gas may be dissolved in oil to varying amounts that are determined by the physical properties of the gas and oil and by the characteristics of the deposits. These deposits are considered undersaturated in that there is

insufficient gas to occur in the free form; in contrast, free gas deposits may be known as saturated deposits.

Where natural gas is associated with only water, some gas may occur dissolved in water. However, its solubility in water is only about 6 percent of that in crude oil. Despite this low solubility, there could be substantial volumes of natural gas dissolved in water, owing to the large volumes of water commonly present in such reservoirs.

- Liquified gas occurs under conditions of high reservoir pressure. In such cases, natural gas and crude oil become virtually indistinguishable.

With the foregoing brief description of natural gas types and characteristics of occurrence, we may now proceed to a consideration of the gas resources that are present in the USSR and the countries of Eastern Europe. The discussion which follows begins with a review of the natural gas resources of the USSR, and then proceeds to examine the resources occurring in the other CMEA countries. Also presented is a brief account of the patterns of gas production and use in these countries, as an aid to the work being performed by other analysts.

For the purposes of assessing the estimated amounts of natural gas reserves in the USSR and other CMEA countries, we shall employ the procedure of Lovejoy and Homan[2] for estimating gas resources. This procedure is based on explicit definitions of categories of reserves established by the American Gas Association. These are as follows:

Definition	Percent of Total Reserves (U.S.A.)
Nonassociated gas "free gas not in contact with crude oil in the reservoir; and free gas in contact with oil where the production of such gas is not significantly affected by the production of crude oil"	75%

Associated gas "free gas in contact with crude oil in the reservoir where the production of such gas is significantly affected by the production of crude oil"	15
Dissolved gas "gas in solution with crude oil in the reservoirs"	10

Although these relations among types of gas were developed for U.S. deposits, it is assumed for purposes of this study that the physical and geological characteristics of gas deposits that led to the derivation of the above relations will not differ significantly from those that may occur in other geographical areas. This assumption permits use of these relations in calculations. The importance of this assumption in arriving at a complete understanding of Soviet gas reserves (and probably those of CMEA countries as well) may be illustrated by reference to Campbell's work:[3]

> "Soviet statements on natural gas reserves do not (original emphasis) include gas dissolved in oil." The Minister of Oil and Gas was quoted, after citing "in the usual figures on natural gas reserves. . ." and noting that "in addition we have huge commercial deposits of oil-well gas."

It is not clear what is meant by "oil-well gas." Strictly speaking, oil-well gas includes any gas produced along with the oil, and conceivably could be both associated gas and dissolved gas according to the above definition. However, for this analysis, it is assumed that the Soviet estimates of gas resources include nonassociated and associated (free) gas, but that they do not include dissolved gas. Thus, the Soviet reserve estimates cover only about 90 percent of the total gas present.

In contrast to the other fuels, recovery of a high percentage of the gas originally in place is usually accomplished from natural gas deposits through primary production means. Secondary recovery of gas is uncommon. Tiratsov[4] notes that recovery rates for gas deposits range from 80 to 90 percent of the total resource present. These recovery rates are for the nonassociated and associated gas deposits; however, if applicable to the dissolved gas as well, it may be that the Soviet reported data for gas reserves are actually equivalent to recoverable reserves in the sense of that term as employed here.

In the United States, natural gas is usually measured in cubic feet. However, in the USSR, natural gas may be measured in either cubic meters or metric tons of oil of equivalent heating value (1,000 cubic meters of natural gas = 0.824 metric ton of crude oil). Whenever practicable, we will seek to present data in both sets of units; should this prove cumbersome, conversion factors will be provided.

For the most part, the basic geology of the USSR gas fields was presented in Appendix C on oil, and hence will not be repeated here. Instead, only pertinent deposit features of particular importance to the occurrence and development of natural gas will be presented.

- Volga-Urals. The prospects of discovery of large gas fields are the southeast part of the region, where the Orenburg gas-condensate field occurs. The gas reservoirs are in Upper Paleozoic carbonate rocks underlying salt.
- Timano-Pechora. The main gas pool of this region occurs at Vuktyl, where a gas-condensate deposit is present in limestone and dolomite of Upper Paleozoic age. Other gas deposits are found in this region, also occurring in limestone strata, and there are several other areas of importance for prospecting.
- Dnepr-Pripyat. In recent years, large gas-condensate pools were discovered in Upper Paleozoic/lower Mesozoic sediments at depths of 3,000 to 4,000 meters in this area.
- Prebaltic. Although there are indications that locally important small oil fields occur in this region, developable gas deposits have yet to be found.
- North Caucasus. Gas fields occur mainly in the western part of this region. They are confined to large platform tectonic units, where the gas occurs in Upper Mesozoic and lower Tertiary sediments.

- <u>South Caspian</u>. In this region gas occurs together with oil in a number of fields (see discussion in Appendix C).
- <u>Central Asia</u>. Large gas fields occur in the southeastern part of the region, in Middle to Upper Mesozoic sandstones at depths of 600 to 4,000 meters. In fact, Mesozoic sediments are gas-bearing or oil-bearing over much of the area.
- <u>West Siberian Basin</u>. Several giant and supergiant gas fields with truly enormous apparent reserves occur in this region. The largest gas fields are associated with huge, elogate, meridianal arches. Gas occurs in Tertiary sandstones, but deeper drilling has revealed the presence of oil, gas, and gas-condensate pools in Mesozoic sediments as well. Although not yet well-known, these latter rocks probably also contain large reserves of gas and condensate.
- <u>East Siberian Platform</u>. Shows of oil and gas occur where sediments have been down-warped in intermontane basins (see discussion in Appendix C).
- <u>Far East</u>. Gas deposits occur in southern Sakhalin, and recent data suggest the existence of promising potential gas-bearing structures off-shore.
- <u>Offshore</u>. The principal prospects for offshore gas development in the USSR at present are in the Caspian Sea, Baltic Sea and the Sea of Azov.

Table D-1 shows the geologic age of natural gas deposits in the USSR as of 1 January 1966 according to categories of reserve estimates. The table shows that more than half of the A + B + C_1 reserves are of Mesozoic age, with roughly a quarter of the reserves being of Paleozoic age. The age of Soviet natural gas deposits is, as was the case for oil, a reflection of the magnitude of the West Siberian Basin deposits, which dwarf the European deposits that are commonly Paleozoic. Again, the fact that the large gas reserves of the West Siberian Basin are of Mesozoic age underscores the relatively smaller reserves of older fields of the European sector of the country.

Table D-1

DISTRIBUTION OF SOVIET GAS RESOURCES BY AGE

Age	A + B	A + B + C
Cenozoic		
Neocene	9.3	9.2
Paleocene	12.5	10.9
Total	21.8	20.1
Mesozoic		
Cretaceous	39.8	44.6
Jurassic	9.2	9.8
Triassic	-	0.1
Total	49.0	54.0
Paleozoic		
Permian	15.2	15.0
Carboniferous	12.5	9.3
Devonian	1.5	1.6
Total	29.2	25.9

Table D-2 shows the distribution of natural gas resources by depth beneath the surface. Two separate categories are shown:

- According to reserve categories, more than three-quarters of the best-known natural gas reserves occur at depths less than 2,000 meters. This, of course, will greatly facilitate their development.
- Upon analysis by region and by total estimated potential reserves as of 1 January 1966, it is found that about two-thirds of the reserves occur at depths less than 5,000 meters.

2. Total Gas Resources

The previous discussion alluded to estimates of natural gas reserves present in the USSR. However, in order to place such estimates in perspective, it is essential to have in mind an idea of the total amount of potential gas resources that may actually occur in the USSR. This, of course, is a difficult problem in analysis. It is hard enough to estimate the amount of recoverable reserves for areas that have been

Table D-2

DISTRIBUTION OF USSR GAS RESOURCES BY DEPTH
(Meters)

By Category (Percent)	Less than 1,000	1,000 to 2,000	2,000 to 3,000	More than 3,000
A + B	39.8	37.7	19.7	2.8
A + B + C_1	30.7	41.1	21.1	7.1

By Region (Billion cubic meters)	Less than 1,000	1,000 to 3,000	3,000 to 5,000	5,000 to 17,000	Total Potential Reserves
RSFSR	2,050	28,300	9,770	1,970	42,090
Latvia	-	30	-	-	30
Lithuania	-	30	-	-	30
Belorussia	-	100	100	-	200
Ukraine	-	1,060	1,940	-	3,000
Moldavia	-	10	90	-	100
Azerbajian	-	130	570	760	1,460
Georgia	-	120	190	90	400
Armenia	-	120	-	-	120
Turkmen	1,150	2,750	2,100	-	6,000
Uzbekistan	20	1,060	540	50	1,670
Kirgiz	-	40	60	-	100
Tadzhik	10	190	200	-	400
Kazakhstan	400	2,100	1,170	730	4,400
Total	3,630	36,040	16,730	3,600	60,000

thoroughly explored; it is quite another thing to attempt to predict the potential gas resources for large areas that have yet to be examined.

In an attempt to present such information, we employ the Meyerhoff data on predicted gas resources in the USSR.[5] Working with detailed geological and geophysical data for the USSR, supplemented by aerial photographs of the principal oil and gas bearing areas, Meyerhoff prepared a new predictive estimate of the potential oil and gas resources of the USSR (the estimate for oil is included in Appendix C). On the basis of geological and geophysical principles, Meyerhoff arrived at the predicted USSR gas resources shown in Table D-3. The data suggest a total natural gas resource in place of 240 trillion cubic meters (8,500 trillion cubic feet), a truly staggering amount of gas in place. The largest volumes are estimated to occur in the West Siberian Basin (about one-third the total) and the Pechora Basin (although this area is estimated to constitute about one-quarter of the natural gas resources). The estimate includes offshore deposits in the Barents Sea which may be developable only with great difficulty. Although the predicted potential gas resources are indeed enormous, it is important to bear in mind that:

> "The very large gas deposits, discovered in recent years, are located in inaccessible regions, and for this reason important significance is attached to the prospecting of gas deposits in the European part of the USSR and in those regions adjacent to the routes of operating gas pipelines. Here again the promise held by the exploration of those horizons found at depths of 4 km and more has to be pointed out. Thus, analysis of the seismic data permits the assumption that in the PreCaucasus regions and in the PreCaspian depression at depths of 4 to 7 km there may be significant accumulations of gas."[6]

While this estimate may be subject to the normal uncertainty attendant to any estimates of the amounts of essentially undeveloped resources, it serves to set the stage for review of data for known Soviet gas fields and their currently estimated recoverable reserves.

Table D-3

ESTIMATED GAS RESOURCES IN THE USSR

Area	Potential Gas Resources (Trillion cubic feet)	(Trillion cubic feet)
European Russia		
Precarpathian Foredeep	5-6	
CRIMEA	1	
Baltic Platform	?	
Dnepr-Donets	42	
Pripyat	1-2	
Subtotal	49-51	1.4
Trans-Caucasus		
Rioni Basin	0.1	
Kara/S. Caspian/Trans-Caspian	30-40	
North Caucasus Foredeep	60-80	
Subtotal	90-120	3.0
Central Asia	1,000	28
Aral Sea	-	-
Emba Salt Basin	20	0.6
Volga-Urals	455	13
Pechora Basin	2,000*	57
West Siberian Basin	3,000	85
Taymyr Peninsula and Laptev Sea	1,100	31
Anabar Basin	10	0.3
Vilyvy Basin (Lena Valley)	150	4.3
Irkutsk Basin and Far East	100	3
East Siberian Sea	500	14
Anadyr Basin	20	0.6
Khatyrka Basin	20	0.6
Kamchatka	20	0.6
Amur River	22	0.6
Sakhalin	10	0.3
Pergana Basin	2	0.06
Subtotal	8,429	239.0
Total	8,568-8,600	243.4

*Including offshore.

3. Natural Gas Reserves

Table D-4 shows data for the major USSR gas fields that are known at present, including data on the date of discovery, geologic age of the productive horizons, depth to reservoirs, production, and estimated remaining reserves. The total estimated remaining reserves in these deposits are considered to be on the order of 20 trillion cubic meters. This estimate appears to be the accepted Western view of the reserves of natural gas in the USSR, as it has been published (in varying detail although the totals are in good agreement) by several workers;* however, it is only about one-third of that resulting from Soviet sources† (all categories, Table D-5). Note also that the Soviet gas reserve estimates are only as of 1 January 1966, and that they do not include the substantial discoveries achieved in the late 1960s and early 1970s. A more recent listing of Soviet natural gas reserves is given in Table D-6. This shows that reserves in categories $A + B + C_1$ have increased five times in just six years, with total reserves in close agreement with those from Western sources. Therefore, it would be reasonable to expect that more recent estimates of Soviet gas reserves (when finally published) will be increased over the levels reported at these earlier times. It remains to be seen to what extent such more recent estimates may approach that of Meyerhoff.

---

* See "Geology of Giant Petroleum Fields," American Association of Petroleum Geologists, Memoir 14, pp. 502, 528, 1970, and H. O. Klemme, "Giants, Supergiants and their Relation to Basin Types," Oil and Gas Journal, March 1, 8, 15, 1971.

† This estimate includes D_1 and D_2 reserves which are admittedly quite speculative. If only $A + B + C_1 + C_2$ reserves were included, these estimates could be in fairly good agreement.

Table D-4

MAJOR GAS FIELDS OF THE USSR

Field	Discovered	Pay	Age	Depth (ft)	Billions Cubic Feet: 1971 Prod.	Billions Cubic Feet: Est. Prod.	Billions Cubic Feet: Cumul. Prod. 1/1/72	Billions Cubic Feet: Remaining Reserves 1/1/72	Number of Wells
Solaniskoye	-	-	-	-	-	5,295	0	5,295	-
Achak	1968	K,J	K,J	4,954- 7,770	420	5,171	1,200	3,971	54
Ackticheskoye	1968	-	-	1,968	-	6,354	-	6,354	-
Buyrdeshik	1969	K	K	4,500	-	3,871	-	3,071	-
Yefremovskoye	1965	L.P.	P.Carb.	8,204-11,484	100	4,589	200	4,389	25
Gazli	1956	K	K	1,739- 3,937	810	17,032	5,982	11,050	200
Gubkinskoye	1964	K	K	2,510- 2,920	0	12,481	0	12,461	8
Gugurtli	1965	K,J	K,J	4,101- 7,382	0	3,600	-	3,600	-
Kandym	1967	J	J	7,500	0	3,812	0	3,812	-
Kazanskoye	1967	J	J	-	-	3,600	-	3,600	-
Korobki	1949	J	J	-	-	4,200	-	4,200	-
Krasnokholmskoye	1966	Perm	Perm	3,937	-	24,945	-	24,945	12
Krestishchenskoye	-	-	-	-	-	3,500	-	3,500	-
Layayozh	-	-	-	-	-	17,500	-	17,500	-
Luginets	1967	J	J	-	-	3,800	-	3,600	-
Orensorgskoye	1967	L.P.Carb.	P.Carb.	3,937- 5,906	35	31,700	35	31,735	-
Yuzhno-Russkoye	-	-	-	-	-	17,850	-	17,850	-
Maastakhskoye	1967	J	J	5,810-	-	4,723	-	4,723	-
Maikop	1957	J		-	-	3,200	-	3,200	-
Medvezh-Ye	1957	K	K	3,881- 3,855	0	54,350	0	54,650	-
Messoyakh	1957	J	J	2,395- 2,953	50	15,000	100	14,900	-
Myloznino	1964	J	J	7,218	0	4,900	0	4,900	-
Nydinskoye	1957	K	K	3,510	0	3,600	0	3,600	-
Pelya-Tinskoye	1969	J	J	8,862	0	10,590	0	10,590	-
Punga	1951	J	J	5,485- 6,233	282	3,500	1,500	2,000	-
Russkoye	1968	K	K	2,854- 2,926	0	10,800	0	10,800	-
Saman-Tepe	1964	J	J	7,546- 7,874	-	4,236	-	4,236	-
Severo-Stravropolskoye	1950	Ter.	Oli.Mid	2,179- 3,396	530	21,180	4,590	16,590	-
Sheblinka	1950	P.Carb.	P.Carb.	2,825- 6,725	1,100	16,520	10,900	5,620	350
Shekhitli	1968	K	K	11,090	0	60,000	0	80,000	-
Solenaya	1969	K	K	2,190- 6,510	0	3,500	0	3,500	-
Sredne-Vilyuy	1963	J	J	1,772- 9,760	-	15,885	-	15,885	-
Tazovskoye	1962	K	K	3,782- 7,218	1	48,400	3	48,397	-
Yamburk	1966	K	K	3,300	0	35,300	0	35,300	-
Anastasiievvsko-Troitskoye	1953	Plio.	Plio.	2,460- 5,643	-	2,400	220	2,180	-
Glynsku-Rozbysheu	1964	Carb.	Carb.	9,540-11,412	-	1,732	0	1,732	-
Komsomolskoye	1966	K	K	-	-	13,414	0	13,414	-
Kotur-Tepe	1956	Plio.	Plio.	-	-	2,071	-	2,071	-
Novyy Port	1964	K,J	K,J	-	0	5,100	0	5,100	-
Uregngoiskoye	1956	K	K	3,543- 3,930	0	159,200	0	159,200	-
Urtabulak	1963	J	J	7,909- 6,120	-	5,400	-	5,400	-
Vingapurskoye	1968	K	K	3,235	0	7,080	0	7,080	-
Vuktylskoye	1964	Carb.	Carb.	4,285	353	17,650	670	18,960	20
Zapadno-Krestischche	1968	-	-	-	-	3,600	-	3,600	-
Zapolyarnoye	1965	K	K	3,707	-	57,186	-	57,188	-
Zhetybay	1961	-	-	-	-	1,126	-	1,128	-
Yubilenoye	1969	K	K	-	-	28,240	0	28,240	-
Total								763,515	

Source: International Petroleum Encyclopedia

Table D-5

USSR ESTIMATED GAS RESOURCES
AS OF 1 JANUARY 1966

	Natural Gas (Billion Cubic Meters)				
	A + B	C_1	$C_2 + D_1$	D_2	Total
RSFSR	929	768	23,136	20,930	45,763
Arkhangel Oblast	-	-	-	300	300
Komi Assr	9	30	518	800	1,357
Perm Oblast	6	18	225	280	529
Bashkir Assr	5	26	146	200	377
Kuibyshev Oblas	6	5	71	70	152
Orenburg Oblast	16	9	234	630	889
Saratov Oblast	41	29	843	660	1,573
Volgorad Oblast	68	22	221	1,200	1,511
Astrakhan Oblast	2	-	100	180	282
Kalmyk Assr	21	26	212	200	459
Rostov Oblast	-	4	100	200	304
Krasnokar Kraj	379	86	933	820	2,218
Stravropolskii Kraj	192	43	447	100	782
Checheningush Assr	6	3	50	80	139
Dagestan Assr	10	33	544	130	717
Western Siberia	149	306	12,293	3,800	16,548
Eastern Siberia	8	90	5,803	11,000	16,901
Sakhalin	11	38	396	280	725
Ukraine	448	207	1,034	2,130	3,819
Azerbaijan	27	27	398	1,100	1,552
Kazakh SSR	4	88	1,041	3,400	4,533
Turkmen SSR*	971		4,693	5,785	11,465
Uzbek SSR*	758		2,138	860	3,906
Tadzhik SSR*	32.5		204	298	536
Kirghiz SSR*	16.0		82	34	134
Georgian SSR	-	-	100	300	400
Armenian SSR	-	-	60	60	120
Moldavian SSR	-	-	30	70	100
Belorussian SSR	-	-	-	200	200
Lithuanian SSR	-	-	-	30	30
Latvian SSR	-	-	-	30	30
Total	2,021	1,545	29,364	33,750	66,680

Note: To convert to cubic feet, multiply by 35.31; total = 2,354 trillion cubic feet.

Source: R. W. Campbell, "The Economics of Soviet Oil and Gas," 1961.

*"Prospects for Oil and Gas in Central Asia," Neftegazcvaya Geologiya i Geofizika, No. 2, pp. 3-7, February 1972.

Table D-6

USSR RESERVES OF NATURAL GAS IN CATEGORIES
A + B + C AT BEGINNING OF YEAR
(Billion Cubic Meters)

Year	Reserves	Increment During Year
1965	3,219.7	158.2
1966	3,565.9	346.2
1967	4,381.5	815.6
1968	7,985.4	3,603.9
1969	9,470.3	1,484.9
1970	12,099.8	2,629.5
1971	15,795.7	3,695.9
1972*	17,902.8	2,107.1

Source: Gazovoe delo, No. 4, pp. 30-37, 1972.

* Preliminary

Table D-7 gives a summary comparison of these several estimates of Soviet gas resources and reserves. The ultimate recoverable reserves cited by

Table D-7

COMPARISON OF ESTIMATES OF SOVIET GAS RESOURCES

Estimate	Year	Description	Trillion Cubic Meters
Meyerhoff	1973	Predicted resources	244
Soviet Sources (cited by Campbell)	1966	Potential resources	67
Klemme	1971	Ultimate recoverable reserves	~22
Halbouty	1970		
International Petroleum Encyclopedia	1972		

Halbouty, Klemme, and the IPE are roughly one-tenth the results of future exploration efforts in the USSR to observe how new discoveries may add to the reserves and how closely the predicted figure is approached over time; clearly, such work will require a long time and the results will not be available to meet the energy needs of the near future.

4. Natural Gas Outlook

For the short term, the natural gas situation in the Soviet Union is not nearly so encouraging. Table D-8 presents a summary of predicted gas resources by region compared to currently estimated developable gas reserves for the same regions. Although the predicted gas reserves in the Soviet sector west of the Urals are about 29 percent of the total, nearly three-quarters of these reserves occur east of the Urals, away

Table D-8

SUMMARY OF SOVIET GAS RESOURCES BY REGION
(Trillion Cubic Meters)

Region	Predicted Gas Resources (Meyerhoff)		Potential Gas Reserves (AAPG Memoir 14)	
European Russia	1.4	= 29% of total	0.7	= 12% of total
Volga-Urals	13		1	
Pechora Basin	57*		1	
Caucasus	3		0.5	
Central Asia	28		1	
East Siberia	56		0.6	
West Siberian Basin	85		16.6	= 78% of total
Total	244		21.4	

* Includes offshore.

from the centers of consumption. It seems inescapable that substantial time delays will be required to realize the gas production from the east to satisfy projected demands in the European part of the country. Moreover, in view of the fact that only about 12 percent of potential gas reserves in currently known deposits occur west of the Urals, it would appear that the USSR may face an important near-term shortage of usable natural gas in these areas. This observation is supported by a recent analysis of the subject by King:

> "Plans for developing gas production in the Soviet Union were reoriented from rapid development of the large fields of the northern west Siberian basin toward reliance for supplies through 1975 on 4 different areas which were to be tied to existing pipeline systems by 40, 48, and 56 in. lines. These sources were Vuktyl' in the Pechora Basin, Orenburg near the southern Urals, Shekhitli in Southeastern Turkmenistan, and Medvezh'ye in the northern West Siberian basin. The last named is to be produced through the 73-km pipeline under construction to the east Ural industrial centers and is being laid in place of a line previously projected which was to connect the field with the Northern lights pipeline. Full-scale production from the northern West Siberian fields was deferred because of the formidable problems of laying the 99.2 in. pipeline previously planned for this region, much of which would have several years in producing from Urengoy, the world's largest gas field."[7]

Thus, rather than enjoying a superabundance of natural gas from their enormous (but virtually undeveloped) resources east of the Urals, it could be that the Soviets may be forced to devote so much attention to extension of supplies from currently producing gas fields of the West as to result in a delay in achievement of the much-desired gas production from the West Siberian Basin. Such a condition would have serious consequences for the USSR energy balance over the short term, which may be reflected in its international policy and strategy.

C. Historical Production of Gas

The dramatic growth in natural gas production occurred with the discovery and production of gas from the fields of Central Asia, the Ukraine, Southwestern USSR, and the Volga in the late 1950s and early 1960s. Although natural gas was produced before, it was mainly gas associated with oil production. Most of it was then either flared or consumed as local fuel in adjacent production facilities. The residential and commercial needs were met primarily by manufactured gas from coal and oil shale gasification.

A great deal of effort was spent in the 1950s on schemes to increase gas production from coal while controlling and trying to limit the required expenditures. In this regard, an ambitious program of underground coal gasification was attempted and eventually abandoned as being too costly when natural gas became available in sufficiently large quantities. Manufacture of gas from coal and oil shale is still going on and meets certain local needs. However, it has lost its importance to natural gas. Table D-9 shows the statistics of gas manufacture in the USSR covering the period 1913 through 1970. It can be seen that in terms of volumes produced, gases from coal and shale accounted for less than 1 percent of the total in 1970. If one considers that most of this manufactured gas is of lower Btu value, then its quantity really pales into insignificance.

Other industrial gases are produced, such as coke oven gases and refinery fuel gases. These are consumed, primarily by the industries responsible for their manufacture, either as direct fuel or in the generation of local, industrial electric power.

It can be observed from Table D-10 that production of gas from coal is small and has been declining since 1960, while production of gas from oil shale is restricted to Estonia and is only of small local importance.

Table D-9

PRODUCTION OF GAS* IN THE USSR FROM 1913 TO 1970
(Million Cubic Meters)

Year	Natural gas	Gas from coal and oil shale	Total
1913	-	17	17
1928	304	27	331
1932	1,049	40	1,089
1937	2,179	138	2,317
1940	3,219	173	3,392
1945	3,278	133	3,411
1946	3,902	158	4,060
1950	5,761	420	6,181
1955	8,981	1,375	10,356
1960	45,303	1,911	47,214
1961	58,981	1,916	60,897
1962	73,525	1,719	75,244
1963	89,832	1,646	91,478
1964	108,566	1,662	110,228
1965	127,666	1,690	129,356
1966	142,962	1,713	144,675
1967	157,445	1,735	159,180
1968	169,101	1,713	170,814
1969	181,121	1,719	182,840
1970	197,945	1,634	199,579

* Coke works gas and refinery gases are not included.

Table D-10

PRODUCTION OF GAS* FROM COAL AND SHALE BY SOVIET REPUBLICS (1940-1970)
(Million Cubic Meters)

	1940	1950	1960	1965	1969	1970
USSR						
RSFSR	173	420	1,911	1,690	1,719	1,634
Estonian SSR†	167	226	1,448	1,175	1,138	1,053
Total	0.9	173	433	515	581	581

* Coke works gas and refinery gases are not included.

† Principally gases from shale.

Source: Narodnoie khoziaistvo SSSR v 1970 g (National Economy of the USSR for 1970), USSR Statistical Annual, Moscow, 1971.

Production of gas from fields that are not predominantly connected with oil production did not become important until the early 1960s, with the associated gas providing an important fraction of the total natural gas extraction up to that time. Table D-11 illustrates the rapid increase in the growth of nonassociated gas production--an increase that coincided with the founding of an independent gas industry in the early 1960s. Whereas in 1950, associated gas accounted for 31 percent of natural gas production, by 1971 it had dropped to less than 12 percent. There has, however, been a steady growth in production of associated gas in conjunction with the growth of the oil industry.

As in the case of oil, regional distribution of production is uneven, with Central Asia, Northern Caucasus, and the Ukraine accounting

Table D-11

EXTRACTION OF NONASSOCIATED AND ASSOCIATED NATURAL GAS IN THE USSR
(Billion Cubic Meters)

	Nonassociated	Associated
1950*	4.0	1.8
1955*	5.9	3.1
1960*	37.6	7.7
1965†	111.2	16.5
1966	125.2	17.8
1967	138.6	18.9
1968	149.5	19.6
1969	159.5	21.6
1970	175.0	23.0
1971‡	187.4	25.0

---

* Data from A. K. Kortunov, gazovaya promyshlenost SSSR (Gas Industry of USSR), p. 65, Moscow, 1967.

† For years 1965-1971, data from **Gazovoe delo**, No. 4, pp. 30-37, 1972.

‡ Preliminary.

for most of it. Regional distribution of production for 1970 and 1971 is presented in Tables D-12 and D-13, respectively. Western Siberia, which accounted for only 5 percent of total production in 1970, will have to carry the major brunt of expansion in the future, since it contains the biggest discovered gas reserves in the USSR. Undoubtedly, Western Siberia's share in production will grow with the exploitation of the two giant fields discovered in 1966 and 1967, Urengoy and Medvezhie. According to Soviet estimates, these two fields alone account for almost 31 percent of total proven reserves of natural gas in the USSR; Western Siberia as whole accounts for 61 percent. Pipelines and processing facilities are being built at present in order to start large scale production from these fields.

Table D-12

EXTRACTION OF NATURAL GAS BY REPUBLIC, 1971 (PRELIMINARY)

Republic	Billion Cubic Meters: Nonassociated	Billion Cubic Meters: Associated
RSFSR	69.8	17,614
Ukraine	62.2	2,496
Azerbaijan	2.9	2.955
Uzbek	33.5	0.109
Kirghizia	0.4	0.004
Tadzhik	0.5	0.005
Turkmen	15.5	1.356
Kazakhstan	2.6	0.127
Belorussia	-	0.295
USSR Total	187.4	24.961

Source: Gazovoe delo, No. 4, pp. 30-37, 1972.

Table D-13

SOVIET NATURAL GAS PRODUCTION IN 1970 BY REGION

Gas Producing Regions	Amount Produced (billions of cubic meters)
Northern Caucasian Region	51.3
a. Krasnodar fields	
b. Stavropol' fields	
c. Groznyi fields	
Central Asian Region	46.0
a. Uzbek fields	
b. Turkmenian fields	
c. Tadzhik fields	
d. Kirghizian fields	
Donets-Dnieper Region	42.9
a. Kharkov fields	
b. Poltava fields	
Volga Region	18.1
a. Lower Volga fields	
b. Bashkir fields	
c. Kuibyshev fields	
Southwestern Region	18.0
a. Lvov fields	
b. Ivano-Frankovsk	
Western Siberia (Tyumen fields)	9.9
Caucasus Region (Azerbaijan fields)	5.5
Urals Region (Orenburg fields)	0.7
Northwestern Region (Komi fields)	2.4
Far Eastern Region (Yakutiia fields)	0.9
Kazakhstan (Mangyshlak Peninsula fields)	2.1
Total Soviet Production	197.8

However, the current five-year plan production goals for natural gas are unrealistic and will probably not be met by 1975. The inability to meet production goals for natural gas has plagued the Soviet planners from the beginning of the gas industry and could be blamed on the lack of transport and processing facilities, discussed elsewhere. Figure D-1 presents the history of actual and planned production of natural gas in the period of 1965 to 1975.

D. Natural Gas Processing in the USSR

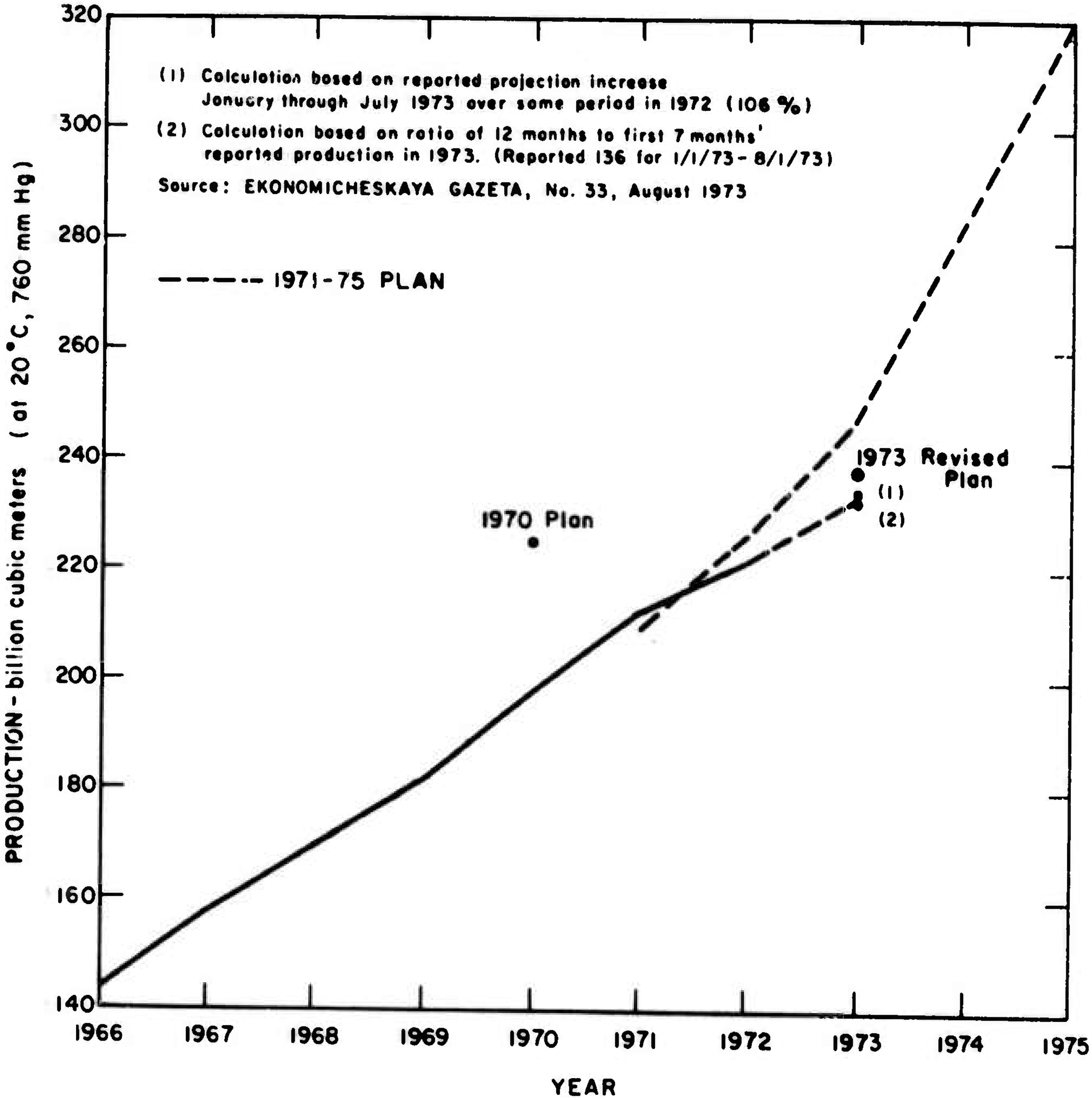
1. LPG Processing Facilities

In 1970 there were ten main centers for producing LPG in the USSR from natural gas (mainly from associated gas). These centers accounted for all the reported LPG production from natural gas sources, and their production statistics are presented in Table D-14.

Table D-14

PRODUCTION OF LIQUEFIED GASES AT GAS PROCESSING PLANTS
(Thousand Tons)

Plant	1965	1966	1967	1968	1969	1970 (plan)
Minnibayevo	525.6	595.8	730.6	903.8	944.4	980.0
Tuimazy	303.5	305.5	312.2	313.4	263.6	196.0
Shkapovo	214.2	234.4	256.4	269.2	257.1	188.0
Perm	-	-	-	-	6.0	141.4
Korobky	-	0.6	34.0	48.0	52.8	61.0
Afipskaya	22.5	44.6	50.3	51.7	43.7	62.0
Borislav	14.0	15.4	17.0	12.6	13.2	15.0
Priluki	-	-	-	-	-	22.0
Dolina	39.0	61.7	72.6	113.1	140.4	150.0
Azerbaijan, Karandag, Baku	50.2	50.1	48.6	68.9	11.4	-
Total	1,169.0	1,308.1	1,521.7	1,708.8	1,732.6	1,815.0



Sources: 1966 through 1971: NARODNOJE KHOZIASTVO SSSR 1922-1972
1972: VESTNIK STATISTIKI, No. 8, p.85, August 1972

Figure D-1

NATURAL GAS PRODUCTION IN THE USSR (INCLUDING ASSOCIATED GAS)

The first two plants, Minnibayevo (Tatar ASSR) and Tuymazy (Bashkir ASSR), are of the oil absorption type. Another plant added at Minnibayevo in the middle 1960s was of the refrigeration type.

The improvement on the straight oil absorption plant, as far as the depth of recovery of LPG fractions is concerned, is the chilling and oil absorption plant. At least two of these plants, Afipskaya (Krasnodar Kray) and the Dolina (Ukranian SSR), are of this type.

The best plants (relative to depth of recovery and purity of hydrocarbon fractions) are of the refrigeration type and are represented by Perm (Perm oblast), Otradniy (Kuibyshev oblast), and others, in addition to the new Minnibaev plant mentioned above.

The Shkapov (Bashkin ASSR) and the Korobki (Volgograd oblast) plants as well as probably the plants at Karandag and Baku in Azerbaijan are charcoal adsorption plants. The locations of the major plants are shown in Figure D-2.

New plants are scheduled for construction in the 1971-1975 five-year plan period at Mangyshlak, Orenburg, and Samotlor.

The recovery of LPG suffered prior to 1957 because of rather primitive oil absorption facilities used up to that time. The recovery of propane was no more than 40 to 50 percent, and recovery of butanes, 70 to 80 percent. Plants built after 1958 were designed for 70 to 80 percent recovery of propane and up to 90 percent of butanes.

It was hoped that by 1970, 85 to 95 percent of the butanes and 95 to 99 percent of the pentanes were to be recovered through introduction of new refrigeration plants. These goals were apparently not met because of construction lags.

In sophistication of refrigeration cycles, the Soviet gas processing technology is lagging behind the technology used at present in

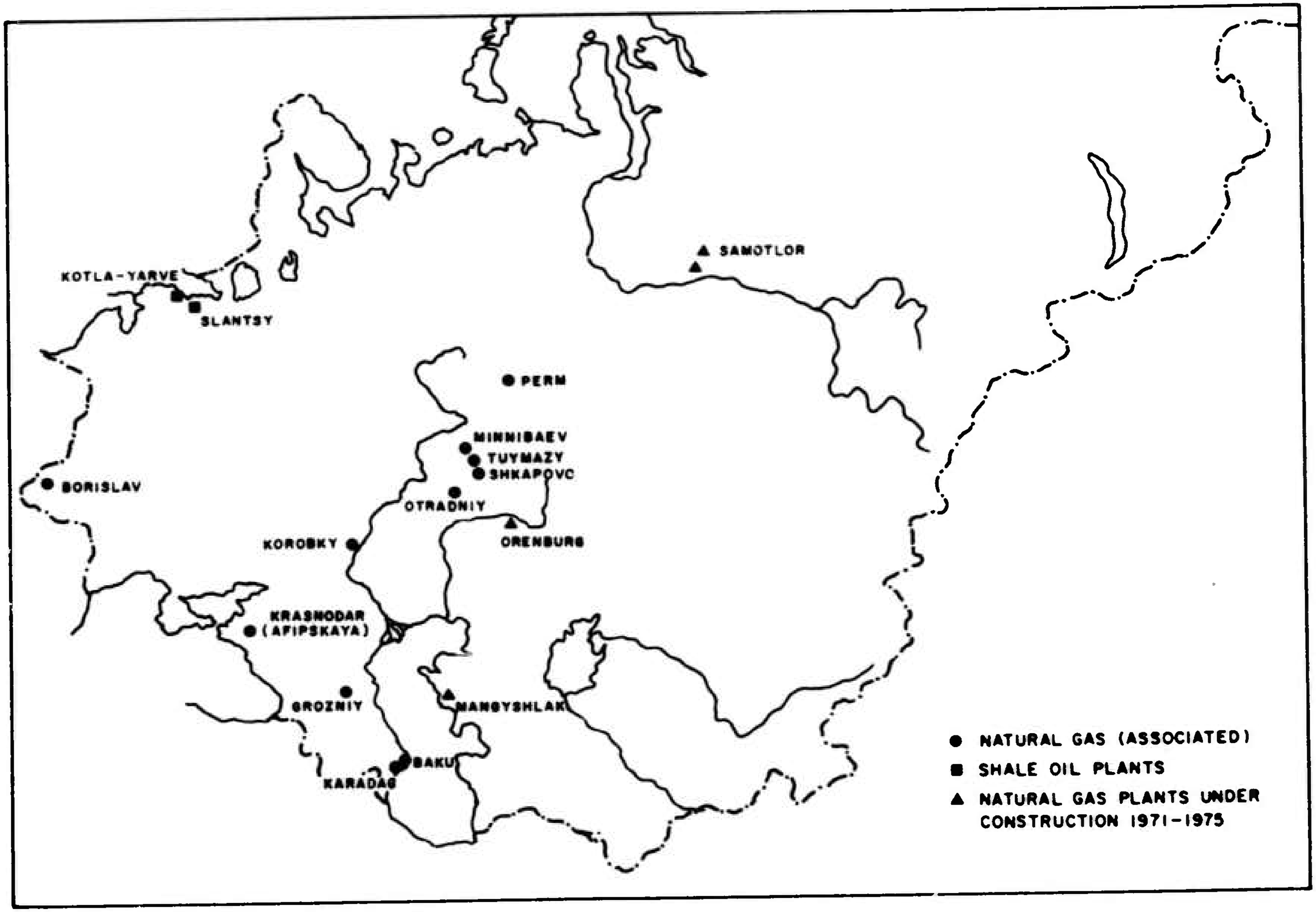


Figure D-2

GAS PROCESSING PLANTS IN THE USSR

Western Europe and the United States. Future plans call for construction of rather unsophisticated plants similar in design to those used in the West some 10 or 15 years ago. The Soviets seem to lack construction capabilities for manufacturing complex cryogenic heat exchange equipment at this time. Perhaps the decision to use outdated technology is based on the choice of getting the job done in a hurry, with available means at hand, rather than waiting for development of new, more sophisticated, technology. Certainly they are quite aware of foreign technology and have their own research programs in this field.

The reported purities of propane and butanes in 1967 left something to be desired as well. These were about 90 and 95 percent, respectively. The purities of the isobutane fraction were about 92 percent. The plans for 1970 were to produce these fractions with purities up to 97 percent; but if one is to judge their performance in this regard by the new plans for 1975, which outline the same aims, they must not have met their 1970 goals.

2. Condensate Processing

Up until about 1970, condensate production had usually been reported with that of crude oil. This situation arose, again, from lack of equipment to use this resource, and known condensate fields were not exploited. In many cases, byproduct condensate from natural gas production was dumped or burned. The following tabulation shows the production of condensate in the USSR.

Production of Gas Condensate in the USSR

	Year					
	1955	1960	1965	1970	1971	1972 (Plan)
Production (million tons)	0	0.7	1.2	4.2	5.3	7.6

There are only limited facilities for condensate processing. A plant built exclusively for condensate processing is in operation near the Shebelinka (Ukraine) field. Some condensate processing takes place at the Afipskiy (Krasnodar Kray) plant, mainly for aromatics recovery and recycling to the platforming sections at the local refinery.

3. Acid Gas Removal

The USSR has been fortunate in its natural gas relative to the requirements for acid gas removal. Most of the gas produced up to now has had low carbon dioxide and hydrogen sulfide content. As a consequence, few acid gas removal facilities have had to be installed. In recent years, however, sizable reserves of gas with fairly high hydrogen sulfide content have been discovered in Central Asia. For example, the Samantepe field in Western Turkmen SSSR, discovered in 1964 and located near the well-known Gazli field, has a sulfur content reported to be 3.3 percent. The Gazli field itself has 200 to 700 ppm of this gas. Two other fields in Central Asia, Northern Mubarek and Urtabaluk in Turkmen SSSR, also have gases containing appreciable quantities of hydrogen sulfide. All of these gases have to undergo acid gas removal. The capital expenditures required for plants are proportional to the amount of acid gas to be removed, and would represent sizable investments.

The usual practice in the USSR for removal of acid gases is to use the methanol amine (MEA) absorption system. Although it is an improvement on the old dry chemical systems or the carbonate method, it is no longer widely used in the United States or Western Europe. It is more expensive both in operating costs and equipment replacement costs. The solvent degrades easily, and equipment corrosion is a problem. The MEA system has been replaced by other systems in the West, with similar operating characteristics but with the use of different solvents. Most of these processes are under license in the West, and operating data and detailed engineering know-how are not available to any but the process licensees. The Soviets had shown interest in acquiring the newer technology from the West, particularly the diethanol amine (DEA) system, which can be used with some modification in their old MEA plants. The advantages of the DEA system are well-known in the USSR,[2] and undoubtedly this solution has been tried in some of their MEA plants. But it is doubtful that they have the facilities available to manufacture DEA in sufficiently large quantities for wide application at this time.

The recovery of sulfur from absorbed hydrogen sulfide is usually done in Claus plants. These plants have been growing in complexity in the West because of high sulfur dioxide emission standards that the operators had to face in recent years. Claus plants have grown to three or more catalytic conversion stages, and with additional downstream processing equipment, should be able to meet 99.5+ percent sulfur recoveries. The Soviet practice seems to be to operate two-stage Claus units with, at best, 90 to 95 percent sulfur recovery. The justification for these plants had been based on economic grounds--i.e., the recovery of sulfur, rather than on the necessity of avoiding fouling the air with sulfur dioxide.

The production of sulfur from gas amounted to only 9,500 tons in 1970. This amount represents the production of one relatively small plant. By 1975, the Soviets plan to produce up to 720,000 tons per year of sulfur from natural gas. This amount might represent a total investment of US$2 million to US$5 million for construction of required plants.

E. Transportation of Natural Gas in the USSR

1. Overview and Statistical Data

In 1970 the total production of natural and associated gas in the USSR was 197.8 billion cubic meters (bcm) or 7.0 trillion cubic feet (tcf), which compares with a U.S. production of 21.8 tcf for the same year. Natural gas produced in 11 economic regions is transported by means of ten major pipeline systems to points of gas demand throughout the country. The principal uses of natural gas in the USSR as a whole during the year 1970 were as follows: 59 percent (116.7 bcm) for industrial boilers; 24.4 percent (48.3 bcm) for electric power plants; 13.2 percent (26.1 bcm) for residential needs: and 3.4 percent (6.7 bcm) for export and other needs. Exports in 1970 amounted to 3.8 bcm--1 billion to Austria, 1 billion to Czechoslovakia, 300 million to Hungary, and 1.5 billion to Poland.

The total length of all gas pipelines in use in the USSR in 1970 was 67,500 km, and the total volume of gas transported through the pipelines amounted to 181.5 bcm or 91.8 percent of all the natural and associated gas produced that year (see Table D-15).

Table D-15

LENGTH OF GAS PIPELINES BY TYPE AT BEGINNING OF YEAR

Year	Kilometers: Transmission	Collection	Distribution	Total
1965	36,908	3,898	30,083	70,889
1966	42,273	4,428	34,479	81,180
1967	47,550	4,459	39,069	91,078
1968	52,749	5,673	43,771	102,092
1969	56,088	7,223	49,727	113,038
1970	63,159	8,315	55,787	127,261
1971	67,519	11,286	62,628	141,433
1972*	71,777	14,186	68,828	154,791

* Preliminary.

As of 1969, the proportion of pipelines with diameters of 38 cm (15 inches) or less was 23 percent, that of pipelines with diameters from 42 cm to 53 cm (16-1/2 to 21 inches) was 24 percent, and that of pipelines with diameters of 63.0 to 122 cm (25 to 48 inches) was 53 percent (see Table D-16. From 1970, pipes of 142 cm (56 inches) have been produced, and pipes of 2-2.5 meter (79-98 inch) diameters have been tested.

The cost of constructing pipelines has been established at the following levels, according to the Ministry of the Gas Industry.

	Diameter of Pipes (cm)			
	102	142	202	252
Cost of constructing 1 km of gas pipeline (thousand rubles)	122	222	443	780
Capital investment per million cubic meters of gas transmitted (rubles)	15	11	9	8

The general costs of gas transport to the economy for the years 1960-68 are shown in Table D-17.

The growth of gas pipelines and the volumes of gas transported over the 20 year period from 1950 to 1970 is shown in Table D-18.

From Table D-18 it can be determined that total length of pipelines in the USSR increased at an average annual rate of about 18 percent in the 1950-1970 period, and even in the latest five-year period, 1965-70, have continued to increase at the rate of 10 percent per year. The volumes of gas transmitted by pipeline in the 20 year period increased at an annual average rate of 27 percent, and in the 1965-70 period increased at a rate of 10 percent per year. The average volume of

Table D-16

DISTRIBUTION OF TRANSMISSION GAS PIPELINES BY PIPE DIAMETER AT BEGINNING OF YEAR

Diameter (millimeters)	Kilometers 1965	1966	1967	1968	1969	1970	1971
Up to 273	3,625	4,232	5,071	5,523	6,523	8,021	8,330
325-529	14,614	15,919	17,124	18,114	18,908	19,963	21,394
630-820	13,565	14,594	15,240	16,101	16,603	17,400	18,940
Above 1,000	5,104	7,528	10,112	13,011	14,054	17,775	19,755
Total	36,908	42,273	47,550	52,749	56,088	63,159	67,519

Source: Gazovoe delo, No. 4, pp. 30-37, 1972.

Table D-17

GAS TRANSPORT COST, FROM 1960 to 1968

	1960	1962	1963	1964	1965	1968
Gas production (billion cubic meters)	47.2	75.2	91.5	110.2	128.	169.1
Total gas transported* (billion cubic meters)	26.0	50.8	71.7	87.5	103.3	145.7
Average distance (kilometers)	607	629	650	660	680	900
Cost of transport (rubles per thousand cubic meters)	2.21	1.91	1.60	1.60	1.68	1.88

---

* Only that gas which is under the jurisdiction of the gas industry.

Table D-18

GROWTH OF NATURAL GAS PIPELINES AND VOLUMES OF NATURAL GAS TRANSMITTED BY PIPELINES IN THE USSR - 1950-1970

Year	Total Length of Pipelines at Year End (thousand kilometers)	Volumes of Gas Transmitted (billion cubic meters)
1950	2.3	1.5
1955	4.9	3.5
1960	21.0	32.8
1965	41.8	112.1
1970	67.5	181.5

gas transmitted per kilometer of gas pipeline increased from 652 cubic meters in 1950 to 2,689 cubic meters in 1970--probably reflecting not only increased average diameter of the line but also greater installation of compressor stations.

For perspective, the relative use of gas as a percent of total fuel use has been:

Year	Gas Use as Percent of Total Fuel Use
1950	2.3%
1960	7.9
1972	19.5
1975*	

* Gosplan.

Another point for comparison with the U.S. gas pipeline network is that the Soviet pipeline network has a very high proportion of its total length in the transmission part of the system, compared to that of the distribution network and the gas gathering network. In the USSR the distribution network is only about two-thirds as large as the transmission network, whereas in the United States, the distribution network is twice as long as the transmission system. The gas gathering network in the USSR is also smaller than in the United States--about 6 percent of the total system compared to 10 percent in the United States. Until very recently at least, the intent of the Russians has probably been to minimize extensive distribution networks in cities in order to concentrate their investments and resources, especially steel pipe, on long distance transmission lines for gas transport (see Table D-18).

The percentage of total USSR gas line length in larger diameter pipes is greater in the USSR than in the United States. However, the throughput capacity is not correspondingly high because compressor station installations are relatively fewer. Also, in some cases the gas is insufficiently dried before entering the transmission system, and moisture and condensate on the inner walls of the pipelines have resulted in reduced carrying capacity in many instances.

In the USSR, finding and production costs for natural gas are very low, while transport costs are high. It has been estimated, for instance, that the average cost of gas production in the USSR is only about 40 kopecks per conventional ton of fuel compared to 2.4 rubles per ton for oil and 10 rubles for coal. Exploration costs double or triple this cost for gas finding, but even so, gas at the source is very cheap in the USSR. The contrast provided by transport costs is shown in Table D-19.

There are, in addition, the costs of transport within the distribution networks. The cost of gas at point of delivery to the consumer in the USSR consists of: production costs, 18 percent; transmission costs, 66 percent, and distribution costs, 16 percent. These figures point up the importance of transportation costs in decisions concerning interfuel competition within a region and allocation of gas to other regions from regional resource sites in the USSR. However, Soviet sources report that the payout period on gas pipelines has been very short (less than one year for the Stavropol-Moscow gas line). This would tend to cause decision makers to expand gas pipelines as rapidly as possible. Constraints such as lack of adequate production capacity for pipes (and hence, ultimately, of steel) and compressors are probably partly responsible for consistent failures to meet pipeline goals. However, it is also true that gas cannot cover the entire fuel economy of the USSR and therefore, ultimately, the goals for additional gas pipelines will

Table D-19

TRANSPORT COST FOR VARIOUS FUELS IN 1960
(Per Ton of Conventional Fuel for a Distance of 1,000 kilometers)

Fuel and Transport Mode	Capital Cost (per/ton annual capacity) (rubles)	Operating Cost Without Interest (rubles)	Operating Cost Including Interest @ 10% (kopecks/ton-kilometer)
Coal			
Electrified railroad Class I	8.1	1.33	0.21
Crude oil			
720 millimeters diameter pipeline	3.5	0.40	0.075
Natural gas			
1,020 millimeters diameter	13.6	1.62	0.30
Electric power			
DC 600 kV	20.0	1.37	0.34

Source: R. W. Campbell, The Economics of Soviet Oil and Gas (Johns Hopkins Press, Baltimore, Maryland, 1968).

depend on goals set for finding, extraction, and production of natural gas in the USSR. These decisions in turn will hinge on decisions about the desirability of conversion to gas from other fuels in the various end uses. Questions of this nature are discussed in sections other than the transport section of this report. Suffice it to say, for example, that electrical power generation was the biggest user of gas in the earlier years of USSR gas development because such facilities could be advantageously located near the gas fields and could absorb large supplies of gas with only small transmission investments. As gas transmission facilities were extended, the next logical set of users became other large and concentrated industrial facilities that were located along transmission lines and that did not require expensive distribution mains, such as would be required for household use. Thus, cement plants, blast furnaces, and glass making plants have become large industrial users of natural gas.

The major elements of the Soviet gas pipeline system are shown in Figure D-3. Large interregional movements of gas occur from Central Asia to the Urals (which is a general fuels deficit area), and from the Western Siberian fields near Tyumen, Shaim, and Berozovo to the Urals. The Northern Caucasus, which until 1965 had the largest developed gas reserves in the USSR, transmits gas via pipeline primarily to the central industrial regions, although some gas goes on to Leningrad and some goes to the Ukraine. The capacity of this system is about 40 bcm (1.4 tcf) per year. The gas fields of the Volga-Ural Region transmit gas by pipeline primarily to the central industrial region and some eastward to the Urals. The Western Ukraine fields are the main source of supply for Belorussia and the Baltic region, and also supply local needs, sending a small surplus to the central industrial region.

The Central Asia fields, during the five-year period completed in 1970, were linked by two large pipelines, one 1,020 millimeters (40

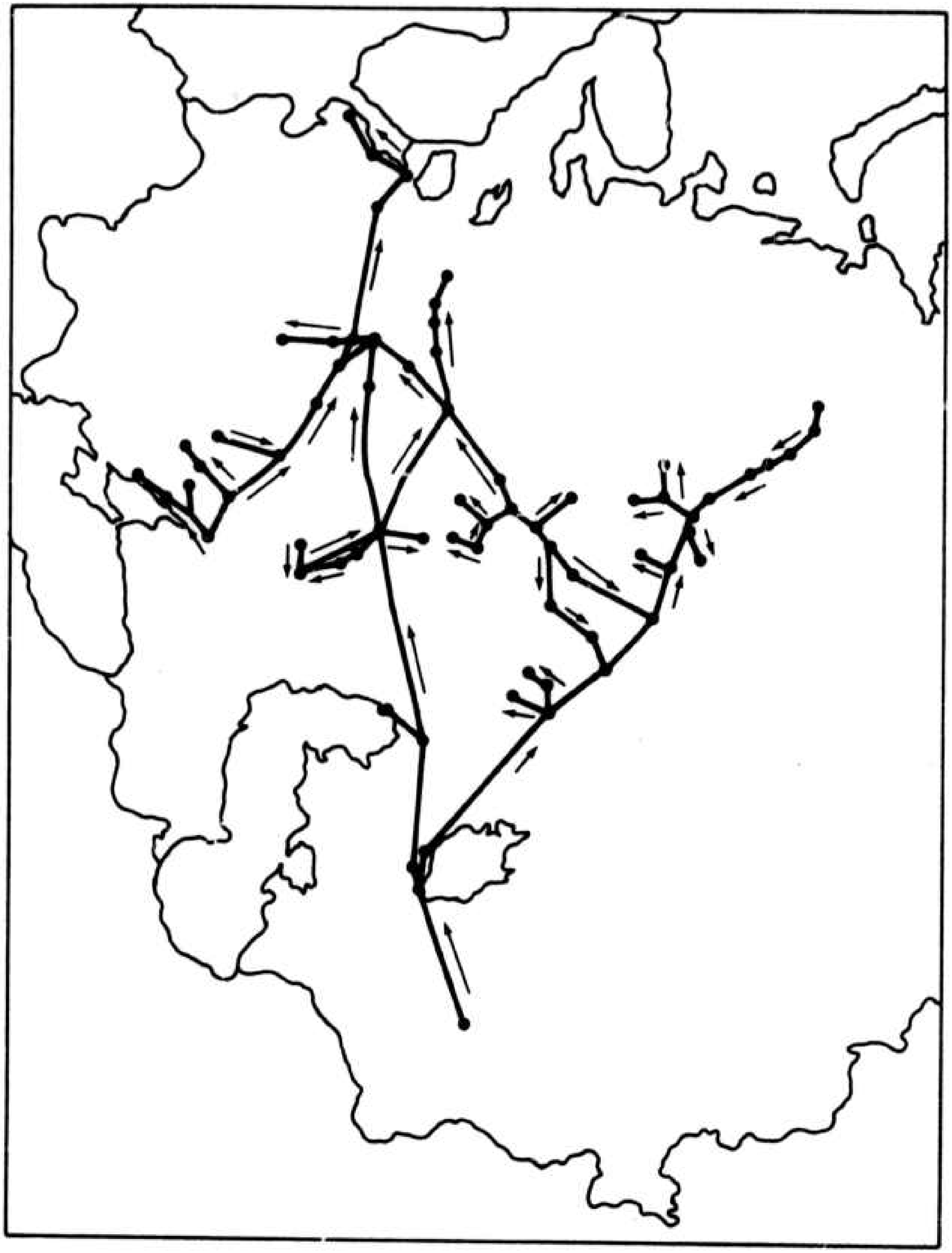


Figure D-3

MAJOR ELEMENTS OF THE USSR GAS PIPELINE SYSTEM inches) in diameter and the other 1,220 millimeters (48 inches) in diameter, to the central industrial regions (a distance of about 6,000 kilometers). These lines deliver about 25-30 bcm (971 bcf) per year.

The Western Siberia gas fields are now deemed large enough to supply the Northwest and Western regions as well as the nearby Urals. The first gas pipeline built for this purpose was the 1,220 millimeter (48 inch) diameter line from Western Siberia to Cherepovets (a distance of 2,400 kilometers). A second line is to follow; it will be 1,420 millimeters (56 inches) in diameter, extending to Leningrad. This system, when at full capacity, will deliver about 80-90 bcm (about 3.0 tcf) per year.

In addition to these major domestic lines, an international gas pipeline has been laid parallel to the Druzhba crude oil pipeline. In 1967 natural gas from the USSR began to flow through this pipeline to Czechoslovakia. A line was built, through the joint efforts of the USSR and Poland, from the Ukraine through Lyublin to Warsaw. Beginning in 1973-74 a large volume of gas will be directed also to East Germany, Bulgaria, and Hungary.

A gas pipeline from the USSR to Bulgaria is being laid across Romania, and beginning with 1975, this pipeline will move 3 bcm (106 bcf) of gas annually. The USSR is providing technical assistance in the building of the Bulgarian portion of the pipeline, and Bulgarian specialists are aiding in the construction of the line on Soviet territory.

Figure D-4 illustrates the system of transmission gas pipelines through which natural gas will be transported from the USSR to Czechoslovakia, East Germany, West Germany, and Italy. Within Czechoslovakia, a transmission gas pipeline 1,220 millimeters (48 inches) in diameter is being laid from the border point of Ruska to the city of Yablonitse. Along this portion it is planned to build a second string 914 millimeters (36 inches) in diameter.

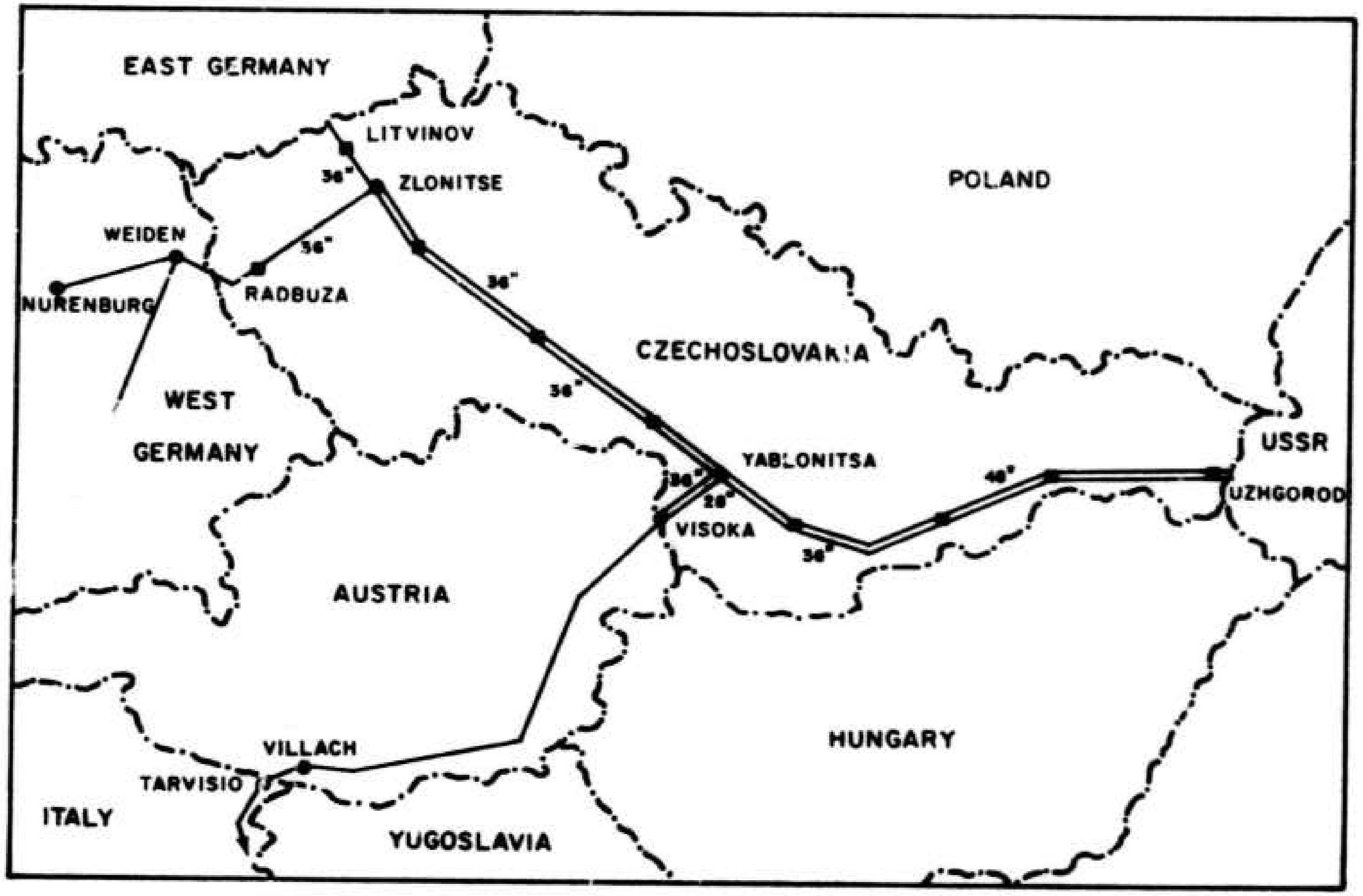


Figure D-4

PLANNED SYSTEM OF GAS PIPELINES FROM THE USSR TO COUNTRIES OF EASTERN EUROPE

Near Yablonitse the line will split into two branches. One of the branches will consist of two pipelines, 712 (28 inches) and 914 (36 inches) millimeters in diameter, and will be laid in the direction of Visoka. The 914-millimeter line will be continued through Austria to the border with Italy.

The major pipeline will continue beyond Yablonitse to Prague and further to West Germany. On the portion between Yablonitse and Zlonitse, a distance of 296 kilometers, there will be two lines, each 914 millimeters in diameter. Near Zlonitse these gas pipelines will split; one will be laid to the city of Litvinov, and the second will be laid in the direction of Bavaria to the border point of Rozvadov. The sector between Zlonitse and Rozvadov will be 914 millimeters in diameter and 129 kilometers in length.

The first string of the basic line within Czechoslovakia will have nine compressor stations, which will have a total established gas-pumping capacity of 536,400 horsepower. During the initial period, the productivity of these compressors will reach 6 bcm (212 bcf) per year. Subsequently, it is proposed to double the carrying capacity of the line.

After the completion of all of the sections of the gas transport system, it is proposed to raise the delivery of gas to the various countries to these amounts.

	Billion Cubic Meters/Year	Billion Cubic Feet/Year
West Germany	4.71	166
Austria	1.47	52
Italy	10.00	353
East Germany	0.7	25
Czechoslovakia	0.3	11

2. Future Situation in Soviet Gas Transmission Systems

The projected 1975 production of natural gas in the USSR according to the current five-year plan was to be 320 bcm. However, problems developed in the 1971-72 year, and the goal for 1973 was reduced to 238 bcm of natural gas production. It is believed that at the current rate of production so far for 1973, even this reduced goal will not be realized, and that only about 223 bcm of natural gas will be produced in the full year 1973. Hence, a reasonable estimate of total natural gas production for full year 1975 would be in the range 265-270 bcm.

The question arises as to whether or not the shortfall in production lies in problems of field extraction and production or in insufficiencies of the transmission system. In this connection, the data presented in the following tabulation are of interest.

5 Year Increments of Gas Pipeline Kilometrage and Gas Volume Transmitted (Bcm)

Factor	1960-1965	1965-1970	1970-1975*
Increase in km of natural gas pipelines	21,000 km	28,000 km	30,000 km
Increase in natural gas transmitted	79 bcm	69 bcm	122† bcm 72‡ bcm

From the above data, it may be calculated that in the 1960-65 period, the additional gas transmitted per additional 1,000 km of pipeline added was 3.76 bcm/1,000 km. In the 1965-70 period, this ratio fell to

---

* Plan.

† Not likely to be realized.

‡ SRI estimate.

2.46 bcm/1,000 km of added line. The five-year plan for 1970-75, however, called for enough additions to pipeline kilometrage and gas production that a ratio of 4.1 of these quantities would have been the result. SRI estimates that the actual increase in gas production will not be more than 72 bcm. Yet the increase in pipeline kilometrage called for is only a modest 7 percent increase over the entire five-year period, and hence should be readily achievable. Thus, the ratio developed in the preceding discussion would approximate 2.4 bcm/1,000 bcm added, very slightly less than in the preceding five-year plan achievement. Hence, it is concluded that through the year 1975, the shortfall in gas production and use is not the result of insufficient pipeline construction but is more likely the result of problems in the extraction/production/processing system combined with failure to efficiently use the existing natural gas pipelines. Primary problems are (a) insufficient purification of the gas prior to introduction to the pipeline, so that moisture condenses on the walls of the line, making throughput more difficult, and (b) the lack of sufficient numbers of compressor stations to move large volumes rapidly.

That the lack of compressor stations is indeed a problem is well illustrated by the fact that at the end of 1970, there were 128 compressor stations on the natural gas pipelines in the USSR, and that the goal for additional compressor stations to be added by 1975 was 100--i.e., a 78 percent increase over the five-year period. Even so, whereas there were 1.83 compressors per 1,000 km in 1970, there are to be 2.28 per 1,000 km by the end of 1975. Hence, the need for more compression is clearly recognized, but even a large increase in number will raise the average number of compressor stations per 1,000 km by only a relatively small amount. Apparently, this problem has accrued over an extended period; some of the earliest Russian pipelines having relied on field pressure from the wells to propel the gas through the lines.

Further confirmation of the critical importance of enhanced performance and use of the lines rather than insufficient pipeline construction or lack of sufficient kilometrage is found in data relating to capital expenditures for natural gas pipelines (including compressors). In the 1966-70 period, the Russians spent 2.9 billion rubles on pipelines and added 28,000 km of line--i.e., approximately 105,000 rubles/km added. In the 1971-1975 period, the current five-year plan calls for an expenditure of 6.7 billion rubles for natural gas pipeline construction (including compressors). The goal for pipeline to be added is 30,000 km, and as previously stated, this is a modest goal of 7 percent increase over the five-year period, which seems reasonable and readily achievable. Hence, the budgeted capital expenditures will amount to about 225,000 rubles/km added--i.e., an increase of 115 percent over the five-year period. Therefore, it may be inferred that most of the more than two times greater capital expenditure on natural gas pipelines will be for adding compressor stations to existing lines to increase the throughput and use of existing capital structure and equipment. This is especially significant since the Soviets estimate that even now the transmission of gas costs seven to ten times less than the energetically equivalent amount of oil, and four to six times less than shipping an energetically equivalent quantity of coal.

Thus, it may be concluded that failure to reach goals of substitution of gas for other fuels is not caused by a shortage of natural gas pipeline kilometrage as such, but by failures in extraction and purification, as well as by lack of compressor stations, resulting in underutilization of the existing gas transport system. The current doubling of capital expenditures and obvious emphasis on adding compressor stations should enhance utilization of the existing system.

F. Natural Gas Storage

If one considers the variations in seasonal demands on supplies of natural gas by consuming sectors, it rapidly becomes obvious how important storage facilities are to the gas producing industry. The operations of this industry would be seriously hampered and become uneconomic without adequate storage.

It has been estimated that seasonal variations on the demand of natural gas by consumers amounted to about 11 bcm in 1965. This was approximately 9.3 percent of the apparent internal consumption of natural gas in the USSR. Ideally, this would have required an annual storage capacity equal to at least one-half of this seasonal variation in demand, or about 4.7 percent of the annual volume of gas production. The total gas storage capacity in the USSR was equal to only 2 bcm at the beginning of 1966, thus satisfying less than one-half of the necessary capacity. In 1970, if one assumes that the seasonal variations amount to 9.3 percent of apparent internal consumption of natural gas as in 1965, the storage capacity requirement would have been 9.3 bcm. The actual withdrawals and injection of gas into underground storage facilities amounted to only a little over one-half of this quantity, indicating again inadequate storage capacities (the bulk of Soviet natural gas is stored in underground reservoirs). The reported underground storage of gas is presented in Table D-20. There are constant references in Soviet literature of the inadequacies of storage facilities for both natural gas and crude oil. The accepted practice at Soviet refineries is to have only enough crude storage for a five-day supply. This inadequacy brings dislocations in supplies of natural gas during peak demands. Instances of curtailment of gas supplies to electric power stations as well as to industrial consumers during the winter season have often been reported by the Soviets.

Table D-20

UNDERGROUND STORAGE OF GAS

Indicator	1965	1966	1967	1968	1969	1970	1971
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	13	15	15	15

Although current Soviet opinion is that capital costs for storage are only half the cost of additional pipeline throughput capacity, Soviet planners have generally chosen the latter alternative and required industrial end users to invest capital in equipment and facilities enabling them to switch to gas in off-peak seasons. Again, the very low cost of gas to the users plus the short payout for transmission facilities seem to be the decisive factors. However, a detailed analysis of the economics of transport-storage alternatives are beyond the scope of the present study; they would be a very suitable area for further study.

The main underground gas storage facilities in the USSR are shown in Figure D-5. Fifteen of these facilities were reported[3] in 1971, with an approximate storage capacity of 5.5 bcm.

The first of these underground facilities was created at Kaluga, from an aquifer 800-900 meters deep. The capacity of this facility was reported to be 360 million cubic meters in 1966, and it was to be expanded to 1 bcm. The building of this storage facility took five years.

The second facility, Schelkov (near Moscow), was again built from an aquifer at a 760 meter depth. The estimated capacity of this facility is 2.1 bcm.

The third reservoir, Olishev (100 kilometers from Kiev), was explored in 1959 and the first gas was pumped into it in 1964. It uses a sand bed with 25 percent porosity at a depth of 550 meters. The capacity of this reservoir is, however, rather small, only 150 million cubic meters.

The fourth reservoir, Poltoratsk near Tashkent, consists of a sand bed with 15 percent porosity, wedged in between two clay layers at a depth of 530 meters. The ultimate developable capacity of this reservoir was reported in 1968 to be 450-500 million cubic meters. By January 1967, the reservoir was reported to contain 248 million cubic meters of gas. At present, as much as 750 million cubic meters is pumped into it and a further expansion of capacity to 1.2 bcm is planned.[4]

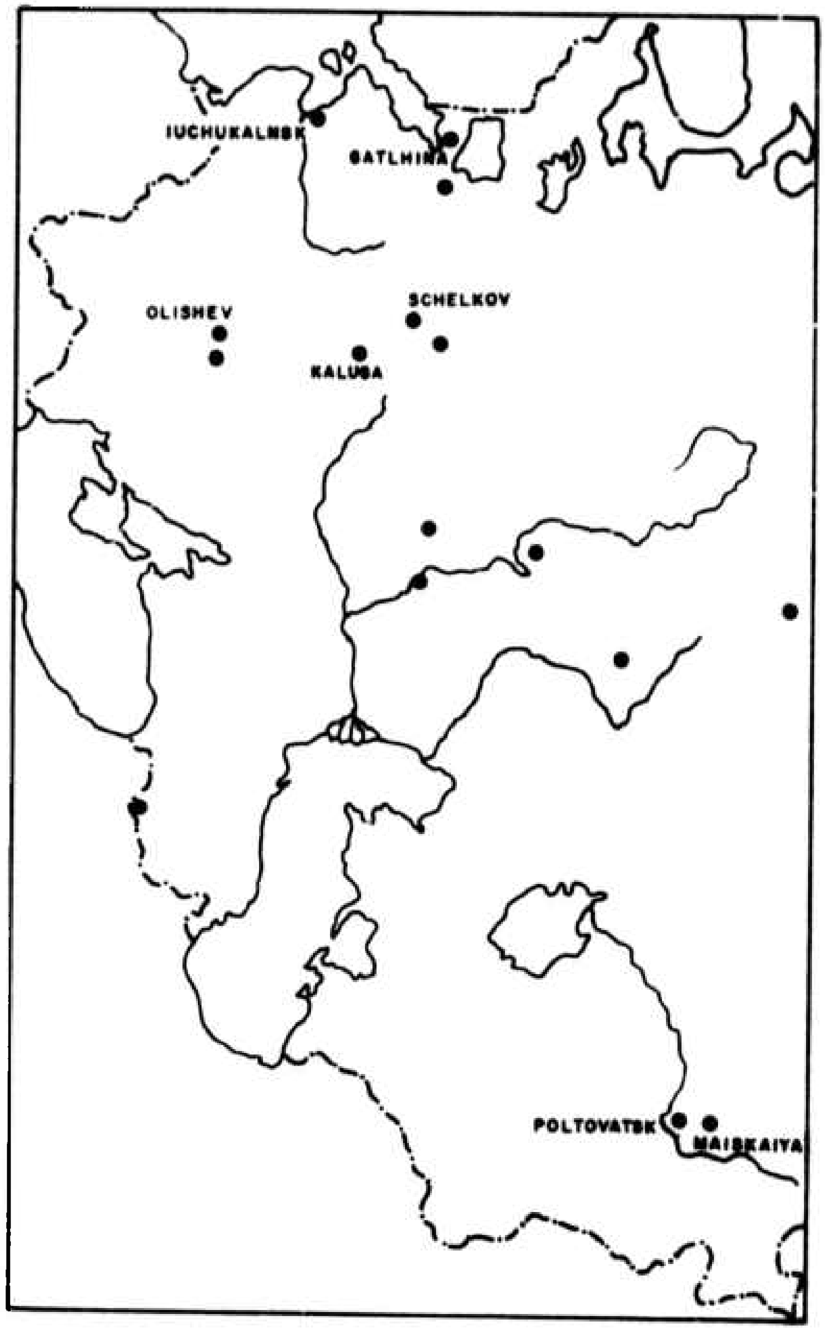


Figure D-5
UNDERGROUND NATURAL GAS STORAGE
RESERVOIRS IN THE USSR

All of the above reservoirs were developed in inclined sand beds with natural traps. The first one to be developed experimentally in a horizontal sand bed was the reservoir near Gatchina (outside Leningrad). This reservoir changes, at some points, from a horizontal layer to a very steeply inclined one. The first gas injection and withdrawals were accomplished in 1962-1965; however, problems were encountered with too much sand being carried out with the gas during withdrawals. By 1966, this problem was apparently solved, and storage of about 120 million cubic meters of gas was accomplished.

The surface equipment installed at these sites is usually comprised of compressors, distribution systems, gas-water separators, filters, cyclones, and dehydrators. The dehydrators are diethylene glycol absorbers and glycol injection systems. This is standard equipment to be found at any sites of this nature and are no different from Western practice.

Other structures have been explored in the mid-1960s and presumably put into operation, such as Inchukalusk near Riga. Active consideration was given to the use of exhausted gas fields close to pipelines, such as those to be found near Saratov on the Central Asia-Center pipeline. Presumably, some of these have become operational, but at present must account for a very small capacity. The Kaluga and the Schelkov reservoirs have undergone expansion and account for much of the present storage capacity.

Although work of research and experimental nature has been reported on underground storage of LNG and cryogenic storage of LPG, no commercial operations of LNG reservoirs are known at this time.

Any deals that the Soviets might envision with the West in LNG trade would involve large expenditures for construction of liquefaction plants and storage facilities. The Soviets have shown interest in barter deals where LNG would be traded for long term credits and technical help in construction of facilities such as pipeline, plants, storage, and tanker terminals.

High costs are likely to deter the building of LNG storage facilities, unless foreign capital can be attracted.

G. Capital Investments in the Gas Industry

The reported amount of associated gas processed in the USSR in 1965 was 5.81 bcm. The incremental growth in gas processing between the beginning of 1966 and the end of 1970 was 5.19 bcm. One can approximate the capital investment required to expand this processing capacity to the planned 23.9 bcm, which the Soviets plan to achieve by the end of 1975. This approximation is made using capital investment data reported for the 1965-1969 period. These data are presented in Table D-21.

Table D-21

CAPITAL INVESTMENT IN GAS PROCESSING PLANTS
(Million Rubles)

Year	New Construction	Reconstruction	Total
1965	24.3	1.0	25.3
1966	28.9	1.1	30.0
1967	32.4	0.4	32.8
1968	49.1	0.3	49.4
1969	48.8	2.5	51.3

Source: Gazovoe Delo, No. 1, pp. 86-91, January 1971.

By applying a scaling factor* on proposed production increment, the capital investment for construction of new plants would amount to approximately 393 million rubles. This is an 89 percent capital investment increase over the previous five-year plan. The capital investments for the whole gas industry in the current five-year plan are to be 88 percent over the previous one. The closeness of these figures is probably a coincidence, however, because natural gas plants represent only a small proportion of funds to be invested in the gas industry.

The largest share will go to pipeline construction and the erection of field installations. Table D-22 shows the reported investment in field installations for the period 1965 through 1969.

Table D-22

CAPITAL INVESTMENT IN THE EQUIPPING OF FIELDS
(Million Rubles)

Year	Planned	Actual
1965	679.6	602.4
1966	680.3	657.8
1967	795.9	686.9
1968	720.3	671.7
1969	771.3	793.4

Source: Gazovoe Delo, No. 1, pp. 36-41, January 1971.

---

* $\text{Cost} = 208 \left(\frac{23.9-11}{5.19}\right)^{0.7}$, assuming an investment of 48.8 million rubles in 1970 and adding yearly investments from 1966 through 1970 (see Table D-21).

$= 393$ million rubles.

If one is to assume an investment of 800 million rubles for field equipment in 1970, then the aggregate investment for these installations in the five-year plan period 1966-1970 would amount to 3.8 billion rubles.

One can estimate the costs of gas pipeline construction by relating to U.S. construction costs and using the reported data for pipeline construction during the 1966-1970 period in the USSR. Gas pipeline construction data, as reported by the USSR, appear in Tables D-23 and D-24. Details of the estimates can be found in Table D-25.

Assuming a conversion rate of $100/90 rubles, the total estimated capital expenditure in the gas industry was approximately 6.9 billion rubles in the period for 1966-1970. If one scales the increment* in planned gas production for 1971 through 1975, the approximate capital cost for field installations for this period can be estimated at 5.61 billion rubles. To this capital cost, one adds the estimated costs of processing plants, 0.40 billion rubles, and pipeline construction costs of 6.74 billion rubles (estimated from the current Soviet five-year plan to invest 2.3 times the amount spent on pipeline construction in the previous plan). The sum of these costs is a total capital investment of 12.75 billion rubles for the current five-year plan. This is an 85 percent increase in capital expenditures over the previous five-year plan. The Soviets' official five-year plan calls for an 88 percent increase. Barring unforeseen circumstances, their investment plans seem to be reasonably close to production goals.

---

* $\text{Cost} = 3.8 \left(\frac{320-198}{198-128} \right)^{0.7} = 5.61$

Table D-23

LENGTH OF TRANSMISSION GAS PIPELINES BY TYPE

Beginning of Year	Transmission		Gas Collection		Distribution		Total	
	Kilometers	Percent	Kilometers	Percent	Kilometers	Percent	Kilometers	Percent
1965	36,908	51.1%	3,898	5.5%	30,083	42.4%	70,889	100.0%
1966	42,273	52.1	4,428	5.4	34,479	42.5	81,180	100.0
1967	47,550	52.2	4,459	4.9	39,069	42.9	91,078	100.0
1968	52,749	51.6	5,673	5.6	43,771	42.8	102,192	100.0
1969	56,088	49.6	7,223	6.4	49,727	44.0	113,038	100.0
1970*	63,159	49.5	8,773	6.9	55,627	43.6	127,559	100.0

* Preliminary.

Table D-24

DISTRIBUTION OF TRANSMISSION GAS PIPELINES BY DIAMETER
(Beginning of Year)

Year	Diameter (Millimeters)				
	Up to 273	325-529	630-820	Above 1,000	Total
1965					
Kilometers	3,625	14,614	13,565	5,104	36,908
Percent	9.8%.	39.6	36.8	13.8	100.0%
1966					
Kilometers	4,232	15,919	14,594	7,528	42,273
Percent	10.0	37.7	34.5	17.8	100.0
1967					
Kilometers	5,074	17,124	15,240	10,112	47,550
Percent	10.7	36.0	32.0	21.3	100.0
1968					
Kilometers	5,523	18,114	16,101	13,011	52,749
Percent	10.5	34.6	30.2	24.7	100.0
1969					
Kilometers	6,523	18,908	16,603	14,054	56,088
Percent	11.6	33.7	29.6	25.1	100.0
1970*					
Kilometers	8,021	19,963	17,400	17,775	63,159
Percent	12.7%	31.6	27.6	28.1	100.0%

* Preliminary.

Table D-25

ESTIMATES FOR PIPELINE CONSTRUCTION COSTS
IN THE PERIOD 1966-1970
(Including Compressor Costs)

Gas collection lines
Installed length of gas collection lines, km - 4,875
Assumed average diameter, 12 in.
At an assumed cost of $50,000/mile

Total cost = $152 million

Gas distribution lines
Installed length, km - 25,544
Assumed average diameter, 120 in.
At an assumed cost of $40,000/mile

Total cost = $639 million

Transmission lines
Installed length, km - 26,251
Calculated average diameter, 28 in.
At an assumed cost of $150,000/mile

Total cost = $2,461 million

Total pipeline construction costs $3.25 billion

H. End Use of Natural Gas

The rapid growth in production and the lack of success of the construction industry in meeting planned expansion in pipelining and processing facilities have led to the perennial underutilization and waste of natural gas.

In the interest of increased oil production, much of the associated gas is being flared in the field because of lack of processing and transmission facilities. The production and percentage of flared associated gas are presented in Tables D-26 and D-27, respectively. Although the use of associated gas had gone up to 70 percent by 1965, it had dropped back steadily to about 64 percent by 1969 and was reported to be 61.1 percent in 1970. This reduction was due to increasing exploitation of new,

Table D-26

EXTRACTION OF ASSOCIATED GAS BY UNION-REPUBLIC
(Million Cubic Meters)

Republic	1965	1966	1967	1968	1969	1970 (plan)
RSFSR	10,559.3	11,708.8	12,783.0	13,706.7	15,275.9	16,395.0
Ukraine	1,576.1	1,703.7	1,863.4	1,957.2	2,259.6	2,120.0
Azerbaijan	3,149.2	3,105.1	2,874.8	2,507.1	2,558.5	2,470.0
Uzbek	107.5	112.7	113.5	98.3	96.9	90.0
Kirghizia	8.2	8.1	6.0	6.0	6.0	6.0
Tadzhik	-	-	-	3.0	4.7	9.0
Turkmen	1,054.0	1,113.6	1,148.9	1,208.8	1,223.8	1,345.0
Kazakhstan	28.6	36.9	66.4	83.9	121.8	100.0
Belorussia	-	-	1.9	10.2	24.4	185.0
Total (USSR)	16,482.9	17,788.9	18,857.9	19,581.2	21,571.6	22,720.0

Source: Gazovoe delo (Gas Industry), No. 1, pp. 36-41 (1971).

Table D-27

RESOURCES, EXTRACTION, LOSSES AND UTILIZATION
OF ASSOCIATED GASES
(Million Cubic Meters; Percent Utilization)

Indicator	1965	1966	1967	1968	1969	1970 (plan)	1970 (actual)*
Resources	23,547.0	25,605.0	27,687.6	30,494.3	33,936.5	33,799.0	
Extraction	16,482.9	17,789.9	18,857.9	19,581.2	21,571.6	22,720.0	
Losses	7,064.1	7,816.1	8,829.7	10,913.1	12,364.9	11,079.0	
Utilization	70.0%	69.5	68.1	64.2	63.6	67.2	61.1%

* Official Soviet five-year plan, 1971-1975.

Source: Gazovoe delo (Gas Industry), No. 1, pp. 36-41, (1971).

still undeveloped oil fields and the lags in the construction industry in supplying appropriate recovery facilities, as mentioned above. A goal of the new five-year plan is to raise associated gas use to 85 or 87 percent by 1975. It is very unlikely that this goal will be reached, judging by past performance.

The consumption of all gas, natural and manufactured, by the consuming sectors is shown in Table D-28.

One of the most important single consumers of gas, besides the electric power industry, is the growing chemical industry in the USSR. The petrochemical industry is also one of the heaviest consumers of LPG, which is obtained from natural gas processing plants and refineries, as indicated in Table D-29.

The pyrolysis of LPG to ethylene, propylene, and butylenes still plays an important role in the supply of feedstocks to the petrochemical industry and is likely to continue for some time in the future. The growth in secondary processing capacity, particularly in refineries associated with the petrochemical industry, should play an increasingly important role in the supply of these unsaturated hydrocarbons. This should help relieve the reported shortage of LPG supplies to other sectors.

About 50 percent of the associated gas extracted in 1970 was processed in gas plants. The Soviet five-year plan calls for a doubling of this processing capacity by 1975.

Table D-28

CONSUMPTION OF GAS IN THE USSR

Consumers	1965 Billion Cubic Meters	1965 Percent	1967 Billion Cubic Meters	1967 Percent	1969 Billion Cubic Meters	1969 Percent	1971* Billion Cubic Meters	1971* Percent
Total consumption	128.9	100.0	157.9	100.0	182.6	100.0	212.4	100.0
Communal-everyday enterprises	14.9	11.6	18.6	11.8	23.6	12.9	27.2	12.8
Electric power production	35.7	27.6	43.6	27.6	47.0	25.8	55.6	26.2
Industry:								
Chemical	6.1	4.7	9.1	5.8	11.2	6.1	13.8	6.5
Heavy and light metallurgy	18.5	14.4	25.0	15.8	29.4	16.1	33.0	15.5
Machine-building and metal-working	12.9	10.0	14.9	9.4	18.4	10.1	21.1	9.9
Oil and Gas	12.4	9.6	13.7	8.7	16.6	9.1	19.6	9.2
Construction materials and construction	13.9	10.8	16.3	10.3	17.9	9.9	21.4	10.1
Light	2.0	1.5	1.9	1.2	2.2	1.2	2.7	1.3
Food	4.2	3.3	5.1	3.2	6.0	3.3	7.0	3.3
Other	3.5	2.7	3.3	2.1	2.8	1.5	4.5	2.1
Total industry	73.5	57.0	89.3	56.5	104.5	57.2	121.7	57.2
Transport	0.4	0.3	0.6	0.4	0.6	0.3	0.7	0.3
Agriculture	0.2	0.2	0.3	0.2	0.5	0.3	0.8	0.4
Other consumers and losses	4.2	3.3	5.5	3.5	6.4	3.5	5.0	2.4

* Preliminary, from

Sources: Gazovoee delo, No. 1, 1971, pp. 36-41.
Gazovoee delo, No. 4, 1972, pp. 30-37.

Table D-29

PRODUCTION AND DISTRIBUTION OF LIQUEFIED GASES
(Thousand Tons)

Indicator	1965	1966	1967	1968	1969	1970 (plan)
Production of gas at:						
Gas processing plants	1,169.0	1,308.1	1,521.7	1,780.6	1,733.4	1,815.0
Oil refineries	1,608.0	1,818.9	2,002.3	2,366.4	2,684.6	3,135.0
Total	2,777.0	3,127.0	3,524.0	4,147.0	4,418.0	4,950.0
Distribution of gas:						
Chemicals and petrochemicals	1,747.8	1,957.0	2,197.6	2,442.1	2,439.2	2,710.0
Everyday consumers	722.8	919.9	1,078.2	1,328.6	1,609.6	1,802.4
Oil refining	149.8	137.4	130.1	20.3	23.5	30.0
Auto transport	17.4	15.0	14.3	13.5	11.8	16.6
Other consumers	139.2	97.7	103.8	342.5	333.9	391.0

II GAS IN EASTERN EUROPE

A. Natural Gas Resources in Eastern European Countries

The Eastern European countries other than the USSR have natural gas deposits estimated to range from one-thousandth to one-hundredth those of the USSR (Table D-30). The largest natural gas reserves* are in Romania and Poland, while the smallest reserves are in Czechoslovakia and the German Democratic Republic.

Recent years have seen extensive exploration for natural gas in Eastern Europe, with the result that estimated reserves have increased substantially in every country (Table D-31). However, the mere presence of estimated reserves suggested from this recent work carries no indication as to the possible timing of their addition to the gas supply of these nations. A further problem is that even the impressive additions to gas reserves consist mostly of a number of fairly small deposits whose development is certain to be costly. Thus, although there have been apparent important recent improvements in the gas reserve situation in the other CMEA countries, it remains to be seen when (and whether) these deposits can actually contribute to the overall fuel supply balance.

Table D-32 shows estimated natural gas resource potentials in the Eastern European countries, as determined by the U.S. Geological Survey. These estimates are regarded as indicative only of the possible order of

---

* Estimated reserves (rather than resources) are emphasized in Table D-22. Less certain estimates of potential resources are discussed later.

Table D-30

ESTIMATED NATURAL GAS RESERVES OF EASTERN EUROPEAN COUNTRIES

	Billion Cubic Meters	Billion Cubic Feet
Bulgaria	29	1,000
Czechoslovakia	15	500
German Democratic Republic	15	500
Hungary	85	3,000
Poland	142	5,000
Romania	170	6,000
USSR	17,993*	635,400

* Recoverable only.

Source: International Petroleum Encyclopedia, 1973.

Table D-31

COMPARISON OF ESTIMATES OF NATURAL GAS RESERVES (Billions Cubic Meters)

Country	1965*	1973†	Net Change
Bulgaria	2	29	+27
Czechoslovakia	10	15	+5
German Democratic Republic	-	15	+15
Hungary	30	85	+55
Poland	20	142	+122
Romania		170	
USSR	3,000‡	17,993	14,993

* Data from Tiratsov, E. N., Natural Gas (Phenom Press, New York, N.Y. 1972).

† Data from International Petroleum Encyclopedia, 1973.

‡ Proved reserves only.

Table D-32

ESTIMATED NATURAL GAS RESOURCE POTENTIAL
IN EASTERN EUROPE
(Billion Cubic Meters)

Country	Onshore	Offshore	Total
Bulgaria	30-300	30-300	60-600
Czechoslovakia	30-300	-	30-300
German Democratic Republic	n.e.	n.e.	n.e.
Hungary	30-300	-	30-300
Poland	30-300	3-30	33-330
Romania	300-3,000	30-300	330-3,300

n.e. - not estimated.

Source: U.S. Geological Survey, Professional Paper 817, 1971.

magnitude of natural gas resources in onshore and (where appropriate) offshore locations. Clearly, the estimates are quite uncertain. Nevertheless, when the estimates are compared to the data of Tables D-30 and D-31, the following conclusions are suggested:

- Bulgaria's estimated natural gas reserves as of 1973 are about equivalent to the lower limit of the estimated potential onshore resources. Further exploration onshore may increase reserves and ultimately approach the upper limit of estimated resources, but will probably become more difficult as the easily discovered and developed deposits are found and exploited. Probably, therefore, the main direction of future growth in the Bulgarian natural gas industry will be toward assessment of the potentials in offshore deposits in the western part of the Black Sea. In this regard, technology for exploration and development could become a limiting factor.

- Czechoslovakia's currently estimated natural gas reserves are about half the lower limit of estimated potential resources. However, the prospects for rapidly extending these reserves to approach the upper limit of potential resources do not appear encouraging. The geology of Czechoslovakia is such that only relatively small deposits are likely, and their discovery and development is likely to be difficult.

- The German Democratic Republic's potential gas resources were not estimated by the U.S. Geological Survey. However, the geology of the GDR is generally similar to that of western Poland, and therefore, gas deposits may also be discovered in the GDR. However, the area of the GDR is only about one-third that of Poland. If the estimated gas resources were to be distributed in proportion to area, then the GDR might be expected to have from 10 to 100 billion cubic meters of natural gas. Table D-30 indicates that estimated gas resources in 1973 were about 15 bcm. It seems likely, therefore, that while additional deposits may be discovered, the total will still be rather small in comparison to demand.

- Hungary's estimated natural gas reserves are nearly one-third the total estimated upper limit for potential resources. Here again, it is reasonable to postulate that the easily discovered deposits have already been found, and that future exploration and development will become more difficult.

- Poland's estimated natural gas reserves are slightly less than half the total estimated resource potential (onshore and offshore). Although future discoveries may be expected, these will probably come with diminishing frequency.

- Romania's estimated natural gas reserves are slightly more than half the lower limit on potential resources. There appears to be substantial potential for adding to these reserves as added exploration is carried out, both onshore (where most resources occur) and offshore.

Despite the above suggested prospects for augmentation of the indigenous natural gas supply of the Eastern European countries, it is apparent that many of these countries will continue to be dependent on imports of natural gas from the USSR. If the USSR is able to develop its enormous gas deposits in Western Siberia in the near future, this will, of course, affect (and possibly curtail) the domestic gas developments in the countries of Eastern Europe.

Figure D-6 shows patterns of natural gas movement in Eastern Europe in 1970. Of the CMEA countries, only the USSR and Romania exported natural gas in that year. Poland and Hungary were the recipients of Soviet gas, while Romania supplied part of Hungary's gas needs. It is also worth noting that the USSR imported significant amounts of natural gas from Iran and Afganistan, to meet the natural gas demands of the southern republics.

B. Geology of Eastern European Gas Deposits

1. Geology of Bulgaria's Gas Deposits

Small accumulations of natural gas are reported to have been discovered in Bulgaria, but these deposits are not well-known and do not appear to have been developed. The gas occurs mainly associated with oil deposits, probably both as free gas and as gas dissolved in oil.

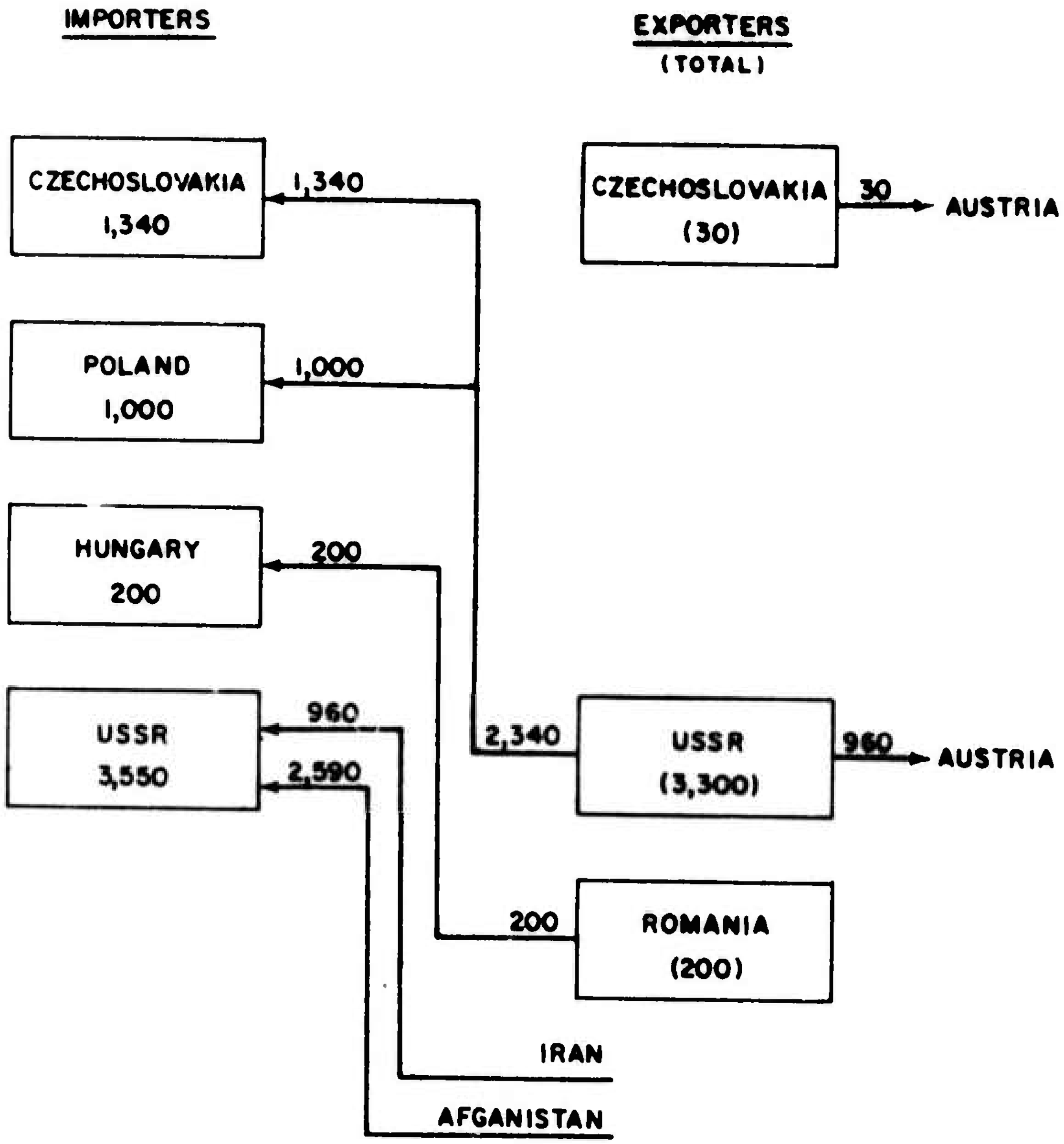
2. Geology of Czechoslovakia's Gas Deposits

Natural gas deposits of Czechoslovakia are small and scattered, mainly in the south central section adjacent to Austria. The gas is principally associated with oil deposits, occurring both as free gas and as gas dissolved in oil.

Table D-33 presents summary data on natural gas production in Czechoslovakia.

3. Geology of E. German Democratic Republic's Gas Deposits

The natural gas deposits of the GDR are apparently small, and are poorly known. (This topic is being further examined.)



Source : United Notions, "World Energy Supplies, 1961-1970," STATISTICAL PAPERS, Series J, No. 15, 1972.

Figure D-6
MOVEMENT OF NATURAL GAS IN 1970
(Million Cubic Meters)

Table D-33

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

	1960	1965	1966	1967	1968	1969	1970	1971
Bulgaria	-	73.2	109	329	506	525	474	327
Hungary	342	1,108	1,552	2,045	2,687	3,235	3,469	3,713
GDR*		133	116	107	143	370	1,233	
Poland	541	1,312	1,290	1,463	2,402	3,672	4,975	5,164
Romania	9,980	16,773	18,046	19,857	21,036	23,093	23,990	25,608
USSR	42,221	118,981	133,236	146,734	157,597	168,798	184,478	197,948
Czechoslovakia	1,443	965	1,070	1,017	1,108	1,185	1,204	1,222

* United Nations, "World Energy Supplies 1961-1970," Statistical Papers, Series J, No. 15., N.Y. 1972.

Source: Statistical Annual of CMEA Member Countries, 1972, Moscow 1972.

4. Geology of Hungary's Gas Deposits

Hungary is located in an area of thick Tertiary sediments, which accumulated during the period of Alpine deformation. The locations of Hungarian natural gas deposits are shown in Figure D-7. The figure shows that gas deposits occur throughout Hungary with no particular geographical concentration. Most of the gas fields are fairly small, however, having reserves of less than 1 bcm. The bulk of the reserves occur in a few large fields that contain several billion cubic meters of natural gas.

Hungary has natural gas deposits that are commonly associated with oil. These natural gases have remarkable variety in composition, which is different from those of Western and Eastern Europe.[5] The amounts of methane and carbon dioxide vary widely with mixtures that include both extremes (nearly all methane or CO_2). Higher methane content is found in stratigraphically higher units, with more carbon dioxide occurring at greater depths. This feature may be related to the high geothermal gradient that exists over much of the Hungarian Basin.

Gas composition and quality tend to be independent of reservoir age, rock type, actual depth, temperature, and pressure. The abundance of carbon dioxide at depth appears related to the concentration of scarce organic matter of Pliocene deposits into oil pools.

Natural gas deposits of Hungary occur as nonassociated gas, mainly in Tertiary sandstones. In 1965, reserves were estimated to be about 30 bcm (1,060 billion cubic feet). However, new discoveries have more than tripled these reserves, to the point where, in 1973, they are estimated to be 85 bcm (3,000 billion cubic feet).[5]

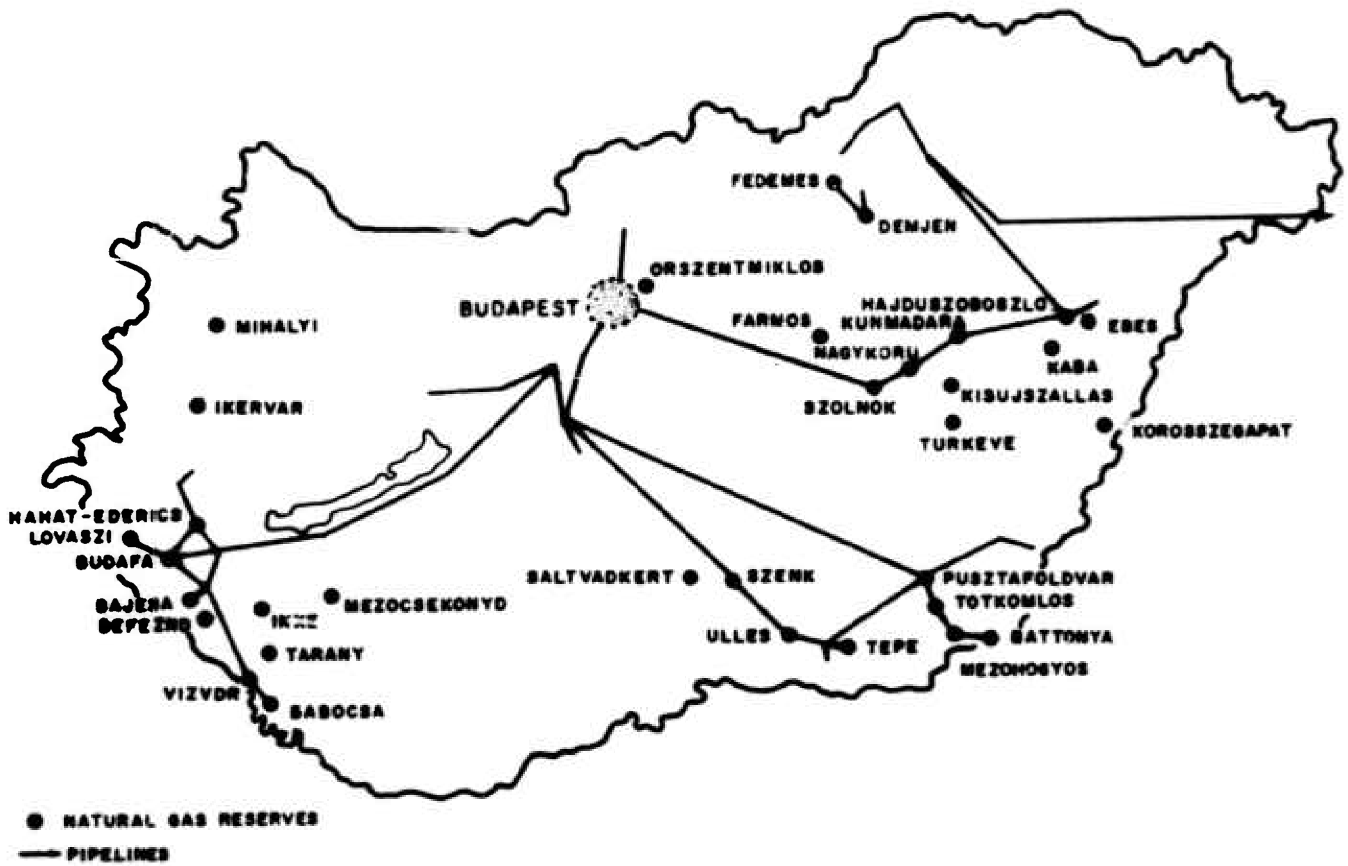


Figure D-7

THE GAS FIELDS OF HUNGARY

5. Geology of Poland's Gas Deposits

The basic structural feature of Poland relative to natural gas occurrence is the Carpathian foothill system of the southern part of the country. Natural gas (together with oil) has been produced from sandstone strata of Tertiary age, but more recently, production has been achieved from Upper Paleozoic dolomite formations. Important new gas fields have been discovered in the southern and western Carpathians, which have added to overall gas reserves. Table D-34 shows the increase of gas reserves over the past eight years.

Table D-34

TRENDS IN POLAND'S GAS RESERVE ESTIMATES
(Billion Cubic Meters)

	1965	1973
Proved	12	60*
Probable	8	82*
Total	20	142

* Estimate.

Sources: For 1965, E. N. Tiratsod, "Natural Gas," Plenum Press, New York, N.Y., 1907.

For 1973, International Petroleum Encyclopedia, 1973.

6. Geology of Romania's Gas Deposits

Natural gas in Romania occurs associated with oil, and for years its production was only as a byproduct to oil. The Romanian gas fields are in structures related to the foothill belt of the Carpathian Mountains, mainly in Upper Paleozoic and Mesozoic strata.

The most sizable reserves of natural gas in Romania, however, occur nonassociated with oil, in gas fields of the Transylvania basin, on the inner western side of the arc formed by the Carpathian mountain system.

The Romanian natural gas is basically dry gas that is largely methane. The gas is produced from relatively shallow depths--2,500 to 5,000 ft or 762 to 1524 meters.

C. Production, Consumption, and Transport in Eastern Europe

1. Overview

a. Production of Natural Gas in Eastern Europe

Natural gas production in Eastern Europe, outside the USSR, does not play an important role in the total energy production. In 1970, the production of natural gas by the Soviet satellites in Europe aggregated to less than 20 percent of the production in the USSR. Romania is currently the only natural gas producer which does not import or plan to import natural gas in the near future. It is also the biggest natural gas producer, outside the USSR, accounting for 25.6 bcm (2.6 billion standard cubic feet/day) in 1971. Statistical production data for Eastern Europe are presented in Table D-25 for the period 1960 through 1971.

It is expected that gas production in Eastern Germany and Poland will grow in the near future, if recent gas discoveries prove to be really as significant as reported. Indeed, production reported for 1972 from East Germany reached 5 billion cubic meters. Compared to the production of 1 bcm in 1970, this indicates some major discoveries. The East Germans expect production to climb to 15 bcm by 1975, indicating great confidence in the growth of estimated reserves which the Soviets had helped them find.

It seems that the recent aid program that the USSR extended to its European satellites in exploration may be bearing some fruit in the case of GDR and Poland. The drilling done in Bulgaria, however, was not as productive, and gas production has been declining from the peak of 0.5 bcm reached in 1969.

b. Patterns of Gas Production, Consumption, and Transport in Eastern Europe

Patterns of gas production, consumption, and trade in Eastern Europe were studied from available statistical information.* To achieve a better overview of the sources, conversion, and consumer uses of gas in each country, data from the several tables were compiled on a series of charts for production and consumption. A separate one will be prepared for each country, with the exception of Bulgaria, for which the data were insufficient. Domestic and foreign transport patterns are presented in maps and discussion for each country.

2. Bulgaria

a. Production and Consumption

Available statistics for gas production and consumption for Bulgaria are not sufficiently complete to permit preparation of a detailed representation of the patterns of gas use, as done for other CMEA countries in subsequent sections. On the basis of limited data

---

* Principally, the "Annual Bulletin of Gas Statistics for Europe" published by the United Nations Economic Commission for Europe, Vol. XVII, 1971 (published in 1972). These data were then verified against statistical yearbooks published by the several nations.

available from the United Nations,[6] it appears that gas is a rather small part of the Bulgarian energy balance.

Bulgaria Gas Production in 1971
(Teracalories)

Natural gas	2,750
Coke-oven gas	862
Blast furnace gas	2,827
LPG	84

The largest gas production is from blast furnace operations. It seems likely that this gas will be used primarily in the iron and steel industry, as is the case in other CMEA countries. The next largest gas production is from natural gas. The use of this gas is probably distributed more widely in the Bulgarian economy, assuming that such uses will roughly parallel those of the other CMEA countries (see later sections). If this apparent pattern is correct, most of the natural gas will probably go for various industrial and domestic uses. Coke-oven gas is the third principal source of gas in Bulgaria. If similar to other CMEA countries, this gas is probably used mainly by the iron and steel industry. Small amounts of LPG are used, probably by both industry and households.

b. Gas Transport

Figure D-8 is a map showing fuel transport (oil and gas pipelines, rail lines, and water routes) in Bulgaria. Numbers after cities named below refer to numbers on the map.

Small quantities of natural gas have been produced at Chiren (29), which is connected by 20 km pipelines to the local residential towns of Beli Szvor (30) and Vratsa (31), as well as at Staro

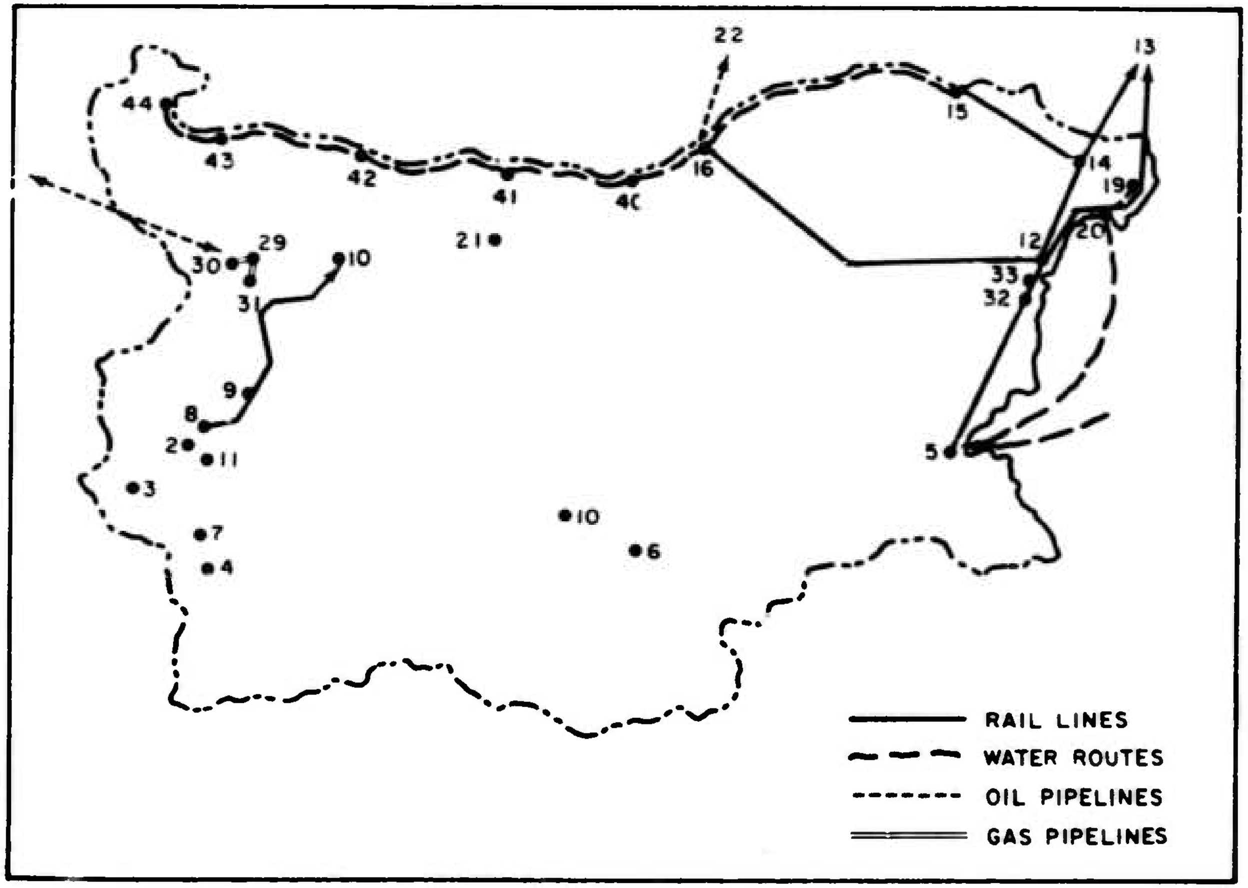


Figure D-8

FUEL TRANSPORT IN BULGARIA

Orjachovo (32), which is connected by a 30 km pipeline to Beloslov (33) and Varna (12). These wells yielded 474 million cubic meters of natural gas in 1970. The gas had little industrial use except at Varna, where it was used as a thermal fuel in the Reka Devnja cement works.

A gas pipeline (the Bratstvo or "Brotherhood" pipeline) is under construction between Izmail in the USSR and the Bulgarian cities of Varna, Burgas, Plovdiv, and Sofia, the capital of Bulgaria (see Figure D-9). By 1975 Bulgaria expects to be importing 3 bcm annually through this pipeline.

3. Czechoslovakia

a. Production and Consumption

Figure D-10 shows gas production and consumption in Czechoslovakia in 1971.

- Natural gas production from domestic sources is not great, and must be supplemented by imports that are half again as great as the amount produced locally. Most natural gas is used by "Other industries and construction," with cracking, reforming, and mixing representing the second largest use. Important amounts of natural gas are also used for non-energy products, fabricated metal products, and generation of electric energy, and in the iron and steel industry.

- Gas works represent an important source of supply for households, trade, and commercial services, and other industries and construction. Gas from this source is largely produced domestically, with very small amounts of imports.

- Coke-oven gas is entirely domestically produced, with roughly one-third going to electric energy and other energy-producing industries. The remaining coke-oven gas is used exclusively by the iron and steel industry and (in lesser amounts) by the chemical industry.

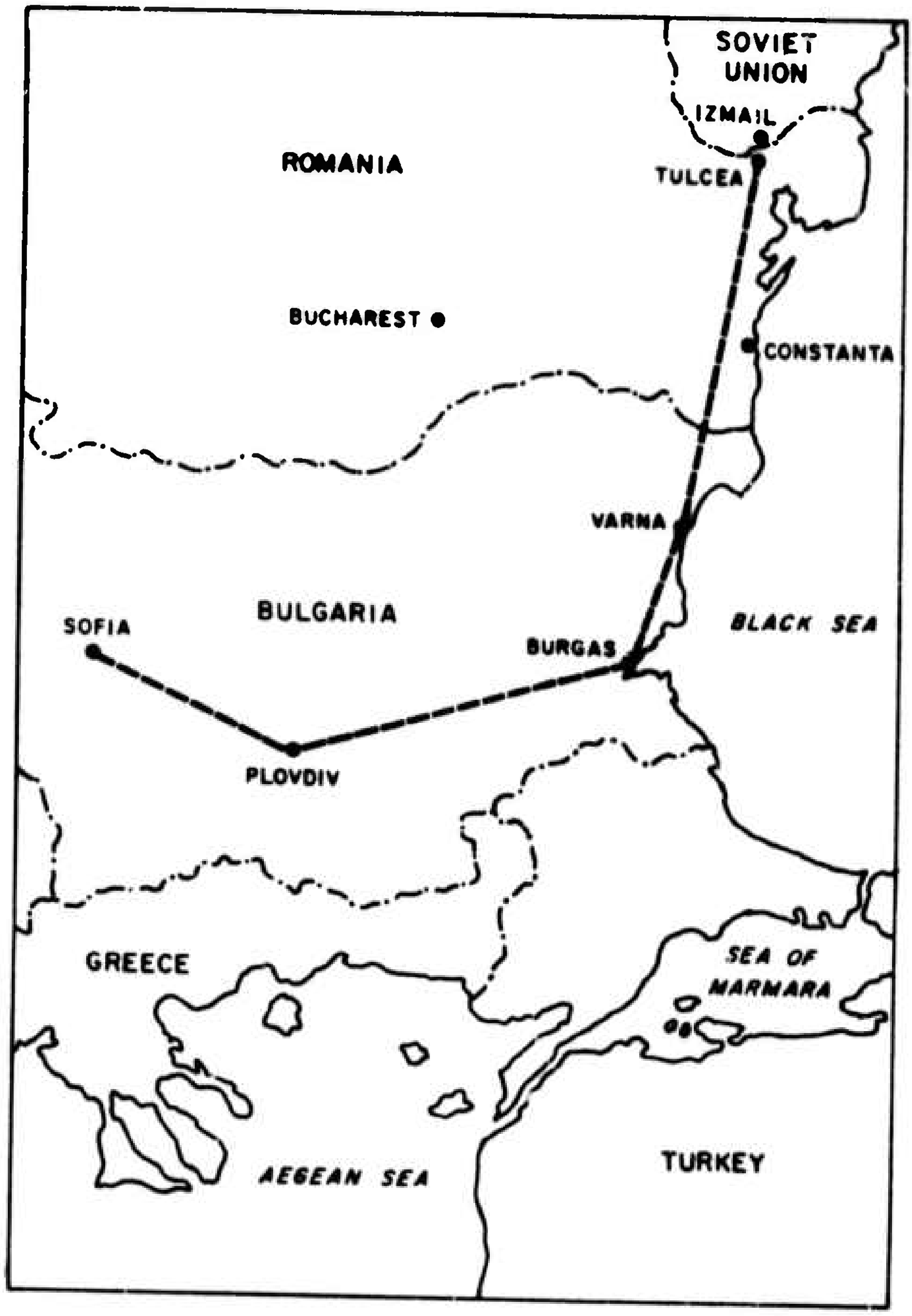
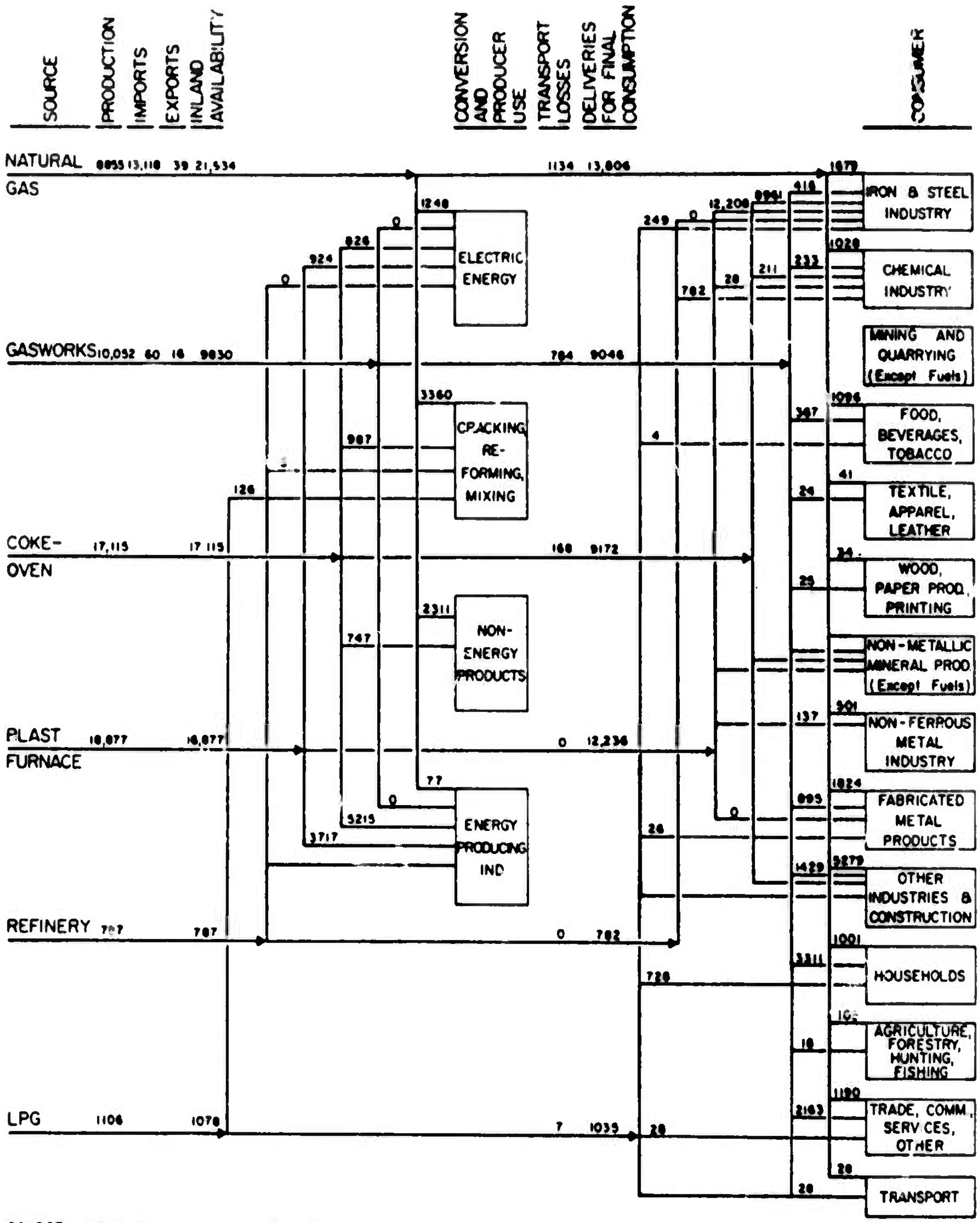


Figure D-9

PLANNED GAS PIPELINE FROM THE USSR TO BULGARIA



SOURCE United Nations, Annual Bulletin of Gas Statistics For Europe, 1971

Figure D-10

GAS - PRODUCTION AND CONSUMPTION IN CZECHOSLOVAKIA, 1971

(Teracalories)

- Blast furnace gas is also only a domestic product. About one-quarter is used in electric energy and other energy-producing industries. Almost all the remaining two-thirds is used by the iron and steel industry, with very small amounts being used by the chemical industry.

- Refinery gases are produced only in small amounts. A very small amount is used in cracking, reforming, and mixing, with nearly all the production going to the chemical industry.

- LPG is also a small contributor to the overall Czech gas production/consumption pattern. Roughly 10 percent of total production is used in cracking, reforming, and mixing, with the remainder used largely in households, and in the iron and steel industry.

b. Gas Transport

Figure D-11 shows fuel transport in Czechoslovakia. Numbers given after cities below refer to numbers on the map.

Gas is produced in the gas-oil field area of Lower Morava (near Breclav (13)), which yielded 1.2 bcm of natural and oil-associated gas in 1970. A broad network of gas pipelines stretch from Breclav to Bratiskeva (14), 100 km, and to the residential areas between Bratislava and Martin (24), 150 km by pipeline from Bratislava. Another pipeline also stretches from Breclav to the mechanical engineering, transport machinery and textile manufacturing, and food-processing city of Brno (4), 70 km by pipeline from Brechav, and to the steel-producing centers of Kolin (23), 200 km and Prague (30), 80 km from Kolin.

Natural gas is also transported from the Western Ukrainian fields near Doline (31), 230 km to Kosice (5), and on to Bratislava, 300 km from Kosice.

Finally, gas manufactured from brown coal in the Sokolov (7) and Most (8)-Teplice (9) basins is transmitted by pipeline to

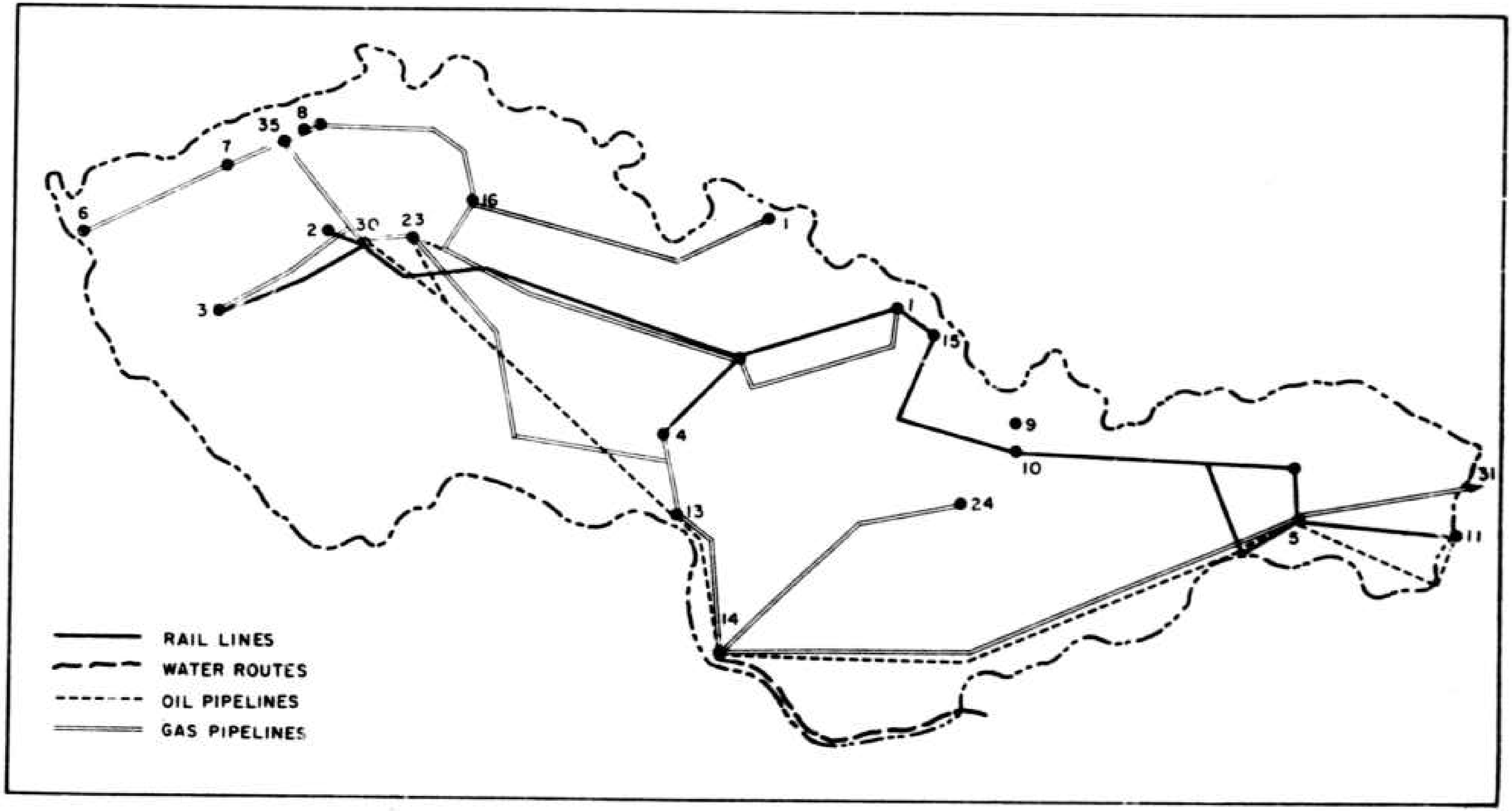


Figure D-11
FUEL TRANSPORT IN CZECHOSLOVAKIA

metallurgical plants and to residential areas in the vicinity of the basins as well as to Prague, 120 km from Zalusi (35) in the Most-Teplice basin, and Plsen (3), a steel-making center. A 480 km manufactured-gas pipeline also connects Teplice with the metallurgical center of Ostrava (1).

4. German Democratic Republic

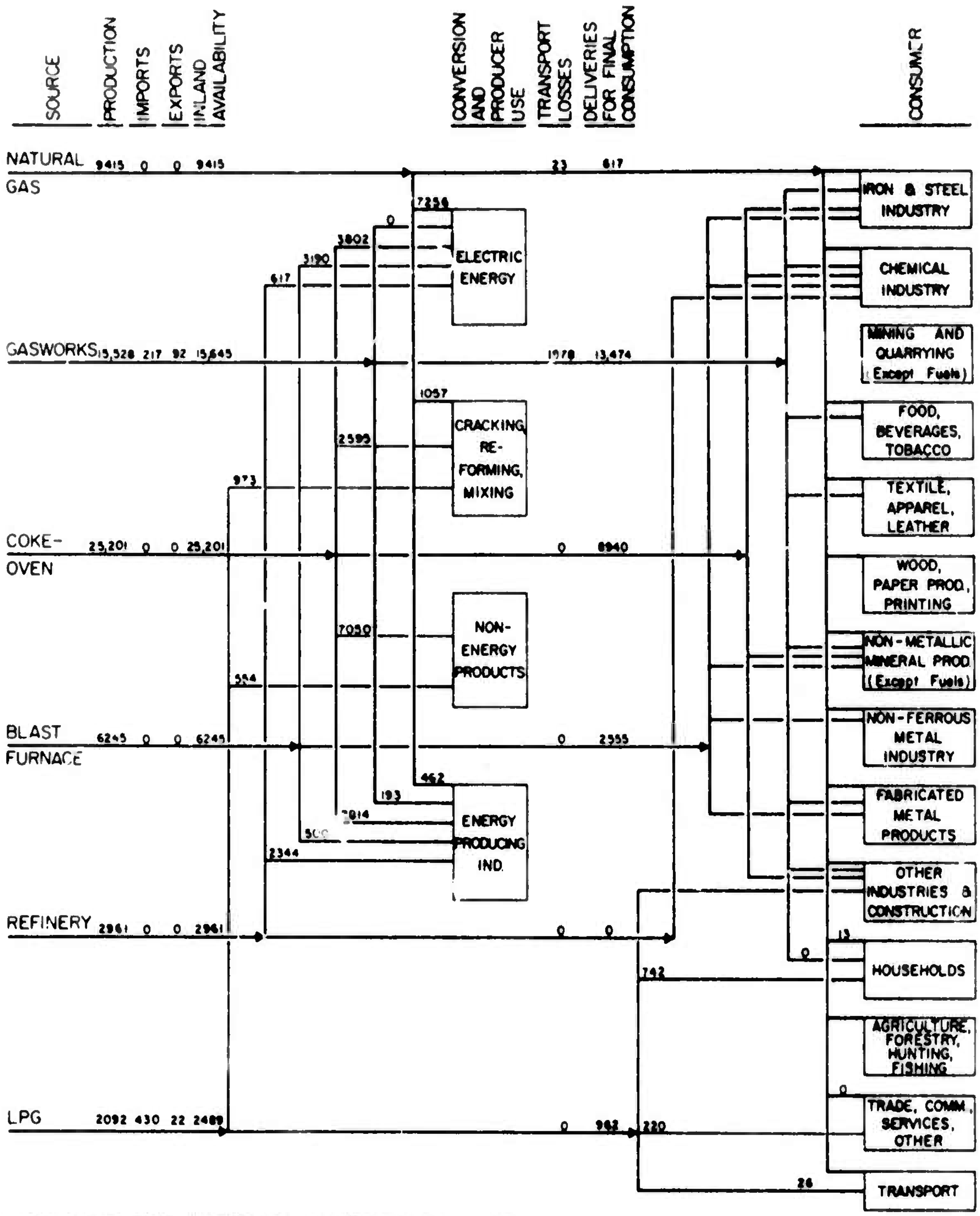
a. Production and Consumption

Figure D-12 shows gas production and producer use in the German Democratic Republic as of 1971. Consumer use is not shown, as this was not given in the references consulted.

- Natural gas is produced domestically, and no imports or exports were reported during 1971. This gas is used mainly for generating electric energy, with lesser use in cracking, reforming, and mixing, and in other energy producing industries. Less than 10 percent of natural gas was used for other consumer purposes (but the breakdown is not known at present).

- Gasworks produced the second largest total of gas used in the GDR in 1971. Only a small amount of gas from this source was imported. The gas was used mainly for consumer purposes, although these remain to be detailed. If the situation is similar to that of Czechoslovakia, the GDR gasworks gas will probably be used largely in households, trade and commercial services, and other industries and construction.

- Coke-oven gas was the largest single source of gas in the GDR in 1971. Two-thirds of total production was used primarily in generation of electric energy; cracking, reforming, and mixing; non-energy products (the largest single use); and other energy producing industries. The remaining third went for various consumer purposes, which remain to be detailed.



SOURCE: United Nations, Annual Bulletin of Gas Statistics For Europe, 1971

Figure D-12

GAS-PRODUCTION AND CONSUMPTION IN GERMAN DEMOCRATIC REPUBLIC, 1971

(Teracalories)

- Blast furnace gas was the fourth largest source in 1971. More than half the production went to generation of electric energy, with the remainder going for consumer uses (probably the iron and steel industry).

- Refinery gas was a relatively small amount of total production in 1971. However, it represented an important supply to energy producing industries and was also used for generation of electric energy. No refinery gas was used by other consumers.

- LPG was produced in smallest amounts domestically, and an amount equivalent to one-fifth of this production was imported. LPG was used in cracking, reforming, and mixing and in non-energy products. Slightly more than two-thirds of LPG production went to consumer uses, assumed to be in households, and iron and steel.

b. Gas Transport

Figure D-13 shows fuel transport in the German Democratic Republic.

Pipelines transport the manufactured gas of Lauchhammer (13) to Dresden (8), 80 km, and Littau (14), 150 km, where it is used in electric generating plants as well as in chemical plants. Some natural gas, together with synthetic gas manufactured from brown coal transported by rail from the Leipzig-Halle coal basin, is produced at Langensalza (15) in the Thuringian forest region. From here, part is used in the Langensalza electric power plant and part is transported by pipe to Berlin (9), 300 km; to Magdeburg (17), 300 km, a metallurgical, chemical, and thermal-electric power center; and to Leipzig (3), 150 km, also a chemical, metallurgical, and thermal electric power center. Leipzig also receives manufactured gas from Lauchhammer (13) through the 100 km Lauchhammer-Leipzig line.

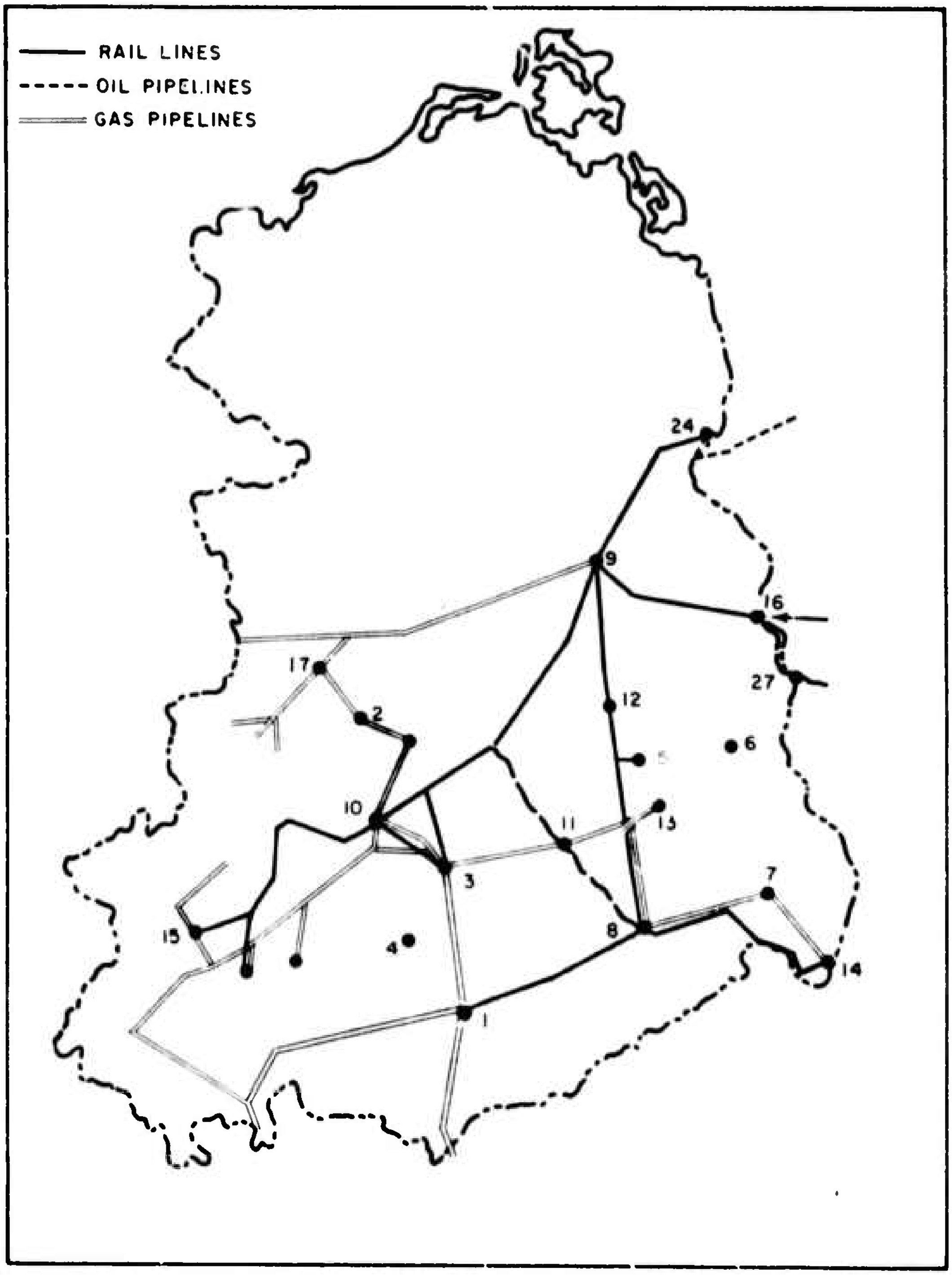


Figure D-13
FUEL TRANSPORT IN THE GERMAN DEMOCRATIC REPUBLIC

5. Hungary

a. Production and Consumption

Figure D-14 shows production, conversion, and consumption of gas in Hungary in 1971.

- Natural gas is the largest source of gas in Hungary, roughly ten times that from other sources. The relatively large domestic production is further supplemented with imports (representing about 5 percent of domestic production). Natural gas is used mainly for generation of electric energy, production of non-energy products, and for cracking, reforming, and mixing. The largest other consumer uses are in the iron and steel industry, other industries and construction, and households.

- Gasworks produce gas that is used only for domestic needs. About one-quarter is used in energy producing industries, with the bulk going to households, trade and commercial services, and other industries and construction.

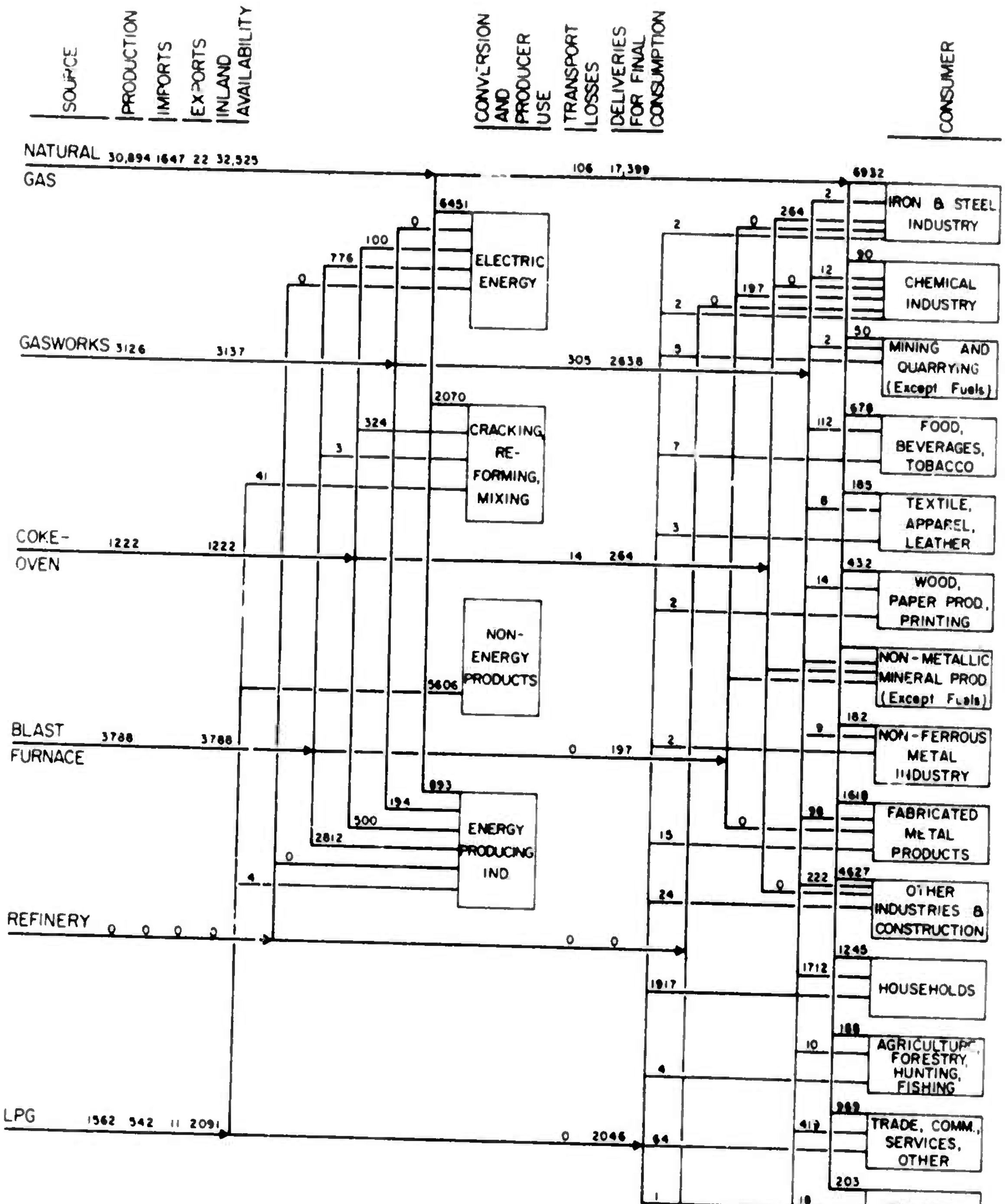
- Coke-oven gas is the smallest increment to Hungary's gas supply. Roughly half is used in generation of electric energy and other energy producing industries; of the remaining half, one-quarter goes for cracking, reforming, and mixing. The final quarter is used for the iron and steel industry.

- No refinery gas was produced in Hungary in 1971.

- LPG domestic production was supplemented by imports equivalent to about one-third the total. Minor amounts were used in cracking, reforming, and mixing. Households represented the principal consumer of LPG, with scattered smaller amounts going for other purposes.

b. Gas Transport

Figure D-15 shows fuel transport in Hungary.



SOURCE United Nations, Annual Bulletin of Gas Statistics For Europe, 1971

Figure D-14

GAS – PRODUCTION AND CONSUMPTION IN HUNGARY, 1971

(Teracalories)

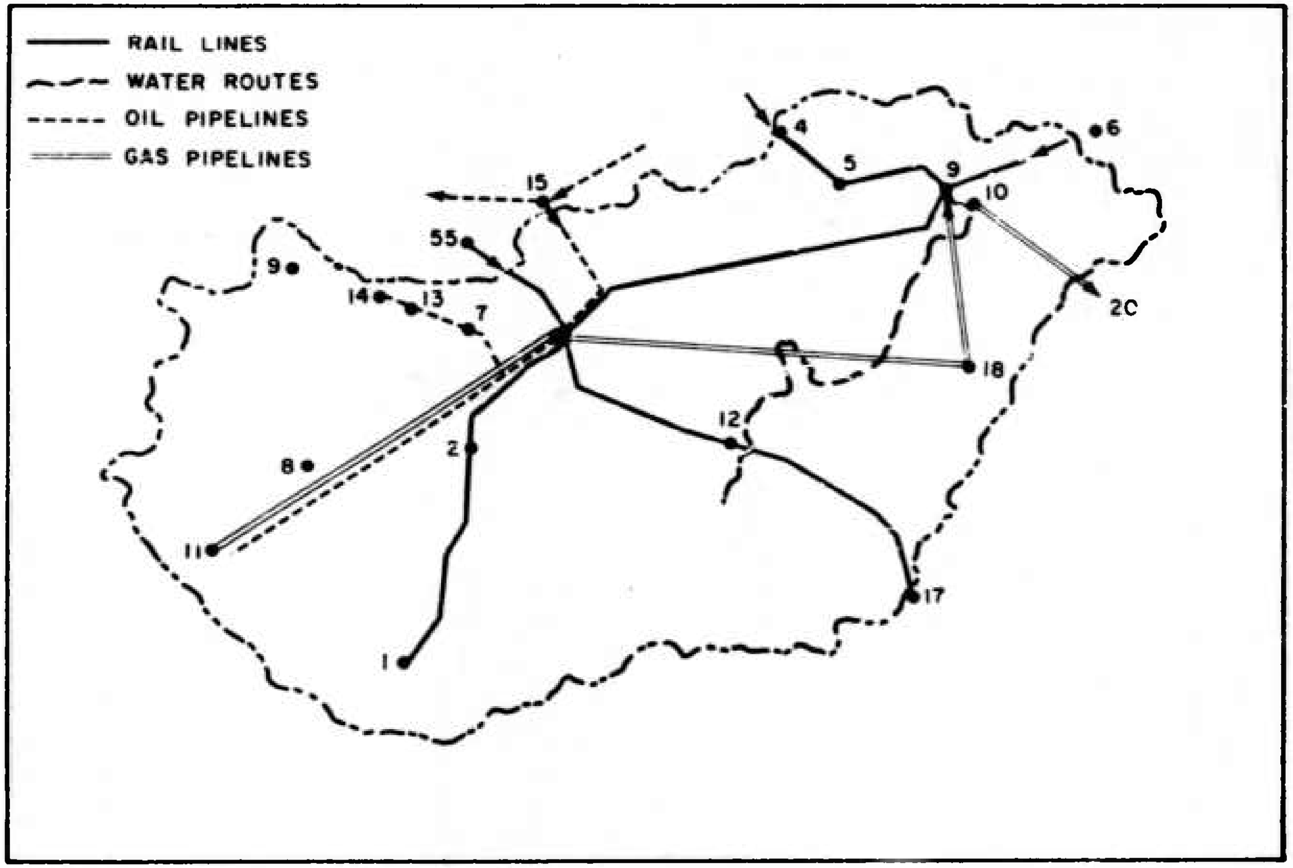


Figure D-15

FUEL TRANSPORT IN HUNGARY

Natural gas is produced in the Debrecen (18) fields east of the Tisza river and in the Zala oilfields near Ujudvar (11). Together, these fields yielded 3.5 bcm of natural gas in 1970. Budapest (3) receives gas through a 200 km pipeline from the Zala fields and through another pipeline from Debrecen, 190 km. Still another pipeline from Debrecen carries gas 90 km to the iron-smelting, mechanical-engineering, textile, woodworking, and cement industries of Miskolc (9). Miskolc also receives gas from Romania via the 260 km Cluj (20)-Miskolc pipeline. In 1970 Hungary imported 200 million cubic meters of gas through the pipeline.

6. Poland

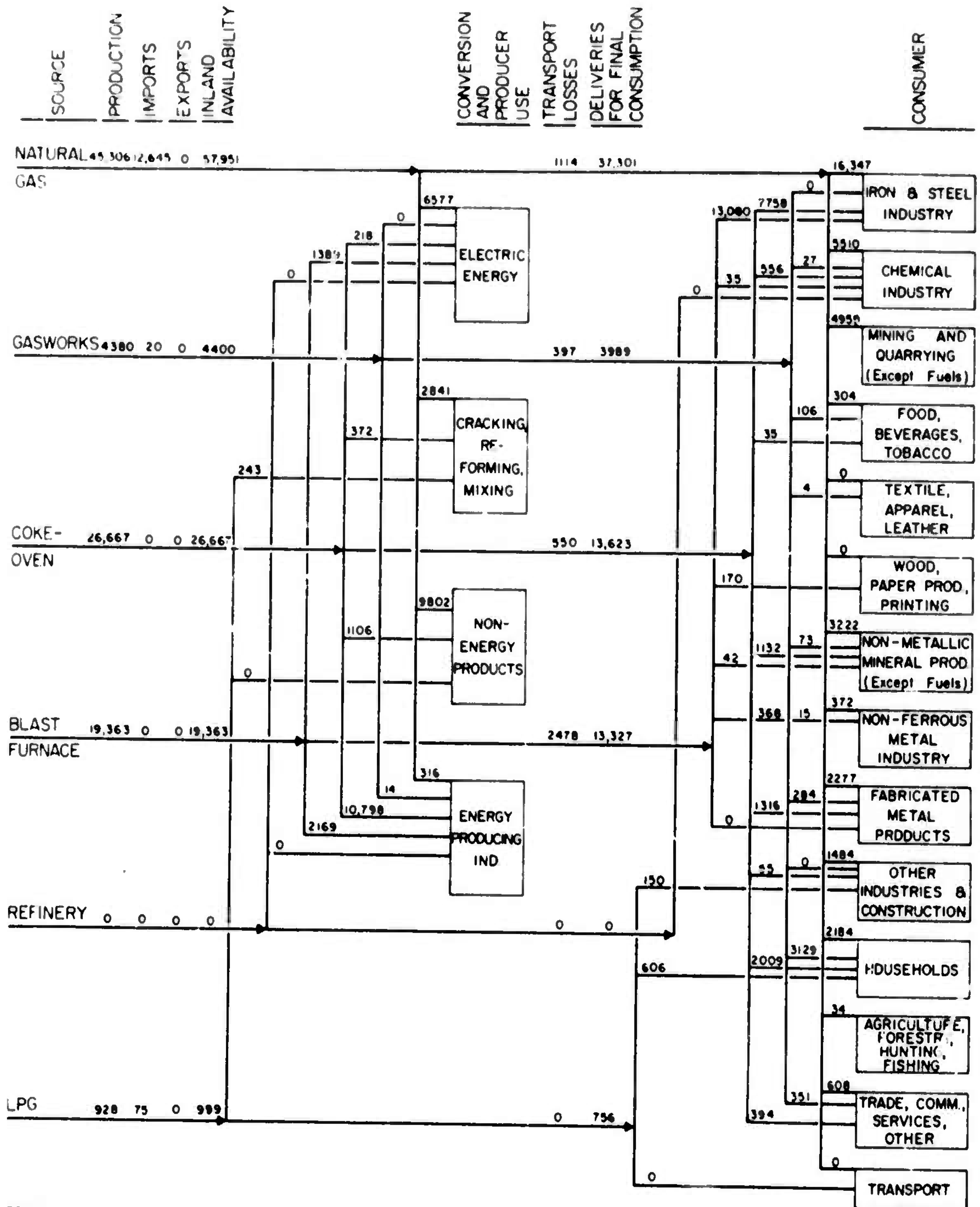
a. Production and Consumption

Figure D-16 shows gas production, conversion, and consumption in Poland in 1971.

- Natural gas was the largest domestic source of gas. In addition, these domestic supplies were supplemented by imports equivalent to nearly one-quarter of domestic production. Total conversion and producer use amounted to about one-third of total production, with most gas in this category going to non-energy products, electric energy, and cracking, reforming, and mixing. The largest single consumer of natural gas in Poland in 1971 was the iron and steel industry, with nearly half the total gas used for consumer purposes. The chemical industry, mining and quarrying, and nonmetallic mineral products were the next largest users of natural gas.

- Gasworks were the second smallest gas producer in Poland. Households were the principal user of gas from this source.

- Coke-oven gas was the second largest gas source in Poland. Nearly half of this gas was used in energy producing industries. The remainder was used primarily by the iron and steel industry, with other important consumers being households, fabricated metal products, and nonmetallic mineral products.



SOURCE United Nations, Annual Bulletin of Gas Statistics For Europe, 1971

Figure D-16

GAS-PRODUCTION AND CONSUMPTION IN POLAND, 1971

(Teracalories)

- Blast furnace gas was the third largest Polish gas source. Roughly one-tenth was used in generation of electricity. Almost all of the remainder was used in the iron and steel industry.

- No refinery gas was produced in Poland in 1971.

- LPG was the smallest gas source in Poland in 1971, and was supplemented by imports equivalent to roughly 10 percent of the total domestic production. About one-quarter was used in cracking, reforming, and mixing. Most LPG was consumed in households.

b. Gas Transport

Figure D-17 shows fuel transport in Poland.

Poland produced 5.0 bcm (177 bcf) of natural and oil-associated gas in 1970 in the oil and gas fields of Southeastern Poland, particularly in Tubacsaw (21). The main gas lines run from the gas fields of Tubacsow and other cities in the vicinity to Warsaw (6), where it is used primarily for residential purposes; and to Krakow (3), the historical and main tourist city, where gas is also used primarily for residential needs; and further west to Krakow's iron and steel producing suburb of Nowa Huta (11) and the coal mining and metallurgical complex of Upper Silesia, centered in Katowice (1).

The length of the Tubacsow-Warsaw pipeline is 325 km, and the lengths of the Tubacsow-Krakow and Tubacsow-Katowice lines are 250 and 375 km, respectively. In Nowa Huta and Katowice, natural gas is used in industrial boilers.

Synthetic gas produced from Silesian coal in Wroclaw's (2) chemical plants are sent along a 200 km pipeline to Zgozhelec (22), and along a 125 km line to Karpacs (23) for export to the GDR and Czechoslovakia. In 1970 Poland exported 7.8 million cubic meters of synthetic gas through these pipelines. Another synthetic gas line connects the coal

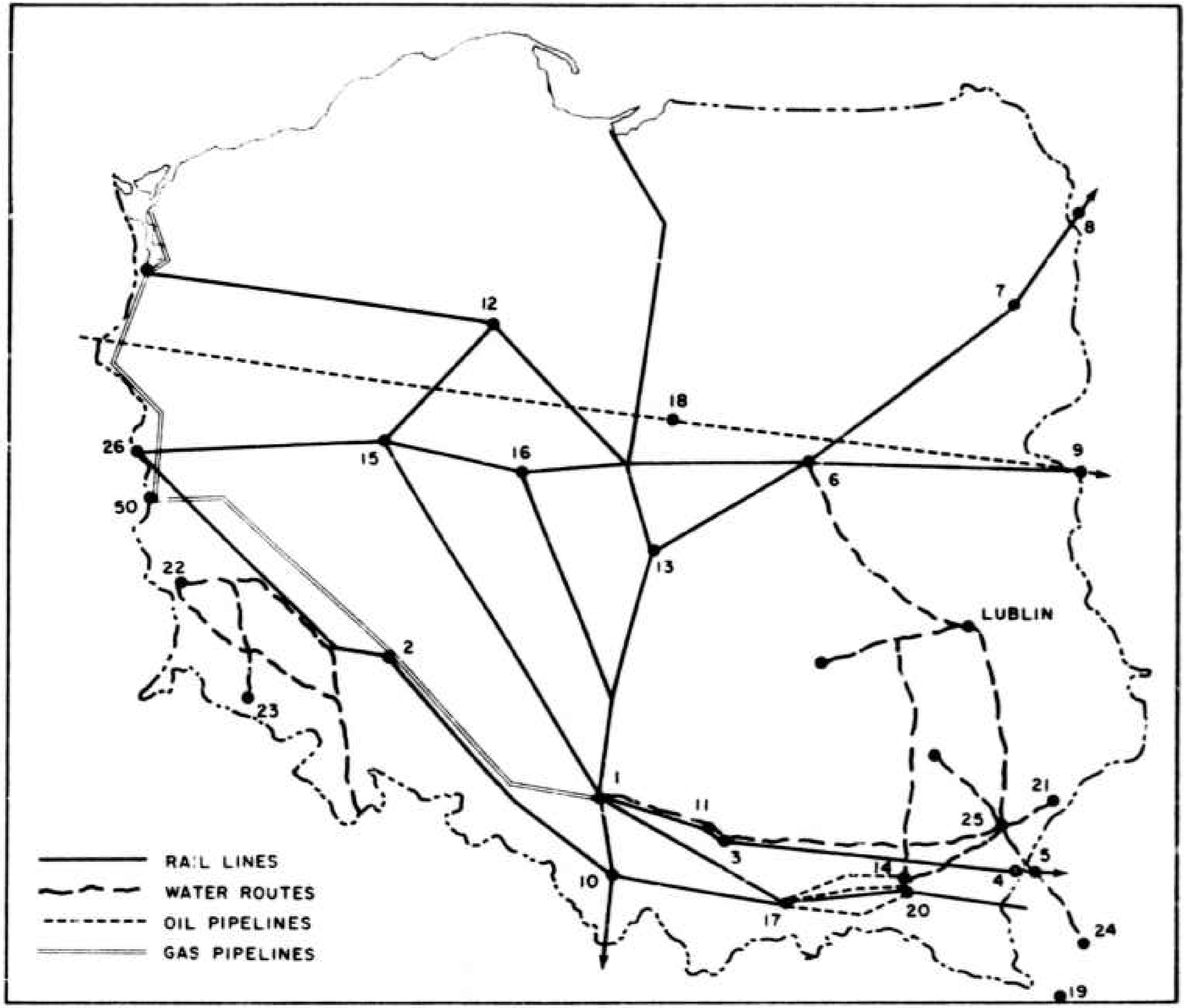


Figure D-17

FUEL TRANSPORT IN POLAND

gasification plants of Katowice in the Upper Silesian basin with Lodz (13) and Warsaw, where it is used primarily for industrial boilers.

In 1970 Poland imported 1.0 million cubic meters (35 million cubic feet) of gas from the USSR, which was pumped from the gas fields of Dashava (24) through 120 km of the "Bratstvo" (Brotherhood) gas pipeline to Jaroslaw (25), where the gas mingles with Polish gas from Tubacsow (21).

7. Romania

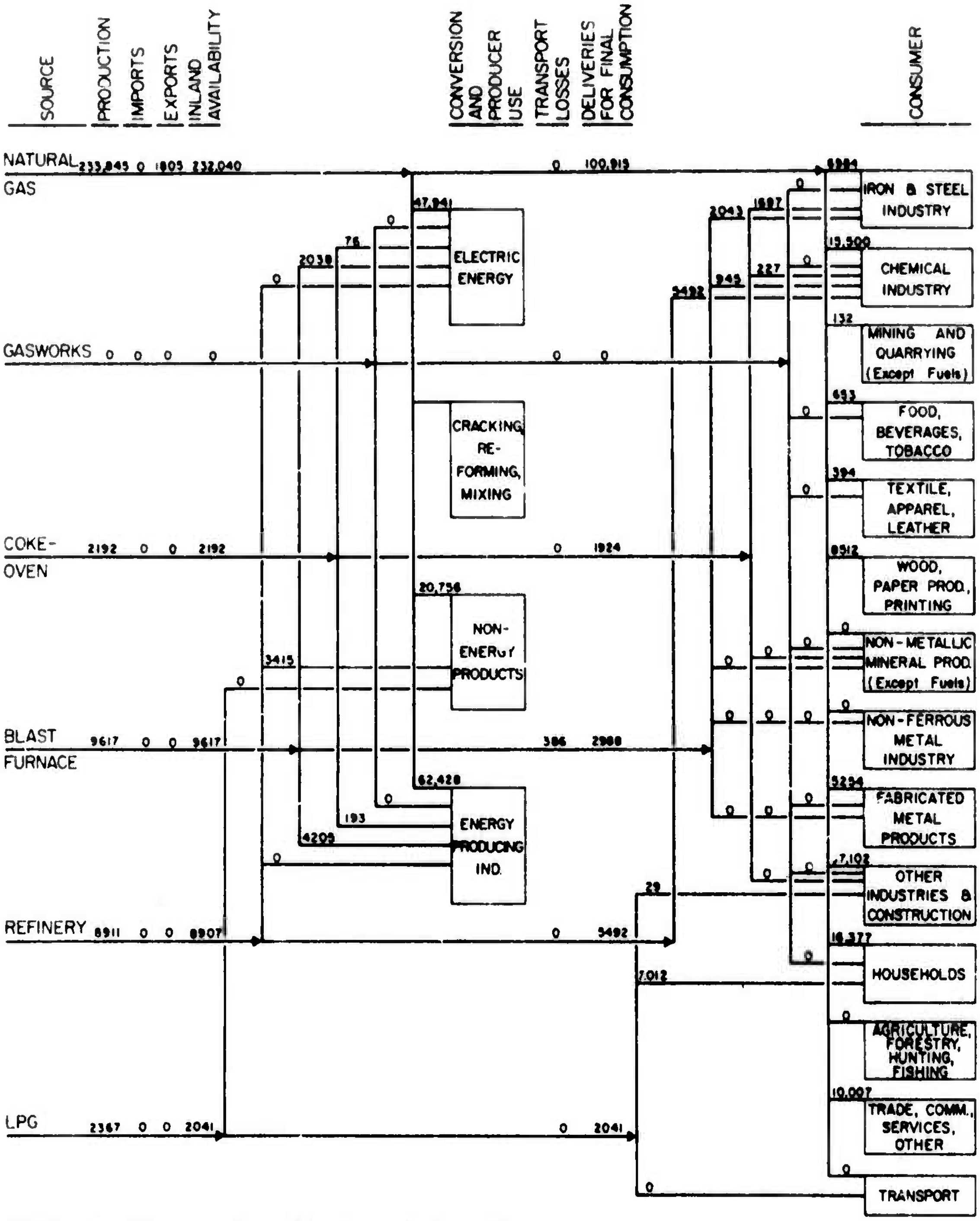
a. Production and Consumption

Figure D-18 shows production, conversion, and consumption of gas in Romania in 1970 (1971 data were not available).

- Natural gas is the principal source of gas in Romania, representing more than 90 percent of all gas used. Romania also exports natural gas in some quantity, which further sets her apart from other Eastern European countries. Nearly half the natural gas is converted to some other energy form prior to use, with electric energy and other energy producing industries receiving the bulk of natural gas production. Non-energy products also represent an important use for natural gas, about 9 percent of the total. The largest consumer uses are for other industries and construction, households, the chemical industry, trade and commercial services, and wood, paper products, and printing.

- No gasworks gas was produced in Romania in 1970.

- Coke-oven gas was the smallest source of supply in 1971. About 10 percent was used for energy purposes. The major consumer of coke-oven gas was the iron and steel industry, with lesser amounts used by the chemical industry.



SOURCE United Nations, Annual Bulletin of Gas Statistics For Europe, 1971

Figure D-18
GAS-PRODUCTION AND CONSUMPTION IN ROMANIA, 1970
(Teracalories)

- Blast furnace gas was the second largest gas source. Roughly two-thirds was used to generate electricity of in other energy production. The remainder was consumed by the iron and steel industry and the chemical industry.

- Refinery gas was the third largest gas source in Romania. Slightly more than one-third of the total was used in non-energy products, with the remainder being consumed by the chemical industry.

- LPG was the second smallest gas source. It was used almost exclusively in households.

b. Gas Transport

Figure D-19 shows fuel transport in Romania.

Most of the 24 bcm of natural gas produced in Romania in 1970 was from the Transylvanian region in the vicinity of Targul-Mures (18).

A 450 km pipeline runs from the Transylvanian fields to a number of small residential towns along the Hungarian border where the gas is used primarily in thermal electric power plants, in public-heating utilities, and for residential needs. Gas for the same purposes is pumped through a 250 km pipeline to Resita (2) and through a 200 km pipeline to Bacau (12) and Iasi (22). The first of the above three pipelines also continues into Hungary to Miskolc (19), 400 km from Targul-Mures, which is connected by pipeline to Budapest (20). About 200 million cubic meters of gas were exported to Hungary through this pipeline in 1970.

By far the largest amount of natural gas is used within the Bucharest-Brasov-Ploesti-Cluj industrial region, of which the Transylvanian fields are a part; and a complex web of pipelines connects all of the major industrial and populated towns of this region. Gas is used here as fuel for electric power plants, as a raw material in the chemical

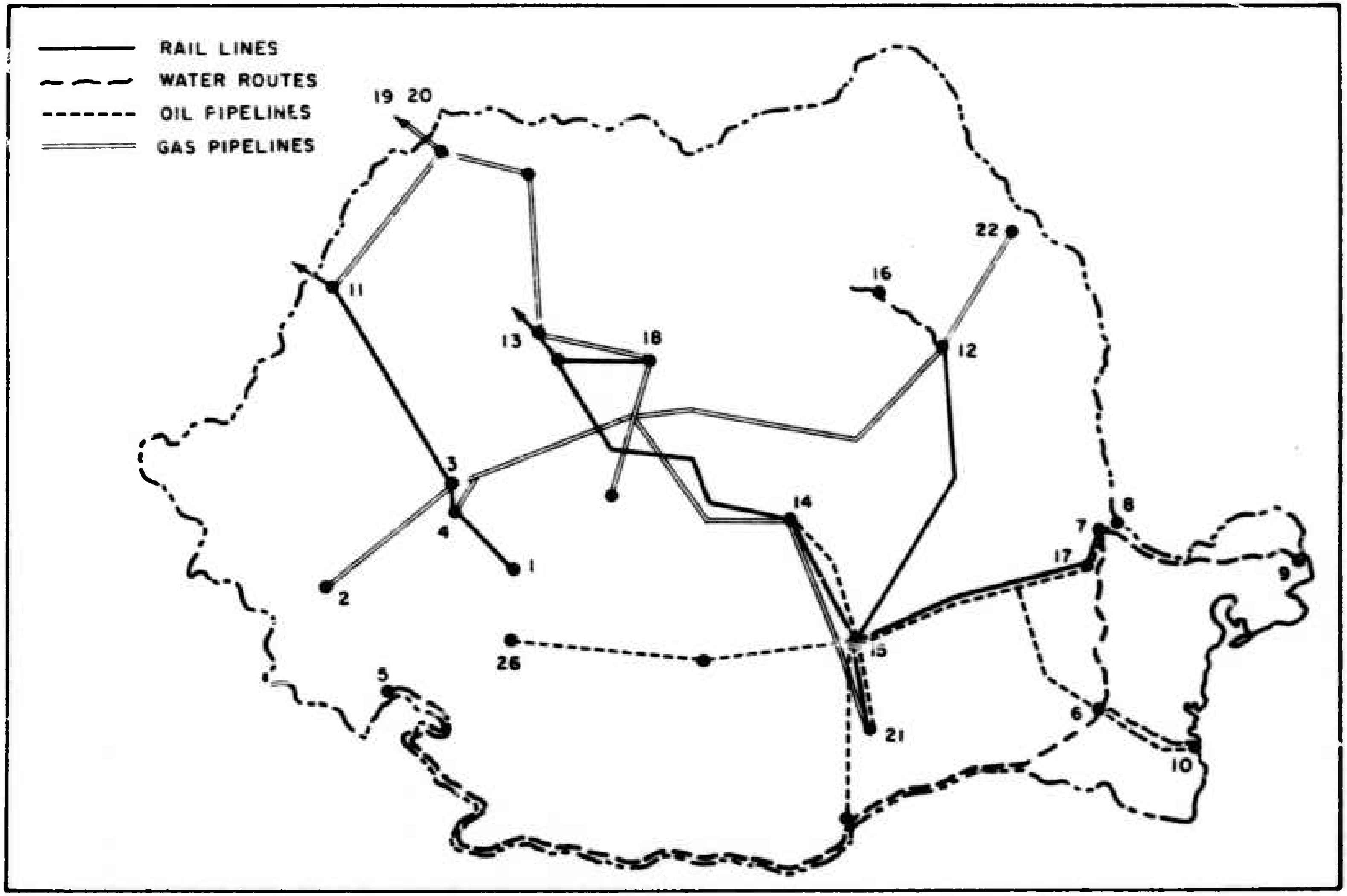


Figure D-19

FUEL TRANSPORT !N ROMANIA

industries of Bucharest, the capital of Romania (21), Ploesti (15) Brasov (14), and Cluj (13), and as a heating fuel in the cement plants of Bucharest and Brasov.

REFERENCES

1. Vestnik Statistiki, No. 8, p. 85, 1972.

2. A. K. Kortunov, Gazovoya promyshlenost SSSR (Gas Industry of the USSR), p. 205, Moscow, 1967.

3. Gazovoe delo, No. 1, 1971.

4. Neftianik, No. 1, 1973.

5. Gy Kertai, "Geology of the Pannonicum," XXIII International Geological Congress, Guide to Excursion 42E, 1968.

6. United Nations, Annual Bulletin of Gas Statistics for Europe, 1971, published 1972.

MISSION

of

Rome Air Development Center

RADC is the principal AFSC organization charged with planning and executing the USAF exploratory and advanced development programs for electromagnetic intelligence techniques, reliability and compatibility techniques for electronic systems, electromagnetic transmission and reception, ground based surveillance, ground communications, information displays and information processing. This Center provides technical or management assistance in support of studies, analyses, development planning activities, acquisition, test, evaluation, modification, and operation of aerospace systems and related equipment.

Source AFSCR 23-50, 11 May 70