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CASE STUDY ON USE OF NATURAL GAS FOR POWER GENERATION IN PAKISTAN

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ABSTRACT

The natural gas industry in Pakistan has completed 15 years of commendable service to all types of consumers in general but to the thermal power generation in particular. In 1956, the installed thermal power generating capacity owned by the public utilities/other supply undertakings totalled some 65 megawatts and claimed 2,937 million cubic feet of utilized production of natural gas. In 1970, this capacity increased to some 1700 megawatts and used 53,870 million cubic feet of gas.

During the past 15 years, the utilized production of gas in Pakistan for thermal power generation saved the country the equivalent of Rs. 332 million (70 million US Dollars) by replacing imported furnace oil, Rs. 58.5 million (12.3 million US Dollars) of which were in 1970 alone.

Pakistan has the highest ratio of reserves to annual production when compared to the other major gas producing countries of the world. The proven rich and large reserves of natural gas comprise one of the country's major tools in the task of attaining economic stability and independence and will continue to serve the power industry as efficiently and effectively as in the past. Increased utilization of gas as fuel for thermal power generation could also have the effects of intensifying further exploration in order to further increase the present ample reserve estimates.

INTRODUCTION

This case study gives a brief account of development in gas production and its transportation in Pakistan since supplies of natural gas first became available in October 1955. It then goes on to explore the increasingly important role that natural gas has played and will continue to play to meet the fuel requirements of the power industry in both wings of the country.

HISTORY

Production of Gas

In 1947, Pakistan found itself an independent nation geographically divided into two wings and having very inadequate indigenous fuel resources with which to sustain its growing industry. Supplies of coal and oil from indigenous sources were meagre and the burden of importing fuel was causing a large drain on the precious foreign exchange sources of the country. In view of this, the necessity of discovering and proving further indigenous fuel resources became quite apparent. The Government of Pakistan, being aware of the value to its economy that the indigenous energy sources could render in adding a much needed industrial comp[illegible]to our predominantly agricultural economy, offered attractive terms to the foreign entrepreneurs interested in the exploration and drilling of oil/gas. Government's efforts were crowned with success when Pakistan Petroleum Limited first discovered gas at Sui in the north-east Baluchistan (West Pakistan) in 1952. Further drilling of this area proved an accumulation of about 6.3 million million cu. ft. of recoverable gas and, thus, made Sui the 7th biggest gas field in the world. A recent study has put the recoverable gas reserves of Sui at 8.62 million million cu. ft. Later in early 1957, Pak Stanvac (now Esso) discovered Mari, another big gas field, located about 40 miles east of Sui. The recoverable reserves of gas from this field are estimated at about 3.942 million million cu. ft.

In all, 18 gas fields have so far been discovered in both wings of the country with proven recoverable reserves, in terms of Sui quality raw gas of about 23 million million cu ft. Appendix 1 gives both the location and recoverable reserve estimates from these fields. Appendix 2 gives the composition of gas for each of these fields and their recoverable reserve equivalents in terms of Sui quality raw gas. Apart from these dry natural gas fields, associated gas is also available from Dhulian, Meyal, Tut oil fields, discovered in the northern part of West Pakistan.

Transportation of Gas

In West Pakistan, with the commissioning of 347 miles long, 16'' diameter Sui-Karachi pipeline, the commercially utilized production of Sui field started in October 1955. Natural gas by virtue of its convenience, cheapness, ready availability and multiple advantages over alternative fuels, *i.e.*, coal and oil, soon established its ascendency. Within a span of two years, all large and small industries in the Sukkur, Hyderabad and Karachi areas were using gas. Being assured of the continuous and dependable supply of this valuable indigenous fuel, industrial activity was stimulated.

In 1958, another 16" pipeline, 217 miles long, this time northwards, was constructed between Sui and Multan. This line was later extended to supply gas to the Lyallpur, Lahore, Khewra, Gharibwal, Wah, Islamabad and Rawalpindi areas. This line is being further extended to supply gas to the Peshawar, Gujranwala and Daudkhel areas. Also due to the rapid growth of gas demand, both in the old and the new areas, the high pressure transmission line between Sui and Multan has already been reinforced with 18" diameter pipeline partial loops. In addition, the high pressure pipeline system north of Sui has 23,100 horsepower installed capacity at its 5 different compressor stations whereas the system south of Sui has 9,000 horsepower divided equally among its two compressor stations. On the northern system, some additional 10,000 horsepower and about 106 miles of 18" and 16" partial loops are being added and are scheduled for completion by the end of 1972.

Until 1960, the East Wing did not appear to contain any appreciable quantities of natural gas and all the discovered reserves were dedicated to Fenchuganj Fertilizer Factory in the Sylhet district and the Assam-Bengal Cement Works near Chhatak. An 8" diameter pipeline, 27 miles long, was constructed by Pakistan Industrial Development Corporation to link Sylhet with Fenchuganj and was commissioned in January 1960. A 12 miles long, 4" diameter pipeline was constructed by Pakistan Petroleum Limited and commissioned in August 1960 in order to supply gas from their Chhatak field to Assam-Bengal Cement Works. Discoveries of high quality natural gas potentials at Rashidpur, Kailas Tila, Habiganj, Bakhrabad, added substantially to the already proven reserves and opened fresh avenues for the development of natural gas industry in this Wing. To supply gas to Dacca, a 14" diameter pipeline, 50 miles long, from Pakshell's Titas field, was constructed and commissioned by Titas Gas Transmission and Distribution Company Limited in March 1968. The construction of high pressure pipeline from Pakshell's Bakhrabad gas field to Chittagong has been agreed in principle by the Government of Pakistan and it is hoped that in the not too distant future the fuel and raw material requirements of the Chittagong and Khulna industrial centres will also be met by this indigenous source.

UTILIZATION OF GAS

Growth of Gas Consumption

Since October 1955, that is, the time of the first commercial utilization of gas in Pakistan, the sales of natural gas have grown steadily but surely. During 1956, the first full year of natural gas supplies in Pakistan, the total sales amounted to 6,866 million cubic feet and the production of gas remained confined only to Sui field in West Pakistan. In 1970, that is, 15 years later, the

sales of natural gas increased to 121,892 million cubic feet and 7 different fields were responsible for these sales. Appendix 3 gives the year by year sales from different fields in both wings of the country.

In West Pakistan, both because of the earlier gas discoveries and comparatively heavy requirements of fuel in this region, growth of gas sales has progressed at a faster rate than the East Wing. The total sales during the first 15 years of operation amounted to 725,699 million cubic feet of which 649,799 million cubic feet were sold in West Pakistan only.

For case of reference and in order to compare like with like, sales from different gas fields in Pakistan have all been converted and their equivalents in terms of Sui quality raw gas are given in Appendix 4. During the past 15 years, the total sales in terms of Sui raw quality gas amounted to 763,789 million cubic feet or equivalent to about 17.4 million tons of furnace oil. Assuming F.O.B. Karachi price of furnace oil at Rs. 48 per ton, the foreign exchange savings to the country over this period amount to Rs. 835 million. Rs. 138 million of this were saved in 1970 alone.

Growth of Gas Consumption by Thermal Power Generation

The natural gas industry in Pakistan, thanks to the thermal power based on gas, has successfully outgrown her years of infancy into bright youthfulness. But for the utilization of gas by the power sector, the initial years of the gas industry would have been the most trying years. Nothing supports this contention better than the figures themselves. Appendix 5 gives the year by year growth of gas consumption by various thermal power installations owned by Public Utilities/Supply Undertakings but excluding some 250/300 megawatts thermal power generating capacity owned by numerous private industrial establishments in Pakistan. Appendix 6 shows the growth of gas sales to the thermal plants and compares these with the total sales made by the gas industry in Pakistan.

During 1956, gas sold to the Public Utilities/Supply Undertakings amounted to 2,937 million cubic feet in terms of Sui raw quality gas, whereas this figure increased to 53,870 million cubic feet in 1970. The sales to the power industry over the 15 years amounted to 304,054 million cubic feet. Due to displacement of imported furnace oil, this represents a foreign exchange saving of Rs. 332 million, Rs. 58.5 million of which were saved during 1970 alone. The thermal power generation, all along, has claimed the highest utilized production of gas than any other industry in Pakistan. When compared as percent of the total sales by the gas industry, the consumption by thermal power stations varied from the lowest of 29.5% in the year 1955 to the highest of 44.9% in the year 1965. The average over 15 years period has been 39.7% (Appendix 6).

Whereas it is true that in its infancy the natural gas industry was greatly assisted by its sales to the thermal power stations, it is also equally true to say that but for the valuable indigenous fuel source, the excellent growth attained by thermal power in the country would not have been possible. In modern times, electrical energy is basic to both the human and the industrial needs and its higher per capita consumption is generally indicative of the prosperity/ well-being of the people. In the absence of any alternative indigenous source of fuel in adequate quantities, the discovery of natural gas proved a true blessing and stimulated the growth of industrial activity in Pakistan in general and of thermal power generation in particular. Appendices 7 and 8 give in detail the growth of thermal power generating capacity in both wings of the country. Appendix 9 gives also the growth of the hydro generation capacity in the West Wing. For ease of reference, Table 1 below provides the growth of both the Thermal and Hydro-electric power in East and West Pakistan since independence in August 1947 :—

TABLE 1.—*Growth of Thermal and Hydro Power Generating Capacity*
(All Capacity Figures in Megawatts).

Year	East Pakistan			West Pakistan			Grand Total Pakistan		
	Ther.	Hydro	Total	Ther.	Hydro	Total	Ther.	Hydro	Total
1947	7.0	..	7.0	58.1	10.7	68.8	65.1	10.7	75.8
1960	74.0	..	74.0	326.7	240.5	567.2	400.7	240.5	641.2
1965	122.0	80.0	202.0	704.4	267.8	972.2	926.4	347.8	1174.2
1970	660.0	120.0	780.0	1130.3	667.8	1798.1	1790.3	787.8	2578.1

Note—The above figures do not include 250/300 MW thermal power generating capacity served on gas and owned by numerous private industrial establishments in both wings of the country.

In West Pakistan, as is clear from Table 1 above, the installed thermal power capacity increased from 58.1 MW at the time of independence in 1947 to 1130.3 MW in 1970, that is, an increase of 1072 MW. With the exception of some 20/30 MW, and about 80 MW which has since been retired, the remaining approximately 1030 MW thermal generating capacity was served on gas during 1970.

In East Pakistan, the growth of thermal power has been no less spectacular from 7 MW in 1947 to 660 MW in 1970, that is, an increase of 653 MW. It is interesting to note that during the third plan period (1965-70), the thermal power

generating capacity in East Pakistan increased by 538 MW whereas the corresponding figure for this period for West Pakistan was only 180 MW. The development of thermal power suffered during earlier years since it was not until 1960 that gas was discovered in East Pakistan in commercial quantities.

GAS *Versus* THERMAL POWER GENERATION

East Pakistan

In East Pakistan hydro electric power potential is very limited. No oil has so far been discovered. Coal has been discovered in the western half and can be used to meet the fuel requirements of large thermal power plants located on or near the coal mines. The thermal power plants based on coal, however, require only slightly less than twice as much capital as a gas fired thermalplant of the similar size. The higher operating/maintenance costs, higher price of coal and added transportation costs in case the coal is to be moved over long distance, are only some of the deterrents which preclude the extensive exploitation of the indigenous coal deposits for the purpose of thermal power generation.

The other source of thermal power for East Pakistan could be the nuclear energy. However, for the nuclear thermal power plants to be economical, the size of the plant appears to be one of the limiting factors. A figure of 300 MW (even that of 500 MW) is being mentioned as the minimum size for a nuclear thermal power plant to prove its economics. Neither a 500 MW nor a 300 MW plant, at the present state of power development in East Pakistan, could be adequately fitted in. Moreover, the capital cost of nuclear thermal power plant, (for same capacity, estimated at least three tirmes that based on natural gas), larger periods of maintenance, and dependence on foreign fuels are only some other deterrents which could and should inhibit the growth of nuclear power in this Wing during atleast the next 20 years or so.

In East Pakistan, the exploration and drilling has proven rich and large deposits of natural gas all over the eastern half of the Wing. Also gases discovered in East Pakistan are of much higher quality than those found in West Pakistan (Appendix 2). These rich and large deposits of natural gas have, in fact, been responsible for a very encouraging growth of thermal power generating capacity in this Wing, particularly so during the third plan period. With the exception of Chittagong and Khulna steam stations, each of 60 MW capacity, the bulk of the thermal power is being served on gas. Even Chittagong and Khulna steam stations will be converted to gas when either Bakhrabad/Chittagong line is constructed or gas discovered by OGDC in their Jaldi and Semutang fields, situated close to Chittagong, is brought to serve the fuel requirements of these areas.

Due to the extensive discoveries of natural gas deposits throughout the eastern half of this wing, transportation of gas also does not present any insurmountable probelms. Most of the large future thermal power stations are likely to be located on/or very near the gas source. For instance, East Pakkistan WAPDA's Shahjibazar gas turbine thermal power station, with an installed capacity of 104 MW, is supplied only through 1.5 miles of 8" diameter pipeline from Pakshell's Habiganj field.

The high pressure gas transmission pipelines required to serve the future thermal stations in East Pakistan are expected to be short and hence inexpensive. Since the thermal power stations will operate to meet the base load demand of power, they will be large consumers of gas. These considerations could induce gas companies to offer gas to these thermal stations at very attractive price. Apart from its cheapness, cleanliness, convenience, gas enjoys multiple other advantages over other alternative sources of fuel, such as oil, coal or nuclear and, therefore, the question of these sources of energy offering any competition to gas does not at all arise.

West Pakistan

In West Pakistan, the growth of thermal power generating capacity during the third plan period, as shown in Table 1 above, remained somewhat stinted when compared to that during the second plan period. This reduced addition in the thermal power generating capacity during the third plan period, with the commissioning of Mangla Dam in 1967, has, however, been more than offset by the addition of hydro electric power. Unlike East Pakistan, the West Wing has huge hydro power potential. The Indus river and its tributaries alone, when fully developed, are estimated to support some 30,000 MW of hydro generating potential. The immediate plans aim at utilizing the full hydro-power potential of Mangla Dam on the river Jhelum estimated at 1000 MW and that of now under construction Terbela Dam on the river Indus, estimated at 2100 MW. These multi-purpose Dams, whose principal purpose is the storage of water to satisfy the irrigation water requirements throughout the year, are estimated to meet the bulk and the base demand on West Pakistan's main integrated transmission grids.

It should be noted that the firm dependable capacity of these Dams (Appendix 9) is much lower than their total generating potential. To bridge the gap, the reduced availability of power from these Dams, particularly the winter months of low water availability in the stroage reservoirs of these dams, the supply to West Pakistan's integrated transmission grids must be augmented by thermal power. The alternative sources for thermal power are :—

(*a*) Nuclear Energy.
(*b*) Oil.

(*c*) Coal.

(*d*) Gas.

The nuclear thermal power plants suffer from the same setbacks as have already been mentioned in the case of East Pakistan. The additional setback for the nuclear power plants in West Pakistan will be their operation as peaking plants in order to augment the periods of low availability of hydro power due to low supply of water in the storage reservoirs of the hydro dams during the winter months. The nuclear power plants, nowhere in the world, are operating to meet the peak demand on the transmission grids and have still to prove their economics for such operation.

The thermal stations based on oil would have to rely on imported fuel and hence could cause a drain on the already meagre resources of the country. Coal which has been discovered in West Pakistan is of very poor quality. Some of the other factors that disfavour the coal fired thermal power plants are the same as have been mentioned in the case of East Pakistan. So this leaves gas being the only logical choice to meet the fuel requirements of the thermal power stations to meet the peak demand on the West Pakistan's integrated transmission grids during periods of low hydro power supply.

It is no wonder that due to some of the above considerations, West Pakistan WAPDA have proceeded to construct a super thermal power station at Guddu based on Sui raw gas and located it only 38 miles away from the source. With an initial capacity of 229 MW when commissioned by October 1973, the ultimate capacity of this station is estimated at 850/900 MW. Furthermore, this station is going to be inter-linked with extra high voltage 500-KV transmission lines with the hydro and the thermal power stations throughout West Pakistan. When more and more hydro generating potential is tapped, the capacity of Guddu and the other thermal stations planned for West Pakistan and based on gas will also require to be increased. With the growth of both the hydro and the thermal power, the capacity of the main integrated transmission grids will also be increased. The future tentative thermal and hydro power plans and the installation of new 500-KV transmission lines in West Pakistan for the period 1971 to 1985 are given in Table 2.

In order to fully utilize the power potential of the hydro dams, the thermal power generating potential must grow simultaneously. Gas, as has already been explained, will be the most logical and economical source to meet the heavy demand of fuel for the huge planned thermal generating capacity during 1971 to 1985 in West Pakistan. In the more distant future, other hydro projects such as Kunhar Valley, Panjar, Doke Pathan, Kala Bagh, Skardu, Gomal River, etc., etc., will require to be developed thereby requiring more

TABLE 2.—*Planned growth of Thermal/Hydro Power and Ehv Transmission Line in West Pakistan for* 1971—1985.

Period	Thermal Megawatts		Hydro-Megawatts		Extra High Voltage Transmission Line
	Project	Capacity	Project	Capacity	
1971—1975	Karachi Nuclear	137	Mangla Units 5 & 6	200	500-KV Guddu to Lyallpur.
	Guddu Thermal No. 3	420	Terbela Units 1 & 2	350	
1976—1980	Guddu Thermal 4.85	500	Terbela Units 3, 4, 5, 6, 7 & 8	1050	500-KV Lyallpur to Terbela.
	KESCO Korangi 4	125			500-KV Guddu to Karachi. 500-KV Terbela to Lyallpur.
	Korangi 5	200			
1981—1985	KESCO Korangi 6	200	Terbela Units 9, 10, 11 & 12	700	500-KV 2nd Circuit from Terbela to Lyallpur
	Other Thernal Stations Planned for Karachi	630	Mangla Units 7 & 8	200	
	Total	2,262		2,500	

and more thermal power stations. As in the case of Guddu Thermal Power Station, these peaking future thermal stations should preferably be located near the gas source and designed to use poor quality gases such as have been discovered in Uch, Mari and Khairpur fields in West Pakistan.

Gas Reserves

Some doubts have been expressed regarding the inadequacy of gas reserves in Pakistan. Facts, however, speak differently. Since the first discovery of natural gas at Sui in West Pakistan in 1952, the reserves have been steadily rising.

At the end of 1970, despite some 763,789 million cubic feet of utilized production of gas during he past 15 years, the remaining reserves in terms of Sui raw quality gas were still some 22 million million cubic feet. Appendix 10 shows the growth of reserves and the utilized production of gas in both wings of the country. Whether taken individually for each wing or for the country as a whole, Pakistan has the highest reserves/utilization ratio among the major gas producing countries of the world. Appendix 11 gives the gas reserves/utilization ratio of Pakistan and compares it with those of the other countries.

In East Wing even if half of the presently proven reserves of gas were dedicated for the generation of thermal power, these could sustain some 3,000 MW of thermal power generating capacity for 30 years. At the end of 1970 the total installed thermal generating capacity in East Pakistan was however 660 MW only.

In the West Wing, the entire thermal generating capacity planned between 1971 through 1985, as shown in Table 2 above, when fully developed would require a dedication of only about 3 million million cubic feet of Sui raw quality gas reserves. The presently proven reserves from Mari gas field alone are sufficient to meet the fuel requirements of this generating potential. The total reserves at the end of 1970 in West Pakistan, in terms of Sui raw quality gas, stood at 12.49 million million cubic feet.

Although the growth of gas reserves in Pakistan has been extremely satisfactory in the past, it should not be forgotten that the increased utilization of this valuable indigenous energy source, whether for thermal power generation, the manufacture of fertilizer/cement or for the manufacture of steel/petro-chemicals, will have the effects of intensifying further exploration in both wings of the country in order to further increase the present ample reserve estimates.

CONCLUSION

Abundant proven reserves of natural gas exist in both wings of the country and comprise one of the country's major tools in the task of attaining economic stability and independence. It is an advantage that few countries possess and could be the key to the success of plans for future industrialization, particularly the thermal power generation.

It is an advantage only if it is used and used for the purpose for which it is so well adapted. As a source of fuel energy, its clear advantages over other alternatives, both in terms of cost and in many other respects, cannot be disputed. Also, there is sufficient gas for many many years to come.

Being the major source of indigenous fuel, the use of gas not only saves money and promotes industrial efficiency but it also saves foreign exchange, so vital for future plans. As a source of fuel for thermal power generation alone,

during the past 15 years, the use of gas saved approximately Rs. 332 million. Rs. 58.5 million of this were in 1970 alone.

The discovery of rich and large reserves of natural gas have greatly stimulated the growth of industry in general and that of thermal power generation in particular. It is hoped that gas will continue to serve as effectively and efficiently the future fuel requirements of the thermal power stations as it has done in the past.

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Appendix 1

PAKISTAN's NATURAL GAS FIELDS AND THEIR RESERVES

Name of the Gas Field	Year of Discovery	Discovery by	Original Recoverable Reserves	Original Recoverable Reserves in terms of Sui Quality Raw Gas (Million Million Cubic Feet
1. Sui (WP)	1952	PPL	8.620	8.620
2. Zin (WP)	1954	PPL	0.100	0.052
3. Uch (WP)	1955	PPL	2.500	0.830
4. Sylhet (EP)	1955	PPL	0.430	0.480
5. Khairpur (WP)	1956	PPL	1.000	0.140
6. Mari (WP)	1957	Pak-Stanvac	3.942	3.050
7. Mazarani (WP)	1958	PPL/Hunt	0.030	0.030
8. Khandhkot (WP)	1959	PPL	0.200	0.180
9. Chhatak (EP)	1959	PPL	0.020	0.020
10. Rashidpur (EP)	1960	Pak-Sheel	1.060	1.150
11. Kailas Tila (EP)	1962	Pak-Shell	0.600	0.680
12. Titas (EP)	1962	Pak-Shell	2.250	2.510
13. Habiganj (EP)	1963	Pak-Shell	1.280	1.400
14. Jaldi (EP)	1967	OGDC	N.A.	N.A.
15. Sari Singh (WP)	1967	OGDC	0.029	0.270
16. Samutang (EP)	1967	OGDC	0.052	0.056
17. Bakhrabad (EP)	1969	Pak-Shell	2.970	3.250
18. Hundi (WP)	1970	OGDC	N.A.	N.A.
		Total	25.083	22.718
Associated Gas				
1. Dhulian	1953	POL	0.12	0.14
2. Tut	1968	OGDC	N.A.	N.A
3. Meyal	1969	Attock Oil	N.A.	N.A.

WP = West Pakistan
EP = East Pakistan
N.A. = Not available
Million Million Cubic Feet = 10^{12} cu. ft.

Appendix 2

RESERVES OF NATURAL GAS IN PAKISTAN

West Pakistan

	Sui (PPL)	Zin (PPL)	Uch (PPL)	Khair-pur (PPL)	Khandh-Kot (PPL)	Maza-rani (PLL)	Mari ESSO	Sari (OGDC)	Hundi (OGDC)
Methane	.. 88.52	46.1	27.3	12.2	79.2	87.0	71.2	78.92	79.40
Ethane	.. 0.89	0.4	0.7	0.2	1.1	2.5	0.2	2.18	1.62
Propane	.. 0.26	0.15	0.3	0.1	0.2	0.1	..	0.81	0.42
Butane & Higher	.. 0.37	0.15	0.3	..	0.4	1.2	..	0.14	0.06
Nitrogen	.. 2.46	8.5	25.2	16.9	16.6	8.0	19.5	15.96	17.04
Carbon-dioxide	.. 7.35	44.7	46.2	70.6	2.5	0.3	9.0	1.99	1.46
Hydrogen Sulphide Grains/100 ft.^{3}	.. 92.2	13.3	33.5	2.0	30.8	10.7	0.1	..	...
Mercaptan Sulphur Grains/100 ft.^{3}	.. 3.8	2.3	10.2		1.2	2.2	..	...	
Gross Heating Value BTU/ft.^{3}	..933.0	484.0	308.0	130.0	842.0	976.0	723.0	870.0	830.0
Reserves in million million cubic feet	.. 8.62	0.10	2.50	1.0	0.20	0.03	3.942	0.029	N.A.
Reserves equivalent to Sui quality raw gas million million cubic feet	.. 8.62	0.052	0.83	0.14	0.18	0.03	3.05	0.027	..

East Pakistan

	Bakhra-rabad (Shell)	Sylhet (PPL)	Chhatak (PPL)	Rashid-pur (Shell)	Kailas Tila (Shell)	Titas (Shell)	Habi-ganj (Shell)	Samu-tang (OGDC)	Jaldi (OGDC)
Methane ..	94.3	95.4	99.05	98.2	95.7	97.2	97.8	96.94	N.A.
Ethane ..	3.4	2.67	0.24	1.20	2.6	1.8	1.5	1.70	„
Propane ..	0.8	0.3	..	0.2	0.9	0.5	..	0.15	„
Butane & Higher ..	0.7	0.78	..	0.1	0.4	0.5	..	NIL	„
Nitrogen ..	0.4	0.37	0.67	0.3	0.2	..	0.7	0.86	„
Carbon-dioxide ..	0.4	0.48	0.04	..	0.2	..	..	0.35	„
Hydrogen Sulphide Grains/100 ft.^{3} ..	..	..	..	..	..	..	..	..	..
Mercaptan Sulphur Grains/100 ft.^{3} ..	..	0.29	0.08	..	..	..	..	..	..
Gross Heating Value BTU/ft.^{3} ..	1022	1052	1007	1014	1050	1039	1020	997	..
Reserves in million million cubic feet ..	2.97	0.43	0.02	1.06	0.60	2.25	1.28	0.052	N.A.
Reserves equivalent to Sui quality raw gas million million cubic feet	3.25	0.48	0.02	1.15	0.68	2.51	1.40	0.056	N.A.

N.A = Not available

Million Million Cubic Feet = 10^{12} cubic feet

GAS SALES IN PAKISTAN
(All Figures in Million Cubic Feet/Calendar Year)

Calendar Year	West Pakistan						East Pakistan					
			SNGPL									
	KGC	IGC	Sui	Dhulian	Mari	West Pakistan Total	Sylhet	Chhattak	Titas	Habiganj	East Pakistan Total	Pakistan Total
1955 ..	350	137	..	..	..	487	..	..	..	..	..	487
1956 ..	4589	2277	..	..	..	6866	..	..	..	..	..	6866
1957 ..	6390	3854	..	..	..	10244	..	..	..	..	..	10244
1958 ..	8358	4272	29	..	..	12659	..	..	..	..	..	12659
1959 ..	9806	4546	1023	..	..	15375	..	..	..	..	..	15375
1960 ..	10763	5793	3981	1528	..	22065	3	283	..	..	286	22351
1961 ..	11913	6209	4790	2066	..	24978	1339	873	..	..	2212	27190
1962 ..	13616	6630	6727	2413	..	29386	3351	787	..	..	4138	33524
1963 ..	14950	8630	9205	3091	..	35876	5449	750	..	..	6199	42075
1964 ..	18980	9439	13299	3317	..	45035	4854	560	..	..	5414	50449
1965 ..	19568	10066	18799	3780	..	52213	5471	536	..	..	6007	58220
1966 ..	20046	10526	23619	4149	..	58340	5283	547	..	..	5830	64170
1967 ..	24338	11340	25724	4310	..	65712	6668	929	..	..	7597	73309
1968 ..	27312	12317	28418	4315	1517	73879	5673	703	636	332	7344	81223
1969 ..	29972	14686	36567	4678	9186	95089	5458	706	1132	3280	10576	105665
1970 ..	31876	15929	35598	8098	10094	101595	5448	799	8030	6020	20297	121892
16-Year Total ..	252827	126651	207779	41745	20797	649799	48997	7473	9798	9632	75900	725699

Appendix 4

GAS SALES IN PAKISTAN IN TERMS OF SUI QUALITY RAW GAS
(All Figures in Million Cubic Feet/Calendar Year)

Calendar Year	West Pakistan				East Pakistan					Total Pakistan
	Sui	Dhulian	Mari	Total West Pakistan	Sylhet	Chhattak	Titas	Habiganj	Total East Pakistan	
1955	.. 509	..	..	509	..	..	..	..	..	509
1956	.. 7175	..	..	7175	..	..	..	..	..	7175
1957	.. 10705	..	..	10705	..	..	..	..	..	10705
1958	.. 13229	..	..	13229	..	..	..	..	..	13229
1959	.. 16067	..	..	16067	..	..	..	..	..	16067
1960	.. 21461	1802	..	23263	3	305	..	..	308	23571
1961	.. 23943	2436	..	26379	1510	942	..	..	2452	28831
1962	.. 28187	2845	..	31032	3778	849	..	..	4627	35659
1963	.. 34261	3644	..	37905	6144	809	..	..	6953	44858
1964	.. 43596	3910	..	47506	5473	604	..	..	6077	53583
1965	.. 50613	4457	..	55070	6169	579	..	..	6748	61818
1966	.. 56630	4892	..	61522	5957	590	..	..	6547	68069
1967	.. 64166	5081	..	69247	7518	1003	..	..	8521	77768
1968	.. 71110	5087	1175	77372	6397	759	708	363	8227	85599
1969	.. 84881	5515	7118	97514	6154	762	1261	3586	11763	109277
1970	.. 87157	9547	7822	104526	6143	862	8950	6590	22545	127071
16 Year Total	..613690	49216	16115	679021	55246	8064	10919	10539	84768	763789

GAS CONSUMED FOR POWER GENERATION BY PUBLIC UTILITIES/SUPPLY UNDERTAKING

(All Figures in Million Cubic Feet)

Calendar Year	West Pakistan WAPDA										East Pakistan WAPDA			Grand Total Sales to Power Industry in Pakistan
	KESCO	MESCO	REPCO	HESU	Hyderabad	Kotri	Sukkur	Multan	Lyallpur	Lahore	Siddirganj	Ashurganj	Shahjibazar	
1955	143	..	..	..	..	..	..	..	..	..	..	..	..	143
1956	2811	..	..	..	..	..	..	..	..	..	..	..	..	2811
1957	3176	..	..	..	..	..	..	..	..	..	..	..	..	3176
1958	3942	..	..	..	..	..	..	..	..	..	..	..	..	3942
1959	4490	329	..	..	..	..	..	73	..	..	..	..	..	4892
1960	5074	502	320	..	..	..	..	2500	..	..	..	..	..	8396
1961	5548	442	430	..	537	..	..	2862	..	..	..	..	..	9819
1962	5950	509	500	..	938	..	..	3475	..	..	..	..	..	11372
1963	6461	475	621	..	1522	..	..	5205	..	..	..	..	..	14284
1964	8286	803	621	..	2037	..	33	8877	..	..	..	..	..	20657
1965	8979	767	730	..	2270	..	456	13279	13	..	..	..	..	26494
1966	9600	767	767	..	2723	..	829	13724	229	636	..	..	..	29275
1967	10330	803	730	269	2993	..	1132	9125	2139	1684	..	..	..	29205
1968	11790	803	803	357	2957	..	1789	7520	2984	754	713	..	332	30802
1969	14274	840	803	..	2855	..	2452	9621	7046	961	927	..	3280	43059
1970	15440	913	730	..	2738	73	2774	10043	8239	930	1837	1230	6020	50967

Appendix 6

GAS CONSUMPTION BY POWER PUBLIC UTILITIES/SUPPLY UNDERTAKINGS AS % OF TOTAL GAS SALES IN PAKISTAN

(All Figures in Million Cubic Feet)

Calendar Year	Total Sales to Power Industry in West Pakistan	Total Sales to Power Industry in East Pakistan	Grand Total Sales to Power Industry in Pakistan	Grand Total Sales to Power Industry in Pakistan Equivalent to Sui Quality Raw Gas	Total Gas Sales to all Types of Consumers including Power Industry	Sales to Power Indus. as % of the Total Gas Sales
1955 ..	143	..	143	150	509	29.5
1956 ..	2811	..	2811	2937	7175	32.6
1957 ..	3176	..	3176	3319	10705	31.0
1958 ..	3942	..	3942	4119	13229	31.1
1959 ..	4892	..	4892	5112	16067	31.8
1960 ..	8396	..	8396	8816	23571	37.0
1961 ..	9819	..	9819	10319	28831	35.8
1962 ..	11372	..	11372	11951	35659	33.5
1963 ..	14284	..	14284	15010	44858	33.5
1964 ..	20657	..	20657	21670	53583	40.4
1965 ..	26494	..	26494	27785	61818	44.9
1966 ..	29275	..	29275	30695	68069	45.1
1967 ..	29205	..	29205	30618	77768	39.4
1968 ..	29757	1045	30802	32362	85599	37.8
1969 ..	38852	4207	43059	45321	109277	41.5
1970 ..	41880	9087	50967	53870	129071	41.7
Total	274955	14339	289294	304054	765789	39.7

GROWTH OF THERMAL POWER GENERATION CAPACITY IN WEST PAKISTAN

(All Capacity Figures in Megawatts)

Calendar Year	Name of Public Utility	Location of Plant	Type of Plant	Size of Plant	No. of Sets	Installed Cap.		Cum. Capacity	
						Name Plate Rating	Firm	Name Plate Rating	Firm
1947	.. ..	..	..	..	..	58.10	58.10	58.10	58.10
1948	.. KESCO	Kyc A Stn	Steam	2.50	2	5.00	5.00	63.10	63.10
1949	.. REPCO	Rwp	Steam	2.80	1	2.80	2.80	65.90	65.90
1950	.. LESCO	Shdr	Steam	8.00	1	8.00	8.00	73.90	73.90
1951	.. ..	..	..	..	..	..	..	73.90	73.90
1952	.. HESU	Hyd	Steam	3.60	..	3.60	3.60	77.50	77.50
1953	.. KESCO	Kyc A Stn	Steam	5.00	3	15.00	15.00	92.50	92.50
1954	.. Lyp & Swl	Lyp	Steam	4.00	2	8.00	8.00	100.50	100.50
	Elec. Power Co.	Swl	Steam	3.00	2	6.00	4.00	106.50	104.50
1955	.. Lyp & Swl		Steam	6.00	1	6.00	6.00	112.50	110.50
	Elec. Power Co.	Lyp	(Diesel	10.00	1	10.00	10.00	122.50	120.50
		Swl	Steam	2.50	1	2.50	2.50	125.00	123.00
1956	.. KESCO	Kyc B Stn	Steam	15.00	2	30.00	30.00	155.00	153.00
1957	.. ..	..	..	..	..	..	..	155.00	153.00
1958	.. MESCO	Mlt	Steam	3.00	1	3.00	3.00	158.00	151.00
1959	.. WAPDA	Mlt	Gas	5.70	1	5.70	5.70	163.70	156.70
1960	.. REPCO	Rwp	Steam	3.00	1	3.00	3.00	166.70	159.70
	WAPDA	Mlt	Steam	65.00	2	130.00	130.00	296.70	289.70
	WAPDA	Hyd	Steam	7.50	2	15.00	15.00	311.70	304.70

Appendix 7 (Sheet 2)

Calendar Year	Name of Public Utility	Location of Plant	Type of Plant	Size of Plant	No. of Sets	Installed Cap.		Cum. Capacity	
						Name Plate Rating	Firm	Name Plate Rating	Firm
1961 ..	KESCO	Site Kyc	D. F. Sets	1.15	13	15.00	15.00	326.70	319.70
1962 ..	WAPDA	Jmr	D. F. Sets	0.375	4	1.50	1.50	328.20	321.20
	KESCO	Kyc B Ext.	Steam	33.00	2	66.00	66.00	394.20	387.20
1963 ..	WAPDA	Mlt	Steam	65.00	2	130.00	130.00	524.20	517.20
1964 ..	WAPDA	Skr	D. F. Sets	0.375	4	1.50	1.50	525.70	518.70
	WAPDA	Skr	Diesel	0.500	2	1.00	1.00	526.70	519.70
	WAPDA	Qta	Steam	7.500	2	15.00	15.00	541.70	534.70
1965 ..	WAPDA	Hyd	Gas	5.70	1	5.70	5.70	547.40	540.40
	WAPDA	Hyd	Steam	8.00	1	8.00	8.00	547.40	537.90
	KESCO	Kyc-Korangi C Stn	Steam	66.00	2	132.00	132.00	679.40	669.90
	WAPDA	Skr	Steam	12.50	2	25.00	25.00	704.40	694.90
1966 ..	WAPDA	Hyd	Steam	15.00	1	15.00	15.00	719.40	709.90
	WAPDA	Lhr	Gas	13.20	2	26.40	26.40	745.80	736.30
1967 ..	WAPDA	Skr	Steam	12.50	2	25.00	25.00	770.80	691.30
	WAPDA	Lyp	Steam	66.00	2	132.00	132.00	902.80	823.30
1968 ..	WAPDA	Lhr	Gas	14.75	2	29.50	29.50	932.30	852.80
	WAPDA	Kotri	Gas	14.50	1	14.50	12.25	946.80	865.05
1969 ..	WAPDA	Lhr	Gas	14.75	2	29.50	29.50	976.30	894.55
1970 ..	KESCO	Kyc-Korangi C Ext	Steam	125.00	1	125.00	125.00	1101.30	1019.55
	WAPDA	Kotri	Gas	14.50	2	29.00	29.00	1130.30	1048.55

Appendix 7 (Sheet 3)

Notes: (1) At the time of Independence in August, 1947, the total installed capacity of the Public Utilities/Supply Undertakings but excluding those owned by private industrial establishments totalled 58.1 MW. Of this 30 MW was based on steam electric plants and the balance on diesel electric plants. Major installations were Karachi 8.00 MW; Sukkur Area 8.6 MW; MESCO 3.38 MW; HESU 1.6 MW; Lyallpur 13 MW; REPCO 3.5 MW. All these have already been converted to gas.

(2) These were second-hand turbines purchased by KESCO and retired in 1958.

(3) 8 MW steam set added to Shahdara Thermal Station was removed by WAPDA in 1964 and installed in 1965 at Hyderabad Thermal Power Station.

(4) 2.5 MW steam set installed in Sahiwal in 1955 was removed by WAPDA in 1965 and installed at their Hyderabad Thermal Station and has since been retired.

(5) With the addition of 3.0 MW steam set by MESCO in 1958 the total capacity increased to 6.68 MW. The other four turbines installed have 1.6, 1.08, 0.45 and 0.25 MW capacity.

(6) By mid 1966, the four large steam sets installed at WAPDA's Multan Thermal Station developed major faults. These turbines were subsequently repaired but their thermal generation capacity was derated from 260 MW to 190 MW.

(7) Kotri gas turbine of 14.5 MW installed in 1968 could never generate the capacity on test. Firm capacity is rated at 12.25 MW.

(8) The above installed thermal generation power capacity belongs to Public Utilities and other Supply Undertakings and excludes those owned by numerous Private Industrial Establishments. The growth of thermal power belonging to this sector has been estimated to rise from some 20 MW in 1947 to over 200 MW in 1970. More than 90% of this thermal installed capacity is already being served on natural gas.

(9) HESU, LESLO, Lyallpur/Sahiwal Power Stations are how being operated by WAPDA.

Abbreviations:

KESCO .. Karachi Electric Supply Corporation.
REPCO .. Rawalpindi Electric Power Company.

Appendix 7 (Sheet 4)

MESCO	.. Multan Electric Supply Company.
HESU	.. Hyderabad Electric Supply Undertaking.
WAPDA	.. Water and Power Development Authority.
Kyc	.. Karachi.
Rwp	.. Rawalpindi.
Shdr	.. Shahdara.
Hyd	.. Hyderabad.
Stn	.. Station.
Lyp	.. Lyallpur.
Swl	.. Sahiwal.
Mlt	.. Multan.
Jmr	.. Jamshore.
Ext	.. Extension.
Skr	.. Sukkur.
Qta	.. Quetta.
Lhr	.. Lahore.

Appendix 8

GROWTH OF POWER GENERATION IN EAST PAKISTAN
(All Capacity Figures in Megawatts)

Period	Thermal Gen. Capacity		Hydro Generation		Total Power Generation.		Remarks
	Additional	Cumulative	Additional	Cumulative	Additional	Cumulative	
1947	7.0	7.0	..	..	7.0	7.0	See Note 1 for details.
1960	67.0	74.0	..	..	67.0	74.0	See Note 2 for details.
1965	48.0	122.0	80.0	80.0	128.0	202.0	See Note 3 for details.
1970	538.0	660.0	40.0	120.0	578.0	780.0	See Note 4 for details.

Notes: (1) At the time of partition in August 1947, the generating capacity belonging to Public Utilities/Supply Undertakings totalled about 7.0 MW and was based on Coal/Oil.

(2) From 1947 to July, 1960, that is, the beginning of Second Plan Period, 67 MW Thermal Generating Capacity was added. Notable additions were Siddirganj 30 MW Steam and 10 MW Diesel; Chittagong 10 MW Diesel and Golpara and Thakurgaon about 10 MW each.

(3) During 2nd Plan Period 80 MW of Hydro Power, consisting of two turbines, each of 40 MW and about 48 MW of Steam/Diesel were added.

(4) During 3rd Plan Period 40 MW was added to Karnafulli Hydro Power. Notable Thermal additions were :

Siddirganj Extension		= 50.00 MW	Steam
Ashurganj	2 × 60 MW	=120 00 MW	,,
Ghorasal	1 × 110 MW	=110 00 MW	,,
Chittagong	1 × 60 MW	= 60 00 MW	,,
Khulna	1 × 60 MW	= 60 00 MW	,,
Shahjibazar	4 × 14.03 MW	= 56.12 MW	Gas Turbines
	3 × 13.70 MW	= 41.10 MW	,,
	1 × 6.50 MW	= 6.50 MW	,,

Appendix 8 (Sheet 2)

Saidpur Power Station

		3×3.5 MW	=	10.50 MW	Diesel
Bogra	,,	5×1.3 MW	=	6.50 MW	,,
Serajganj	,,	2×0.65 MW	=	1.30 MW	,,
		1×1.30 MW	=	1.30 MW	,,
Mymensingh	,,	2×0.65 MW	=	1.30 MW	,,
Cox's Bazar	,,	2×0.65 MW	=	1.30 MW	,,
		1×1.30 MW	=	1.30 MW	,,
		Total Thernal		527.22 MW	,,

(5) The Thermal Generating Capacity given in the above table excludes that owned by numerous private industrial establishments. The growth of Thermal Power in this Sector arose from less than 10 MW in 1947 to about 100 MW in 1970. Most of this has already been converted to operate on natural gas.

GROWTH OF HYDRO ELECTRIC POWER IN WEST PAKISTAN

Appendix 9

(All Capacity Figures in Megawatts)

Calendar Year	Name of Utility	Location of Plant	Size of Plant	No. of Turbines	Installed Cap.		Cum. Capacity	
					Name Plate Rating	Firm Capability	Name Plate Rating	Firm Capability
1947	WAPDA	Malakand	3.2	3	9.6	9.6	9.6	9.6
		Renala	1.0	1	1.1	1.1	10.7	10.7
1948	..	..	..	..	..	..	10.7	10.7
1949	..	..	..	..	..	..	10.7	10.7
1950	..	..	..	..	..	..	10.7	10.7
1951	WAPDA	Malakand	5.0	2	10.0	5.0	20.7	15.7
1952	WAPDA	Rasul	11.0	2	22.0	11.0	42.7	26.7
1953	..	..	..	..	..	..	42.7	26.7
1954	WAPDA	Dargai	5.0	4	20.0	15.0	62.7	41.7
1955	..	..	..	..	..	..	62.7	41.7
1956	WAPDA	Kurram Garhi	1.0	4	4.0	3.0	66.7	44.7
1957	..	..	..	..	..	..	66.7	44.7
1958	..	..	..	..	..	..	66.7	44.7
1959	WAPDA	Chichoki Malian	4.6	3	13.8	10.0	80.5	54.7
1960	WAPDA	Warsak	40.0	4	160.0	110.0	240.5	164.7
1961	WAPDA	Shadiwal	6.75	2	13.5	6.0	254.0	170.7
1962	..	..	..	..	..	..	254.0	170.7
1963	WAPDA	Nandipur	4.6	3	13.8	10.0	267.8	180.7
1964	..	..	..	..	..	..	267.8	180.7
1965	..	..	..	..	..	..	267.8	180.7
1966	..	..	..	..	..	..	267.8	180.7
1967	WAPDA	Mangla No. 1 & 2	100.0	2	200.0	122.0	467.8	302.7
1968	WAPDA	Mangla No. 3	100.0	1	100.0	61.0	567.8	363.8
1969	WAPDA	Mangla No. 4	100.0	1	100.0	61.0	667.8	424.8
1970	..	..	..	..	..	..	667.8	424.8

Note:—Actual capability is recognized as the average sustained output for one hour at the time of system-peak in winter, when hydro-electric capability is at its minimum because of River/Canal conditions

Cap.=Capacity Cum=Cumulative

Appendix 10

PROVEN RESERVES *Versus* UTILIZATION OF NATURAL GAS IN PAKISTAN

(Reserves/Utilization Figures are in Million Cubic Feet)
and in terms of Sui Quality Raw Gas—933 BTUs/Cu. t.)

Calendar Year	Cumulative Original Recoverable Reserves at End-Year	Utilization During the Calendar Year	Cumulative Utilization	Balance Recoverable Reserves at End-Year	Life Expectancy of Reserves in Years or Reserves Utilization Ratio
1952	8,620,000	..	..	8,620,000	Infinite
1953	8,620,000	..	..	8,620,000	,,
1954	8,672,000	..	..	8,672,000	,,
1955	9,982,000	509	509	8,981,491	1,765
1956	10,122,000	7,175	7,684	10,114,316	1,410
1957	13,172,000	10,705	18,389	10,153,611	948
1958	13,202,000	13,229	13,618	13,170,382	995
1959	13,402,000	16,067	47,685	13,354,315	831
1960	14,552,000	23,571	71,256	14,480,744	614
1961	14,552,000	28,831	100,087	14,451,913	501
1962	17,742,000	35,659	135,746	17,606,254	494
1963	19,142,000	44,858	180,604	18,961,396	423
1964	19,142,000	53,583	234,187	18,907,813	353
1965	19,142,000	61,818	296,005	18,485,995	299
1966	19,142,000	68,069	364,074	18,777,926	276
1967	19,168,000	77,768	441,842	18,726,158	241
1968	19,168,000	85,599	527,441	18,940,559	221
1969	22,718,000	109,277	636,718	22,081,282	202
1970	22,718,000	129,071	763,789	21,954,211	170

Notes:—(1) First Commercial Utilization of Natural Gas from PPL's Sui Field started in Karachi, West Pakistan, during October 1955 and from PPL's Chhatak Gas Field in April 1960 in East Pakistan.

(2) For details insofar as discovery of the various fields in East Pakistan and West Pakistan is concerned and the reserves and gas analysis estimates, please see Appendices 1 and 2.

Appendix 11

NATURAL GAS RESERVES, PRODUCTION AND LIFE EXPECTANCY

Country		Reserves at end 1969 (million million cu. ft.)	Production 1970 (million cu. ft.)	Reserves' Life Expectancy at 1970 rate of production (Years)
Pakistan	..	22.0	0.13	170.0
U.S.A.	..	275.1	22	12.5
Canada	..	52.0	3.2	16
Italy	..	7.0	0.4	17
Mexico	..	12.0	0.6	20
W. Germany	..	9.3	0.37	25
France	..	7.2	0.27	27
Argentina	..	6.4	0.17	38
Netherlands	..	85.5	1.71	50
U.S.S.R.	..	427	7.0	61
U.K.	..	29	0.43	67