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The Economic Value of Natural Gas in Residential and Commercial Markets

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World Bank Energy Department

THE ECONOMIC VALUE OF NATURAL GAS IN
RESIDENTIAL AND COMMERCIAL MARKETS

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* The authors are indebted to DeAnne Julius for her helpful review and suggestions.

Summary and Conclusion

Many developing countries have an abundant supply of indigenous, low cost, natural gas. However, their current levels of gas consumption are often very low compared to their potential demand. Most countries have yet to formulate a gas development strategy to make maximum economic use of their resources.

This paper is one of a series prepared by the World Bank on the value of natural gas in various domestic uses and for export. The purpose of these papers is to provide a comparable information base and a consistent framework of analysis to evaluate gas utilization options. By defining the general conditions under which certain gas uses are economically attractive, these papers are intended to provide a sharper focus for country-specific feasibility studies.

Few developing countries have gas distribution systems to serve residential and commercial (R&C) consumers. This is in marked contrast to the situation in OEDC countries, where such consumers account for more than one-third of total gas use, and are generally considered to represent the highest share of the gas market. Many developing countries are experiencing rapid rates of urbanization, and the R&C share of total energy consumption is large and growing. In the absence of natural gas, urban populations often rely on such high value fuels as LPG, kerosene and diesel. Further, developing countries that have built urban gas distribution systems have seen dramatic demand growth, even where gas was not used for space heating. These conditions suggest that there may be significant scope for expanding R&C gas use in developing countries.

This paper is based on a simulation model to estimate the costs and economic netbacks of R&C gas distribution under a range of parameters designed to encompass most developing country conditions. Netbacks range from around $3.3/MCF in the worst case to over $10.0/MCF in the most favorable. Figures are most sensitive to (i) the volume of consumption per connection, (ii) housing density, (iii) whether the area to be served is existing or new, (iv) the discount rate, and (v) the value of the fuel replaced by gas.

The general conclusion is that there is a wide range of conditions under which the provision of gas to R&C consumers is economically attractive. The relative priority of R&C gas use for a particular country can only be assessed through net present value (NPV) analyses which also include the costs and benefits of other gas uses in that country. However, it is apparent that there are significant cost savings for R&C distribution (beyond what is considered in this paper) if it is designed as part of a larger gas network serving bulky consumers such as power and industrial users. Other avenues for cost reduction through appropriate network design and equipment choice are discussed in Annex I.

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I. INTRODUCTION

I.1 Background

Proven natural gas reserves of 46 trillion cubic meters, or about 45% of world reserves, are widely distributed in more than 50 developing countries. These reserves can be developed and transported to the city gate at a relatively low cost; in many cases, less than \$1.50/MCF.[1] However, most developing countries lack a gas development strategy. Those countries that have developed a strategy have largely ignored the residential and commercial (R&C) markets in favor of large industrial and power plants. In part, this is because of the complexity of introducing a new source of energy into urban areas. In part, it is because many energy planners are not aware of the relative costs of natural gas supply and the potential for R&C market development. Another problem is that developing countries lack the long-term financial resources required for developing a gas distribution system.

Many developing countries are experiencing a high rate of urbanization. The residential and commercial sectors are responsible for a large and growing share of total energy consumption primarily for cooking, and for water and space heating.[2] Countries which have gas distribution systems serving residential and commercial sectors are experiencing rapid demand growth, often surpassing the capabilities of the gas distribution network. For example, Pakistan has about 700,000 households and 26,000 commercial customers connected to its natural gas distribution network. These consumers often experience gas shortages during peak demand hours, and many of the new applications submitted each year by households cannot be processed because of the shortage of gas. Similarly, in Iran, when gas was first distributed in the early 1970's, demand increased much faster than the ability of the gas distribution company to meet it in the short run.

In the absence of gas, urban populations in developing countries presently rely on a variety of other fuels such as LPG, kerosene, gas oil, coal and fuelwood. The liquid fuels are generally premium products with a high cost; fuelwood supplies are diminishing and often unavailable in urban areas; coal can be high in environmental and in-land distribution costs. Natural gas is a clean burning fuel that does not contribute to pollution. These conditions suggest there may be significant scope for expanding R&C gas use in developing countries.

1/ See A. Mashayekhi "Marginal Cost of Natural Gas in Developing Countries: Concepts and Applications", Energy Department Paper No. 10, World Bank, July 1983. Costs for 10 developing countries ranged from \$0.46 to \$1.79/MCF in 1982 prices.

2/ The latter is limited, of course, to countries which have colder climates such as Pakistan, Korea, Argentina and Bolivia.

I.2 Existing Residential and Commercial Gas Use in Developed and Developing Countries

Despite these apparent advantages to R&C gas use, developing countries lag far behind OECD countries in the proportion of gas used by residential and commercial sectors. In Pakistan, for example, these sectors account for only ten percent of total gas consumption, while in Mexico they consume less than four percent and in India less than two percent. Residential and commercial sectors in North America, Western Europe, and Japan use large volumes of natural gas. In 1980, these sectors in Europe and the United States consumed 26% and 44%, respectively, of the total. In Holland, which has large indigenous gas reserves, the share of gas used by the R&C sectors was about 54 percent. In all OECD countries the average share of gas consumed by these sectors was 34 percent.[1/] While space-heating demand, in particular, will be less in many developing countries, the city-gate cost of gas is also likely to be lower in many developing countries. The historical record of R&C gas use in the industrialized countries shows a pattern of rapid demand growth following the initial infrastructure investment that may portend similar trends in developing countries as their gas industries matures.

In most of the developed countries, urban gas distribution took off in the late 1940s and was fully developed by the 1960s. For example, in 1945 in the USA the number of residential customers was 18.6 million corresponding to a total consumption of 775 trillion Btu; by 1977 the total number of customers had increased to 41.7 and gas consumption was 4946 trillion Btu.[2/] In some cities, natural gas followed "town gas" which was manufactured from coal or naphta. During the 1940s and early 1950s, most of the R&C demand was for cooking, heating water, space heating and gas-fired refrigerators. Commercial users such as schools, hospitals, hotels, restaurants, shops and offices also expanded rapidly. In the late 1950s and 1960s, gas demand grew as central heating, dishwashers and clothes dryers became more widespread.

Developing countries with urban gas distribution systems include Algeria, Argentina, Bangladesh, Brazil, Egypt, India, Iran, Mexico, Pakistan, Tunisia and Venezuela. Several of these countries are planning expansions of their gas networks; Korea, and Turkey may soon be added to the list. However, the existing distribution networks are all limited to certain suburbs of major cities and, for the most part, are not linked into a country-wide grid. Although in many of these countries there is a large potential demand for gas by residential and commercial consumers, consumption is limited partly due to climatic reasons.

1/ Source: IEA, Natural Gas prospects to 2000, OECD, 1982.

2/ Malcolm Peebles, Evolution of the Gas Industry, McMillan Press, Ltd.

As was the case in OEDC countries, once the infrastructure is put in place, R&C gas demand has grown rapidly. Pakistan is one of the few developing countries with a relatively mature distribution system and accessible historical data. Since it started operating in 1955, the gas transmission and distribution system has been expanded to supply a current customer base of 700,000 households and 26,000 commercial users. The share of natural gas used by these two sectors increased from 3.9% of total gas consumption in 1972 to about 10% in 1982. R&C consumption grew from 4.1 BCF in 1972 to 25.2 BCF in 1982, at an average annual rate of 27% and 17% respectively, for the residential and commercial sectors (Table 1). In spite of this impressive growth, less than 25% of the residential market in Karachi, Lahore and Islamabad has access to gas.

Table 1

Residential and Commercial Gas Consumption in Pakistan
(BCF)

	1972	1974	1976	1978	1980	1981
Residential	2.2	3.9	6.2	9.8	14.3	17.7
Commercial	1.9	3.0	4.2	5.3	6.5	7.5
Sub Total	4.1	6.9	10.4	15.1	22.8	25.2
Total Gas Consumption	111.5	144.5	156.9	179.5	227.9	264.8
Share of Residential & Commercial sectors (%)	4.0	5.0	7.0	8.0	10.0	10.0

I.3 Objectives of the R&C Study

There are many possible reasons for the slow development of urban gas distribution systems in developing countries. Limited financial resources, weak institutional structures and the lack of information on potential urban gas demand are undoubtedly important ones. There is also limited familiarity with the technology of gas distribution in developing countries and little information on its costs or potential benefits. To address the latter problem, the World Bank commissioned a study by Sofregaz to calculate the costs and benefits of urban gas distribution under a range of developing country conditions.

The primary objective of the study was to examine the economic feasibility of gas distribution to serve residential and commercial consumers in developing countries. By identifying the technical and economic parameters that have the greatest effect on system costs and profitability, the results of the study could be used to pre-screen potential projects. The study was also intended to provide a quantitative basis for clarifying some of the issues related to the demand for gas and the design of gas distribution networks. This paper is based on the results of that study[1/].

1/ A study of Economic Costs and Benefits of Natural Gas Utilization in Residential and Commercial Markets, Sofregaz, February 1983.

II. METHODOLOGY AND PARAMETERS

II.1 Scope of the Study

The initial volume of gas used by residential and commercial sectors in most developing countries is likely to be small relative to that used in the early stages by industrial and power sectors. The main transmission network is generally designed and built to serve the bulk users due to their larger demand and economies of scale for larger gas volumes. An earlier Bank study calculated the costs of gas production and transmission to the city-gate on that basis. This study covers all costs from the city-gate to the burner-tip of the final consumer. These gas distribution costs include all secondary transmission, small distribution mains, as well as internal lines, meters, carcassing (where appropriate) and conversion of appliances. The costs are based on actual demand, designs and economic data from Tehran, Tunis, Cairo, Islamabad, Paris and Aix-en-Provence.

II.2 Methodology

The basic approach was to construct a simulation model that could be used to calculate system costs and economic netbacks using a variety of technical and economic parameters. Sixteen model distribution networks were developed to encompass the range of relevant parameter combinations. To develop these model networks, R&C gas demand was projected over a 20 year period, and capital and operating costs were determined on the basis of the physical design parameters. Differences in urban characteristics, climatic conditions and consumption habits resulted in a large number of possible network configurations. The least cost design was selected for each set of assumed parameter values.

Table 2

Model Distribution Networks

Urban Characteristics	Gas Uses	Density	Case	Household Consumption 1/ MCF/yr.	M^3/yr.
Existing City	Base Load (cooking + waterheating)	Very High	A	12.4	350
		High	B	12.4	350
		Medium	C	17.7	500
		Low			
	Base load + Space heating	Very High	E	40.6	1,150
		High	F	40.6	1,150
		Medium	G	56.5	1,600
		Low			
New City	Base load	Very High	J	12.3	350
		High	K	12.3	350
		Medium	L	17.6	500
		Low	M	24.7	700
	Base load + Space heating	Very High	N	40.6	1,150
		High	P	40.6	1.150
		Medium	R	56.5	1,600
		Low	S	64.9	1,980

1/ Yearly household natural gas consumption.

Next the average incremental cost (AIC) of each network was calculated by dividing the present value of the sum of capital and operating costs by the present value of gas consumed over the period. The cost stream included all investment and operating costs from the city-gate to the final consumer. Both costs and gas volumes are discounted to take into account the different time patterns of expenditures and consumption. The resulting figure is consistent with calculations in other studies on the cost of gas development and transmission to the city-gate. The formula used for the AIC of urban distribution is shown below.

$$AIC = \sum_{t=1}^{T} I_t + (O_t - O_o)(1 + i)^{-t} / \sum_{t=1}^{T} (Q_t - Q_o)(1 + i)^{-t}$$

where I_t = investment in period t

O_t = operating costs in period t

O_o = operating cost in the base period

Q_t = gas consumption in year t

Q_o = gas consumption in the base period

i = discount rate.

In addition to the AIC, the netback of gas was calculated for each simulation. The netback represents the average price for gas, at the city-gate, in an urban distribution system that would allow the project to just break even over its lifetime. It is the average willingness-to-pay for gas by urban users, given their alternative fuel choices and the full economic cost (from the city-gate) of gas service. The netback calculation incorporates all of the information used for the AIC calculation plus the value of the fuel replaced by gas at the burner-tip. The formula is shown below:

$$\text{Netback} = \sum_{t=1}^{T} (S_t \times Q_t) \quad (1+i)^{-t} - \sum_{t=1}^{T} [I_t + (O_t - O_o)] \; (1+i)^{-t}] / \sum_{t=1}^{T} (Q_t - Q_o)(1+i)^{-t}$$

where

S_t = opportunity cost of the gas at time t,

Q_t = gas consumption in period t,

O_t = operating costs in period t,

N = netback value,

II.3 Technical Parameters

The simulations are based on a standard model area of 50,000 housing units. These are assumed to be located either in new suburbs or in part of an existing city. Figure 1 provides an illustration of a typical R&C gas distribution network. The optimal network design is somewhat shorter for the new suburbs because the lines can be laid in non-constructed areas rather than strictly following existing streets. It was assumed that the total length of the distribution system would be 20% less in a new suburb than in an existing area. Costs are also reduced by coordinating pipeline laying with installation of water and power lines, and by avoiding the need to dig up and relay roads. In addition, there are some savings in carcassing and conversion costs since inside installations and appliance purchase can be coordinated with the original building construction.

Figure 3
RESIDENTIAL AND COMMERCIAL GAS DISTRIBUTION NETWORK

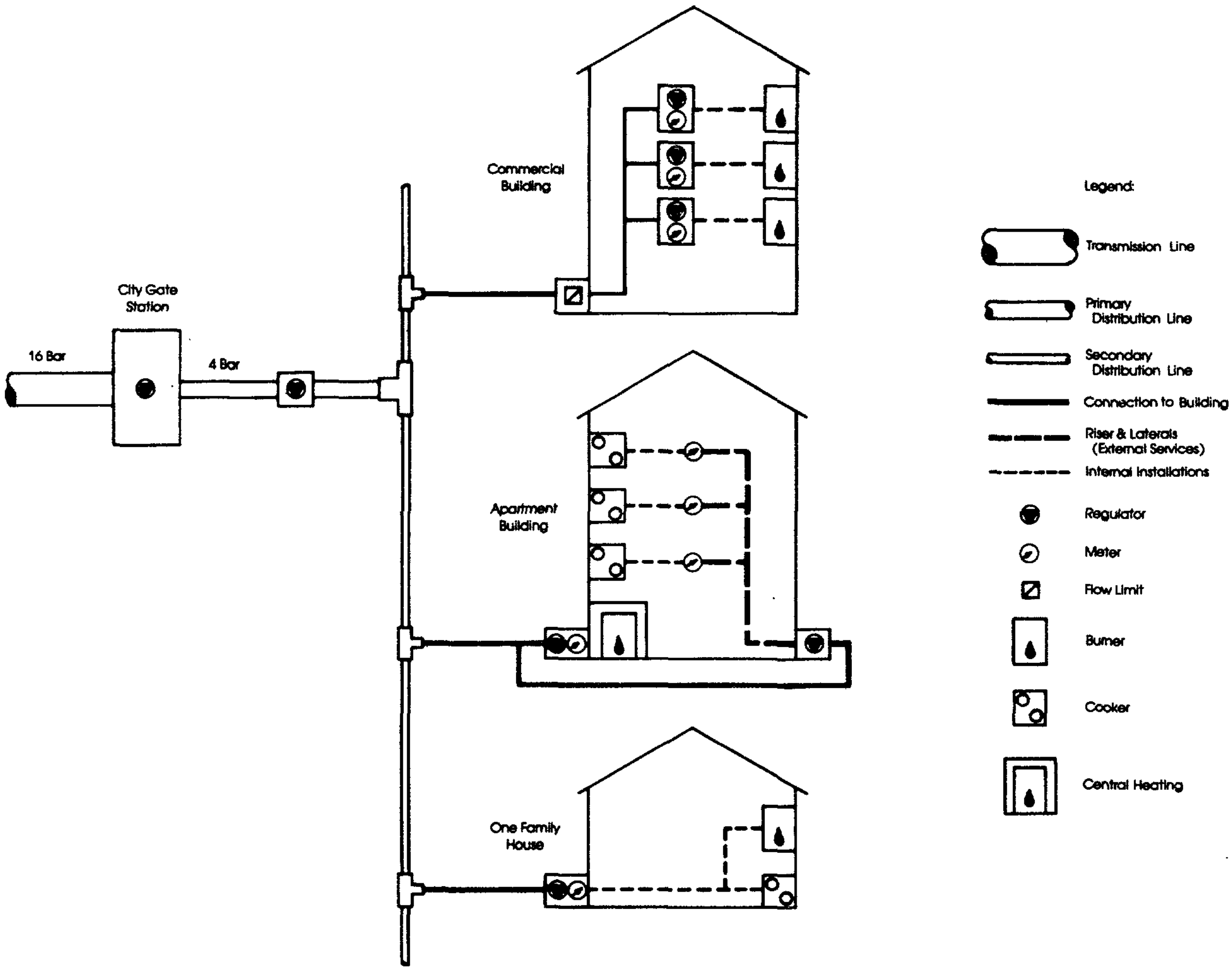

Figure 1

The second important technical parameter is the population density. Four cases were examined: very high density (VHD) with 12,000 households/km² (for example, Mexico City, Rio de Janeiro and Dhaka); high density (HD) with 6,000 households/km² (for example, Tunis and Lahore); medium density (MD) with 3,000 households/km² (for example, La Paz, Lagos and Istanbul) and low density (LD) with 1,500 households/km² (for example, Warri in Nigeria, Santa Cruz in Bolivia and North Tehran). The number of domestic customers in all cases reaches 50,000 by the time the network is complete.

The number of commercial customers in HD and MD cases is assumed to be four percent that of residential customers. This ratio is based on data from several high and medium density cities. For the VHD cases, the ratio was increased by one-third, while for the LD cases it was reduced by one-third. The density parameters are summarized in the first block of Table 3. They are the same for new suburbs and existing city areas.

TABLE 3

TECHNICAL PARAMETERS

	EXISTING CITY				NEW CITY			
	Very high density	High density	Medium density	Low density	Very high density	High density	Medium density	Low density
Cases	A, E	B, F	C, G	D, H	J, N	K, P	L, R	M, S
1 - **URBAN CHARACTERISTICS**								
Projected households	50,000	50,000	50,000	50,000	50 000	50,000	50,000	50,000
Density (households/km^2)	9,000	6,000	3,000	1,500	9,000	6,000	3,000	1,500
Surface area (km^2)	5.6	8.3	16.7	33.3	5.6	8.3	16.7	33.3
Apartments	50,000	50,000	25,000	10,000	50,000	50,000	25,000	10 000
One-family houses	0	0	25,000	40,000	0	0	25,000	40 000
Commercial premises	2,700	2,000	2,000	1,350	2,700	2,000	2,000	1,350
2 - **MARKET**								
Annual unit consumption (scf)								
- Base load	12,360	12,360	17,660	24,720	12,360	12,360	17,660	24,720
- Space-heating	40,610	40,610	55,620	64,620	40,610	40,610	55,800	64,620
Commercial consumption 1/ (%)	20	15	15	10	20	15	15	10
3 - **NETWORK**								
Length (km)	150	300	500	750	120	240	400	600
Length per consumer (m)	3	6	10	15	2.4	5	8	12
Network density (km/km^2)	27	36	30	23	21.5	29	24	18.5
One-family house service lines	0	0	25,000	40,000	0	0	25,000	40,000
Multi-story building service lines	1,650	2,500	1,250	500	1,650	2,500	1,250	500
Commercial service lines	2,700	2,000	2,000	1,350	2,700	2,000	2,000	1,350
Meters	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
4 - **EXTERNAL AND INTERNAL SERVICES**								
External services (apartments)	50,000	50,000	25,000	10,000	50,000	50,000	25,000	10,000
Internal services (apartments)	50,000	50,000	25,000	10,000	50,000	50,000	25,000	10,000
Internal services (one-family houses)	0	0	25,000	40,000	0	0	25,000	40,000
5 - **APPLIANCES**								
To install:								
Cookers	10,000	10,000	10,000	10,000	25,000	25,000	25,000	25,000
Water-heaters	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Radiators (space heating)	35,000	35,000	35,000	35,000	35,000	35,000	35,000	35,000
To convert:								
Cookers	40,000	40,000	40,000	40,000	25,000	25,000	25,000	25,000
Water-heaters	0	0	0	0	0	0	0	0

1/ Commercial consumption is given as a percentage of the residential market.

The third important technical parameter is the total gas consumption. This depends on the number of residential and commercial customers, and the unit consumption of each. The latter is a function of price, income levels and the climatic conditions of the city. For the purpose of this study, the price is assumed to be constant over all cases, and climatic variations are represented by two alternatives: with and without space heating demand. Income levels are related to the housing density assumptions, as described below.

An implicit assumption for each of the density cases is that collective and single family houses have different consumption habits. In VHD and HD cases, all households are assumed to be of a collective type (e.g., apartments). For the MD case, the ratio is 50% apartments and 50% single family houses. For the LD case, only 20% of households are assumed to live in apartments.

Experience in Tehran, Islamabad, Cairo and other developing countries suggests a high degree of correlation between the ratio of single family to collective housing and income levels. The latter, of course, is positively related to energy consumption. Based on observations from various cities, it was assumed that, without space heating, households in the VHD and HD cases would consume about 12 MCF (350 m^3) per year. This is equivalent to about two bottles of LPG per month. MD households were assumed to consume about 17 MCF (500 m^3) per year, and LD households to consume about 25 MCF (700 M^3) per year. By comparison, average household gas consumption is 112 MCF per year in the U.K., 67 MCF in Holland and 41 MCF in France and Italy.

The space heating category adds heating or air-conditioning demands to the above figures. This type of consumption has marked seasonal peaks which necessitates certain changes in the technical specifications of the distribution system. Experience from several countries indicates that gas requirements for space heating are about four times those for "base load" cooking and water heating. The figures used in this study are based on actual observations of 40 MCF per year (1,150 m^3) for apartments and about 70 MCF per year (2,000 m^3) for single family houses. Total consumption figures for all cases are summarized in the second block of Table 3. Consumption per household per year is shown below.

Table 4

Household Gas Consumption

	Without Space Heating (MCF/Yr/Household)	With Space Heating (MCF/Yr/Household)
VHD	12.4	40.6
HD	12.4	40.6
MD	17.7	56.5
LD	24.7	70.0

Consumption by the customers who are already connected is assumed to increase at an average rate of one percent from the second year of consumption. This rate of increase reflects actual operating data in several countries. In all cases, the network construction takes nine years to complete and customer connection starts after the first year of the project and lasts for about 10 years following an 'S' shaped curve. (See Figure 2). The rate of penetration, defined as the percent of connections made by a given time, is an important determinant of the value of gas. If the network construction schedule is observed, but the speed of final consumer connections is lower, then the actual consumption will fall short of planned consumption. Therefore, the actual penetration ratio has a major influence on the economics of gas distribution networks.

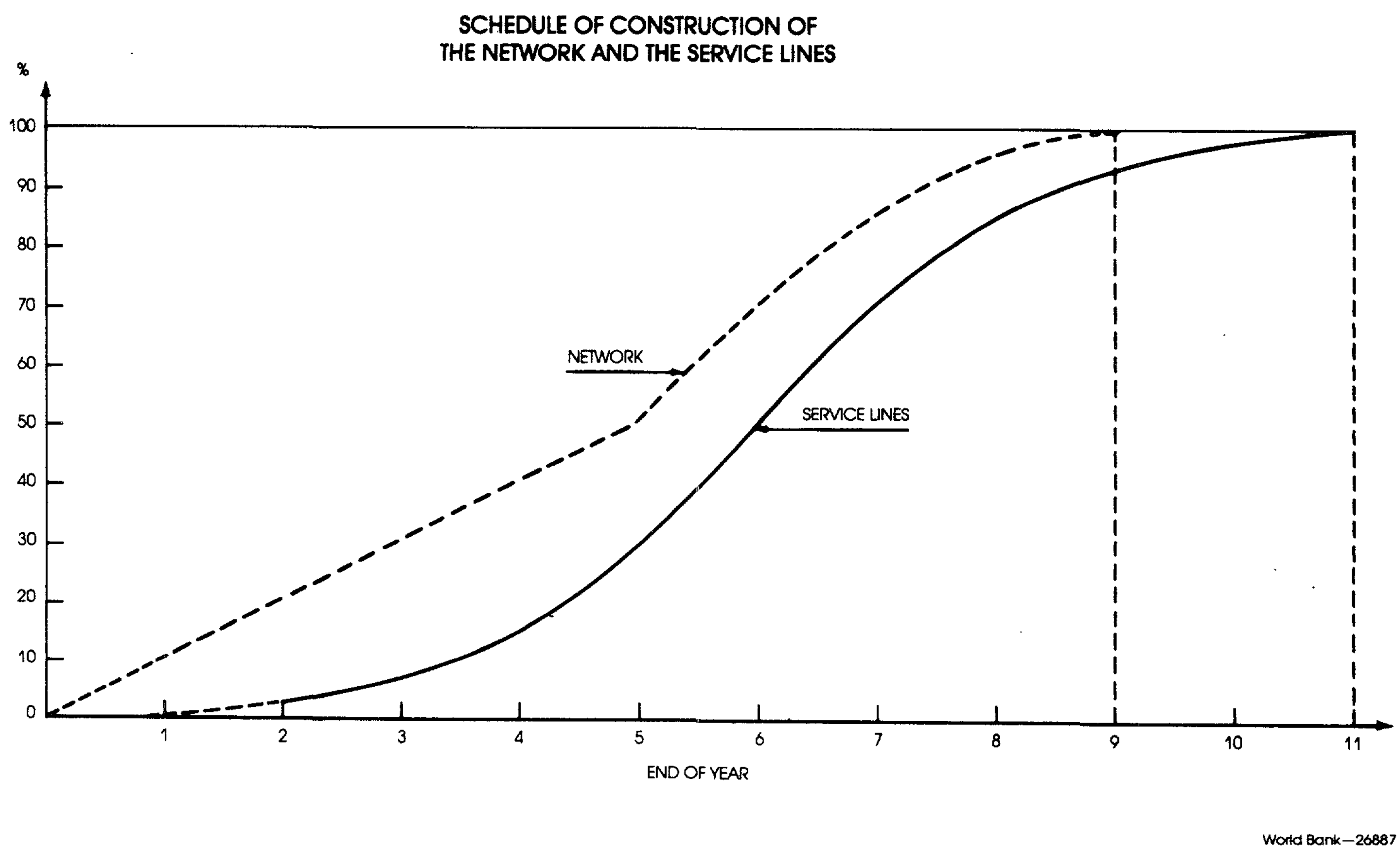

Figure 2

II.4 Costs

The basic data on technical design in Table 3 are used to determine the investment and operating costs shown in Table 5. All figures are in constant 1982 US dollars. The investment costs are the sum of three components: the distribution network, external services, and internal services.

The distribution network costs, I_1, are non-consumer related and are required regardless of the penetration ratio. They consist of the city gate station, pressure regulating and metering stations, steel pipeline network, pipe laying, fittings, and design and supervision costs. The non-consumer related costs vary with the network configuration, whose extent and length is a function of housing density. For example, the network costs for a low density zone are about five times higher than those for a high density zone. These costs also depend on the level of demand, particularly the demand for space heating. Space heating demand raises costs by 30% but the gas flow is about three to four times greater than the base load flow, thereby reducing unit costs overall by a substantial margin.

TABLE 5

CAPITAL EXPENDITURE (UNIT COSTS)
(1982 US $)

		EXISTING CITY		NEW CITY	
	Unit Cost per	Base load	Space heating	Base load	Space heating
		Cases A,B,C,D	Cases E,F,G,H	Cases J,K,L,M	Cases N,P,R,S,
I.1 City gate		Depends on the consumption		Depends on the consumption	
. Network + district regulators	meter	58.50	77.60	29.80	40.30
I.2	customer				
Flats (multi-storey building)					
. Service line + regulator		32 (1)	35 (2)	19 (1)	21 (2)
. Meter		46	46	46	46
. External service (lateral + riser)		187	200	94	100
Subtotal		265 (3)	281 (4)	159 (3)	167 (4)
One-family houses					
. Service line + regulator		480	480	257	257
. Meter		46	46	46	46
Subtotal		526	526	303	303
Small commercial premises		480	480	257	257
. Service line + regulator		46	46	46	46
. Meter					
Subtotal		526	526	303	303
Large commercial premises					
. Service line		640	700	380	420
. Regulator + meter		700	3,000	700	3,000
I.3 Subtotal		1,340	3,700	1,080	3,420
Flats (multi-storey building)					
. Internal services		178	356	143	285
. Appliances		164	434	134	404
Subtotal		342	790	277	689
One-family houses					
. Internal services		267	535	214	428
. Appliances		164	434	134	404
Subtotal		431	969	348	832
Small commercial premises					
. Internal service + appliances		431	969	348	832
Large commercial premises					
. Internal service + appliances		10,600	19,800	8,020	16,380
TOTAL UNIT COST ($I_2 + I_3$)	customer				
. Flats		607 (5)	1,071 (6)	436 (5)	856 (6)
. One-family houses		957	1,495	651	1,135
. Small commercial premises		957	1,495	551	1,135
. Large commercial premises		23,500	11,940	9,100	19,800

(1) 13 US Dollars for VHD cases
(2) 14 US Dollars for VHD cases
(3) 153 US Dollars for VHD cases
(4) 262 US Dollars for VHD cases
(5) 430 US Dollars for VHD cases
(6) 849 US Dollars for VHD cases

Consumer related costs depend on the number of customers and population density, as well as the type of city. These costs include the external and internal services and depend on the type of housing, type of consumption, and the potential volume of consumption. These can be determined by aerial photography and sample survey. The external services (I2) include service lines, mains, customer regulators, meters and external service line, laterals, risers, etc. These costs are consumer-related in an existing city and non-consumer related in a new city where the decision to equip housing units for gas is made before the housing units are constructed. The internal service costs (I3) include carcassing and conversions in existing cities and new appliances in new city cases. In single family houses these costs are about 25% higher than in apartment buildings. These costs are cut by 25% for new cities where the internal gas network service and housing construction are carried out at the same time. Appliance costs are based on observed costs in France (cooker US$91, water heater US$76 and radiator US$270), which may overestimate the costs of the same appliances in some developing countries. The unit costs are presented in Table 5.

The commercial sector includes both large users such as hospitals, hotels, colleges and office buildings; and small users such as shops, bakeries, restaurants and launderies. Large users represent 20% of commercial users and small users 80%. The service line costs for the large users are similar to those of an apartment building. The assumed costs of regulator and meters are based on those observed in France. In the case of space heating the costs of a special regulating station are included. The internal services and appliance costs differ substantially for various commercial users. For simplicity, it was assumed that these costs for commercial users are similar to those for an apartment building. Costs for small commercial users were assumed to approximate those of single family homes.

The operating costs include non-consumer related and consumer related categories. Non-consumer operating costs cover the main network personnel and maintenance. Consumer related costs depend on the number of customers and cover meter reading, bookkeeping, marketing, and legal work. These costs are all based on gas industry experience in developing countries.

II.5 Benefits

The natural gas used by the residential and commercial sectors displaces other fuels such as LPG, kerosene, gas oil, manufactured town gas, coal and non-commercial sources of energy. In many large cities, these fuels are principally LPG and kerosene. Observations in Tehran, Cairo, Tunis, and several other developing cities indicate that LPG is the primary fuel used for cooking and water heating. This study assumed that the fuels displaced by R&C gas for water heating and cooking were 80% LPG and 20% kerosene. For space heating, the porportions switch to 20% LPG and 80% kerosene, because kerosene is more commonly used for heating.[1]

The opportunity value of gas for an oil importing country consists of the international price (cif) of the fuel replaced, adjusted for the difference in marketing and distribution costs. In an oil exporting country, the fob price of the replacement fuel together with the marketing and distribution costs determine the opportunity value of gas delivered to the end consumer. There are no significant differences in fuel efficiency ratios between natural gas and LPG or kerosene. The international oil prices are based on mid-1982 price projections, and were expected to grow at about two percent a year after 1985.[2] Freight costs were found to be $55/ton for LPG and $20/ton for kerosene. The marketing costs for LPG in most developing countries are generally very high. The marketing cost for LPG used in this study was $169/ton which is observed in a number of developing countries. Kerosene marketing costs are much lower--about $34/ton, which corresponds to actual figures in a number of developing countries. The freight and marketing costs are assumed to be constant in real terms throughout the period.

1/ A survey in five suburbs of Cairo in 1980 indicated that LPG is currently used for cooking in all of the houses, for water heating in about 35% and for space heating in 3 percent. In poorer areas, some consumers have kerosene burners to heat water.

2/ Construction of these hypothetical cases is assumed to begin in 1983 and take over 5 years. Operation begins in 1984 at a very low level and starts to reach its peak by 1990. Therefore, the recent oil price fall will not change the netbacks drastically since these values are based on long-term oil price projections. Further, all the value-in-use studies are based on similar prices projections and will therefore remain consistent and comparable. The pricing projections for oil exporting countries are fob and therefore lower and closer to today's cif prices.

III. RESULTS AND SENSITIVITY TESTS

III.1 The Average Incremental Cost (AIC) of Gas Distribution

As indicated in the previous section, the netback is estimated as the difference between the benefits from gas use and its costs. The cost of gas distribution is provided in this section. AIC of gas distribution at an 8% discount rate is presented in Table 6. These costs are very sensitive to the volume of gas use which depends on whether gas is used for space heating. Another important determinant of costs is whether the distribution system is planned in an existing city which requires carcassing, as compared to a new city.

Costs are also very sensitive to the type of city. In an existing city with space heating, costs are only about $3.1 to 4.5 per MCF; these costs fall to a range of $2.1 to 3.2 per MCF in a new city. In the cases without space heating, costs are far higher and in an existing city can be as high as 11.1/MCF and in a new city as high as 7.6. The costs of gas exploration, production and transmission to the city-gate would have to be added to these distribution costs to derive the total gas supply costs. In many developing countries the costs of gas supply to the city-gate is close to $1.50/MCF. This increases total costs of gas supply to a range of $3.60 to $12.60 per MCF.

Table 6

Incremental Costs of Gas Distribution
($/MCF)

	Without Space Heating	With Space Heating
Existing City		
VHD	8.0	3.5
HD	11.1	4.5
MD	10.7	3.1
LD	10.1	4.5
New City		
VHD	6.3	2.8
HD	7.6	3.2
MD	6.9	2.1
LD	6.3	2.9

Netbacks and Net Present Values

The gas netback values (excluding gas exploration, production, and transmission costs) are presented in Tables 7 and 8. There is a wide range of netback values for gas used in the residential and commercial sectors. The netback values are generally between $3.30 - 10.01 per MCF. The lower bound of netbacks compares favorably with the netbacks based on fuel oil replacement in many industries. On the whole, the netback and the net present value figures are higher than is generally perceived. This is so in spite of high distribution costs because of the opportunity cost of gas as determined by the price of LPG, kerosene, and gas oil.

The most important determinant of the net present value and the netback values is the volume of gas consumed. The net benefits from a distribution system built to satisfy space heating and base load (cooking and water heating) requirements more than outweighs the increased costs of this system. Many developing countries such as Bolivia, Iran, Peru, Pakistan and Turkey, require space heating in many cities, over a long winter period. Other countries such as Morocco, Tunisia, Algeria, and some Latin American countries need space heating only during limited periods in certain areas. Many developing countries, can also use gas for air conditioning as is done in Bahrain. This latter air conditioning demand was not included in the study, although it could improve the economics of gas distribution projects using gas for air conditioning.

Table 7

Netback Value for Gas at the City-Gate
($/MCF)

	Without Space heating		With Space heating	
	Oil Exporting Country	Oil Importing Country	Oil Exporting Country	Oil Importing Country
Existing City				
- VHD	5.02	6.38	8.62	9.38
- HD	1.96	3.30	7.53	8.29
- MD	2.39	3.75	7.71	8.47
- LD	2.93	4.29	7.49	8.25
New City				
- VHD	6.73	8.09	9.25	10.01
- HD	5.44	6.80	8.80	9.59
- MD	6.14	7.50	9.13	9.89
- LD	6.78	8.14	9.15	9.91

Table 8

Net Present Values 1/
(in 000 US$)

	Without Space heating		With Space heating	
	Oil Exporting Country	Oil Importing Country	Oil Exporting Country	Oil Importing Country
Existing City				
- VHD	19,100	25,559	118,949	130,813
- HD	4,287	10,480	97,653	109,026
- MD	81,046	25,896	139,769	155,589
- LD	16,842	28,690	159,915	178,642
New City				
- VHD	27,215	33,674	128,792	140,656
- HD	20,235	26,428	116,751	128,124
- MD	33,468	50,318	169,153	184,973
- LD	50,358	62,206	200,800	219,527

1/ Includes gas costs at $1/MCF.

Population density also influences the netback values through its effect on total gas consumption. Generally, in the very high density cities (such Dhaka and Mexico City), there are economies in the use of gas in the network as well as the external services. However, the netback in high density and medium density categories is often lower than that of low density cities because of the assumption about average unit consumption per household. The consumption of single family, high income houses which are predominant in low density zones far outweighs the consumption of customers living in apartments.

Another major determinant of the netback value is the type of city. The netback in new cities if far greater than for existing cities because services lines, external services, and internal services are laid at the construction stage, while existing cities incur carcassing and conversion costs.

The sensitivity of net present values and netbacks with respect to whether a country is an oil exporter or oil importer was also tested. The netbacks in oil importing countries are higher by between 8 to 25% than those in oil exporting countries because of the difference between the cif and fob prices of fuels that can be replaced by natural gas. Also, the present value of net benefits and netback values are very sensitive to discount rates and fall quite drastically at higher rates. For example, for case A, an increase in the discount rate from 8% to 12% reduces the netback value from 6.38 to 4.57 per MCF. Also at a 12% discount rate, there are some negative netback values for cases B and C with no space heating in an oil exporting country.

Overall, the netback values are sensitive to the cost of natural gas delivered to the city gate station. The netbacks in Tables 7 and 8 should be properly adjusted for the specific cost of gas delivered to the city gate in any given country. In most cases, with an 8% discount rate, the netbacks remain positive with a gas cost up to about $3/MCF. However, when the cost of gas production and transmission is high, the netbacks for base load use in an existing city are relatively low. The net present values in Table 8 include a gas cost of $1/MCF at the city-gate.

The study demonstrates that the use of gas in the residential and commercial sectors could provide significant economic benefits, as indicated by the high net present value estimates. These benefits are more pronounced in oil importing countries which use gas for space heating. Density parameters affect netbacks, but overall impacts vary depending on the actual case. However, even for countries using gas only for base load purposes, there are often significant economic benefits to be obtained provided it is technically possible to build a gas distribution network at reasonable cost.

ANNEX I

THE SCOPE FOR REDUCING COSTS OF GAS DISTRIBUTION NETWORKS

1. Suggestions for Reducing Gas Distribution Costs

Existing gas distribution networks in developing countries generally have been designed on the basis of experience in developed countries. In developing countries labor costs are lower and capital costs are higher than in developed countries. As a result total costs are not very different between developing and developed countries. Adapting designs and equipment to local conditions and regulations should result in measurable cost reductions. Much more applied research by the gas industry in both developed and developing countries is needed to identify the potential cost saving measures and to adapt the technology and equipment to local conditions.

Several measures to reduce costs are described below. Not all have been applied so far in practice, but are nevertheless expected to provide potential substantial savings. These savings are based on adapting the design, architecture and technology of distribution networks and equipment to fit local requirements while maintaining adequate safety and quality standards.

2. Distribution Networks Design and Architecture

Distribution networks are designed differently, depending on the country where they are studied and constructed. Modern distribution networks are constructed with two pressure levels: a primary network operating at a maximum pressure of 19 bar and a secondary network operating at maximum pressure of 4 bar. Both are very flexible in allowing growth in consumption.

One cost saving could be made by using a simple, medium-pressure distribution network that uses dead-end lines going out from district regulating stations. General use of a dead-end network system reduces the diameter of certain lines, and the number of valves used, yielding a savings of about 10% over the costs of traditional distribution network costs. However, the quality of service is somewhat reduced with this system since all the customers connected on a dead-end line may be without gas during repairs. Further cost reductions could be made by using polyethylene pipes for pipeline diameters of 6m inch or less in medium pressure distribution networks. This could save 10% of the cost of a steel network.

Another way to reduce cost is by changing the design of regulators. Installing a single line district regulator and standardizing the equipment to allow quick repair of installation could save 20% of the cost of a double line district regulator.[1]

3. External and Internal Services and Operating Costs

The cost of a meter assumed in this study is $46. This is about 10% of the cost of an individual service line. In some cities where consumption can be controlled in other ways, meters can be excluded from the system. Otherwise, as in Pakistan, simple meters could be produced domestically.[2] The internal services and appliances also can be produced locally or simplified to allow easy maintenance while ensuring safety. Operation and maintenance costs also can be reduced by reducing the number and types of different equipment (e.g. pipeline diameters) and by reducing the required stock. A criterion also could be imposed that only equipment with a low maintenance be selected.

1/ The simpler district regulator has only one regulating line with a single safety system; this safety system must be reliable enough for safety.

2/ The cost of meters produced in Pakistan is $40/meter.

ENERGY DEPARTMENT PAPER SERIES

EGY PAPER No. 1

Energy Pricing in Developing Countries: A Review of the Literature by DeAnne Julius (World Bank) and Meta Systems (Consultants). September 1981. 121 pages, includes classified bibliography.

Reviews literature on the theory of exhaustible resources and on sectoral, national and international models for energy demand. Emphasis on project selection criteria and on pricing policy as a tool of energy demand management.

EGY PAPER No. 2

Proceedings of the South-East Asian Workshop on Energy Policy and Management edited by Michael Radnor and Atul Wad (Northwestern University). September 1981. 252 pages.

Contains the edited version of the lectures and discussions presented at the South-East Asian Workshop on Energy Policy and Management held in Daedeok, South Korea, October 27-November 1, 1980.

Topics that are addressed include: the overall problem of energy policy and its relationship to economic development; the management of energy demand and related data; the role and value of models in energy planning, and the use of energy balances. Transport and rural sectors are also discussed in terms of their relationship to energy planning.

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Energy Pricing in Developing Countries: Lessons from the Egypt Study by DeAnne Julius (World Bank). December 1981. 14 pages.

Study on the effects of energy price change in a developing country. Provides insight into the mechanisms through which energy prices affect other prices in the economy and, therefore, the incomes of rich and poor consumers, profitability of key industries, the balance of payments, and the government budget.

EGY PAPER No. 4

Alternative Fuels for Use in Internal Combustion Engines by G.D.C., Inc. (Consultant). November 1981. 179 pages, includes appendices.

Presents several alternative fuels used as replacement for conventional (gasoline and diesel) fuels in internal combustion engines. These alternatives, including LPG, natural gas, alcohol and producer gas, are derivable from natural resources that exist in so many developing countries. Also provides up-to-date information on the newest alternative fuel option currently available and those that are being developed and tested.

EGY PAPER No. 5

Bangladesh: Rural and Renewable Energy Issues and Prospects by Fernando R. Manibog (World Bank). April 1982. 64 pages, includes bibliography.

Analyzes subsector issues and recommends courses of action for energy project possibilities; identifies renewable energy projects which could create a positive impact in the short to medium term.

EGY PAPER No. 6

Energy Efficiency: Optimization of Electric Power Distribution System Losses by Mohan Munasinghe (World Bank) and Walter Scott (Consultant). July 1982. 145 pages, includes appendices.

Discusses the reasons for high existing levels of power distribution losses in developing countries. Identifies areas within a power system where loss optimization would be most effective. Shows that reducing losses is often more cost effective than building more generation capacity.

EGY PAPER No. 7

Guidelines for the Presentation of Energy Data in Bank Report by Masood Ahmed (World Bank). October 1982. 13 pages (includes 4 Annexes).

The growing importance of energy issues in national economic management has led to increased coverage of the energy sector in many types of reports. However, there is still no clear, consistent and standardized format for presenting energy sector information. This paper reviews the problem and proposes guidelines for policymakers and operational staff who deal with energy issues. The paper is divided into three parts: part one sets out the basic framework for presenting aggregated energy data -- "the national energy balance"; part two deals with the use of appropriate units and conversion factors to construct such a balance from raw demand and supply data for the various fuels; and part three briefly discusses special problems posed by: (i) differences in end use efficiency of various fuels; (ii) the inclusion of wood and other noncommerical energy sources; and (iii) the conversion of primary electricity into its fossil fuel equivalent.

EGY PAPER No. 8

External Financing for Energy in the Developing Countries by Althea Duersten (World Bank). June 1983. 66 pages, includes appendices.

Provides an overview of energy financing in the developing countries. Identifies energy investment requirements and past financing patterns. Discusses the historical roles of multilateral and bilateral assistance programs in helping to mobilize financing, particularly for low income oil importers and in providing economic and sector advice. Examines the role of official export credit, and discusses lending by private financial institutions which has been the predominant source of financing for energy projects in the middle and higher income developing countries.

EGY PAPER No. 9 — Guideline for Diesel Generating Plant Specification and Bid Evaluation by C.I. Power Services, Inc. (Consultant). December 1982. 210 pages, includes appendices.

Explains the characteristics and comparative advantages and disadvantages of large low speed two-stroke diesel engines intended for electric generating plant service, and develops a bid evaluation procedure to permit comparing of bids for both types.

EGY PAPER No. 10 — Marginal Cost of Natural Gas in Developing Countries: Concepts and Application by Afsaneh Mashayekhi (World Bank). July 1982. 21 pages, includes appendices.

Defines the concept of marginal cost and average incremental cost. Uses the detailed supply, demand and investment data to apply this concept to estimate the average incremental cost of natural gas supply to major markets in ten developing countries. Demonstrates that the cost of natural gas delivery to the city-gate in many developing countries is far below the cost of competing fuels.

EGY PAPER No. 11 — Power System Load Management Techniques by Resource Dynamics Corp. (USA) Consultant. November 1983. 132 pages.

In recent years, techniques referred to as load management have begun to play an important role in shaping the patterns of electricity consumption in industrialized countries. Along with pricing, a variety of hardware is used to control loads directly and save on energy and peak capacity. This study reviews the state-of-the-art of these so-called "hard" techniques in light of recent technological advances, provides data on cost and manufacturers of this equipment, and identifies controllable loads in developing countries.

EGY PAPER No. 12 — LNG Export Opportunities for Developing Countries and the Economic Value of Natural Gas in LNG Exports by Afsaneh Mashayekhi (World Bank). November 1983. 36 pages, includes appendices.

This paper reviews the LNG export opportunities for developing countries and clarifies some of the issues related to economic costs and benefits of LNG projects from the point of view of an exporting country. It identifies the major technical parameters that affect costs and analyzes factors affecting the economic size of projects and the effect of scaling them down. Its principal objective is to estimate, given explicit assumptions, the netback values for gas at various stages in the LNG delivery system. It examines three basic scenarios of small and medium scale projects as well as a multi-destination project with several small markets. It also tests the sensitivity of netbacks to the level of infrastructure, discount rates and the price of gas delivered at the importing country.

EGY PAPER No. 13 — Identifying the Basic Conditions for Economic Generation of Public Electricity from Surplus Bagasse in Sugar Mills by Syner-Tech Inc. (USA). October 1983. 167 pages, includes appendices.

The study identifies several ways, all using presently available technology, to greatly increase the overall energy efficiency of existing mills, produce surplus bagasse and generate electricity for sale to the grid. These include installing pre-evaporators to conserve steam, drying wet bagasse with flue gasses to improve combustion efficiency, installing high-pressure boilers to increase steam generation efficiency and pelletizing or compressing bagasse to enable it to be stored and used beyond the harvest season.

EGY PAPER No. 14 — A Methodology for Regional Assessment of Small Scale Hydropower by Tudor Engineering Company (USA). December 1983. 105 pages.

This paper presents a methodology for regional assessment of small hydropower development potential involving sampling procedures, study execution, energy planning, regional hydrology development, technical site evaluation, cost and economic analysis, environmental and social considerations. Its use should result in reasonably accurate estimates in a short period of time of the viable small-scale hydroelectric projects in a particular region or country. A development program based on such an assessment would be of sufficient reliability to support requests for financing assistance.

EGY PAPER No. 15 — Central America Power Interconnection: A Case Study in Integrated Planning English Summary by Fernando Lecaros (Consultant). April 1984. 55 pages.

This paper is a summary of the study, titled "Regional Electrical Interconnection Study of the Central American Isthmus", performed by the Regional Office in Mexico of the United Nations' Economic Commission for Latin America (ECLA) between 1975 and 1979. Its goal was to provide a firm economic and technical foundation to decisions about the interconnection investments in the region. The purpose of this English Summary is to disseminate the methodology retained by ECLA and to show an example of integrated system planning using models such as WASP developed by the International Atomic Energy Agency. The figures reproduced in this report are limited to the extent necessary for these illustrative purposes.

EGY PAPER No. 16

An Economic Justification for Rural Afforestation: The Case of Ethiopia by Ken Newcombe, World Bank. June 1984. 23 pages, includes appendices. It has proven difficult to quantify the economic benefits of large-scale rural afforestation and to establish the priority for public investment in traditional rural energy supply vis-a-vis investment in the supply for modern fuels (electricity, petroleum) to the urban industrial market. This paper outlines, in simple terms, the biological links between deforestation and agricultural production at the subsistence level, and quantifies the economic benefits of increased food production obtained by replacing animal dung as a fuel with firewood from rural forestry programs.

EGY PAPER No. 17

The Future Role of Hydroelectric Power in Developing Countries by Edwin Moore (World Bank), George Smith (Consultant). June 1984. 59 pages, includes annexes.

The study examines the role of hydroelectricity in the power programs of 100 developing countries in the period 1982-1995. The report indicates that hydro will continue to play a significant role, accounting for 43% of electricity production in 1995. Preparation and engineering expenditures of about $10 billion will be needed in 1982-1990 for the projects required to support this growth. The study concludes that an intensified hydro program would add only 3% to the capacity otherwise planned because the main constraints to hydro development are economic and lack of poor markets rather than lack of knowledge about resources and prospective projects. Nonetheless, the study identifies specific actions that can be taken in many countries to accelerate hydro development.

EGY PAPER No. 18

Guidelines for Marginal Cost Analysis of Power Systems by Yves Albouy (World Bank). June 1984, 31 pages, includes annexes.

These guidelines provide hands-on but state-of-art instructions for conducting a sound and quick analysis that yields the marginal cost structure needed for applications in the power sector and for the review of related studies. These include not only pricing but also the less known marginal analysis of system planning decisions. The paper does not give the detailed theoretical background but draws on the reference literature. It illustrates the basic principles and calculation methods with the help of many examples going from the simplest to the more complicated system conditions.

EGY PAPER No. 19

The Value of Natural Gas in Power Generation by Yves Albouy and Afsaneh Mashayekhi (World Bank). November 1984. 28 pages.

This paper is one of a series to examine the "netback value" of natural gas in major domestic and export uses. The netback can be compared to the cost of gas to permit a rough estimate of the net economic benefit to gas use in various sectors.

With the help of case studies and simple calculations, the netback value to power generation is found to be fairly high on average even though it diminishes as the use of gas spreads from peak to base load. The paper also highlights the important role of power in the natural gas market and the specific analytical framework in which an assessment of this role can be undertaken for preliminary gas utilization studies.

EGY PAPER No. 20

Assessment of Electric Power System Planning Models by Yves Albouy (World Bank) and Systems Europe, Consultant (Belgium). January 1985. 107 pages, includes annexes.

This paper addresses both the models and methods for power generation and transmission planning. It provides first an overview of the methodology preferred by the Bank and of the promiment planning issues in developing countries. On this basis the study attempts to assess the applicability of forty five models now available from leading utilities and consultants. The paper also contains recommendations on the development and use of models. An extensive bibliography is given in the Annex.

EGY PAPER No. 21

Diesel Plant Performance Study by C.I. Power Services Inc. (Canada). February 1985. 83 pages.

The study was prepared under an EGY-sponsored research project as a guideline for use by Bank staff and consultants. This report summarizes the results of an investigation of the performance and cost of operation of four stroke medium speed engines and two stroke low speed engines used as prime movers for electricity generation in both developing and developed countries. Operating data for units of 4,000 kW and larger was collected from 28 countries and is analyzed here. Data from some 3000 - 4000 kW units was also incorporated.