# NATURAL GAS POTENTIAL IN INDIA

by

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## SECTION I

## A BACKGROUND REVIEW OF RECENT ENERGY TRENDS AND DEVELOPMENTS IN INDIA

### 1. INTRODUCTION

In this paper we have attempted to review recent developments and trends in the consumption and supply of energy in India. This has been done primarily to discuss tentative directions and priorities for India's medium-term energy policy and to provide a background for discussion on the role of natural gas in the Indian economy.

A useful reference point against which recent energy developments can be assessed is the scenario of projections provided by the Working Group on Energy Policy (WGEP) in respect of different forms of energy consumed in the country.

Whereas the WGEP looked at demand and supply prospects extending upto the beginning of the 21st century, we would confine our comparisons to WGEP's predictions upto the year 1982-83. Fortunately, the recent report of the Advisory Board on Energy (ABE) has already carried out a comparison of actual or estimated consumption of different forms of energy as against the WGEP's predictions, and we have, therefore, used the

ABE's estimates and figures in carrying out this disaggregated analysis by energy source and for all major sectors.

The first set of assumptions which need to be reviewed relate to the growth of the Indian economy. The WGEP had assumed an annual growth of 4.7% for the period 1977-78 to 1982-83, but as against this the achievement during the period has been only 3.02% per annum. This five year period has, therefore, been one of low economic growth, which needs to be borne in mind in making predictions for a more optimistic growth future. Inter-sectorally this growth has shown some unexpected disparities. For instance, the agricultural sector which was expected to grow at 2.76% annually during this period, actually grew at only 0.36% in terms of output. Similarly, industrial output which was expected to grow at a rate of 5.03%, actually grew at 3.32% during the period as a whole. In contrast, however, the transport sector which was expected to grow at only 4.65% annually actually grew at 6.54% during this period. The major variable determining the size of the household or residential sector, namely, population also grew at a rate very different from the assumptions of the WGEP. Consequently the estimated population in March 1983 was actually 727 million, which was almost 30 million higher than the estimate of the WGEP.

Since the pattern of fuel consumption varies considerably across sectors, these changes in growth from the assumed growth rates used by the WGEP in its projections for energy demand have resulted in a significantly different mix of energy demand during this period and consequently have in some cases resulted in a greater degree of unfulfilled demand than was anticipated.

## 2. TRENDS IN CONSUMPTION OF DIFFERENT FORMS OF ENERGY

Changes in sectoral growth over the values projected by the WGEP are not the only reasons for a deviation of actual energy consumption from the WGEP's projections, but several other factors, both economic and non-economic, have been responsible for these recent differences. Some of these factors can be broadly identified and discussed sector by sector.

### Household Sector

Looking at the household sector, for instance, the actual consumption of different fuels as against the reference level forecast (RLF) of the WGEP for this sector can be seen in Table I.

**Table I**

**RLF and Actual Energy Use in Household Sector (1982/83)**

| | **Unit** | **RLF** | **Actual** | **Variation** |
|---|---|---|---|---|
| Electricity | bkwh | 10.7 | 11.96 | + 1.26 |
| Kerosene | mt | 4.76 | 5.19 | + 0.43 |
| LPG | mt | 0.71 | 0.52 | - 0.19 |
| Soft Coke | mt | 3.00 | 1.73 | - 1.74 |

Source: Advisory Board on Energy

It would be seen that the excess of electricity consumption over the WGEP's forecast is about 12% of the forecast value for 1982-83. Whereas part of this can be explained by population growth faster than anticipated (even though within the 5 year time span covered, this difference in population growth would not have been substantial), the major reason appears to be that forecasts for the household sector produced in previous such exercises including the report of the WGEP have ignored the income elasticity of demand. Given the availability of a large number of electrical appliances in the Indian market the income elasticity of demand for electricity in the household cannot be treated as insignificant, and is likely to be a major factor in determining future demand in this sector. Mention must be made in particular of the increase in airconditioning load, particularly in metropolitan areas, increase in electrical heaters for water and space heating, particularly in North India, and the larger number of fans and desert coolers, etc. that are being installed throughout the country.

An indication of the growing saturation of household electrical appliances can be seen in the increased production of some of these items, as shown in Table II.

**Table II**

**Production of Household Appliances for Selected Years (in Thousands)**

| | Portable Room Air-conditioners | Refrigerators | TV sets | Electric Fans | Incandescent Lamps |
|---|---|---|---|---|---|
| 1970 | 17.0 | 65.4 | 5.1 | 1,570 | 10,300 |
| 1975 | 19.0 | 108.9 | 39.4 | 1,310 | 12,900 |
| 1980 | 26.2 | 278.6 | 86.8 | 4,120 | 20,200 |
| 1983 | 28.0 | 450 | 139.0 | 4,440 | 27,300 |

Source: Economic Intelligence Service Centre for Monitoring Indian Economy, Production and Capacity Utilisation in 650 Industries 1970 to 1983, November 1984.

As regards the consumption of kerosene in the household sector, whereas the low growth in rural electrification is an important determinant of the demand for kerosene, here again there is evidence of significant income elasticity, which is shown in the higher consumption per household of kerosene in the 32nd round of the National Sample Survey (1977-78) at 37.62 litres for rural and 78.66 litres for urban consumers as against the 28th round (1973-74) estimates of 29.76 litres for rural and 78.66 litres for urban households respectively. The WGEP's norms for consumption per household were based on the latter. The NSS survey is also closer to some other surveys recently carried out than the WGEP's norms for kerosene consumption.

A disturbing feature of household energy consumption is the decline in consumption of soft coke during the period 1976-77 to 1982-83, wherein total recorded consumption actually reduced from 3.16 million tonnes in 1976-77 to 1.73 million tonnes in 1982-83. Also there is considerable regional disparity in soft coke consumption, as would be anticipated, with the States near the country's coal belt consuming the bulk of these quantities.

In general, the trends of the late 70s and early 80s indicate that the demand for electricity would go up substantially, and given that population would be higher than the forecasts of the WGEP, the demand for non-commercial fuels would also continue to be higher than projected.

The most critical problem with household energy consumption, in fact, is the problem of non-commercial forms of energy and the nexus between increasing fuelwood consumption and deforestation in various parts of the country. Several estimates of fuelwood consumption have been attempted by various researchers and committees set up by the Government, but as yet there is no consistent set of estimates available for the country as a whole, and much less so for different regions in the country.

Since energy scarcity in several parts of the country is already limiting household energy consumption, the ABE has made a departure from past practice (in keeping with its earlier recommendation of treating energy for cooking as a basic minimum need) and calculated future demand on the basis of useful energy required for an average household. On this basis fuel scarcities for cooking would be even more serious than estimated earlier. It would perhaps not be relevant to go into the various surveys carried out on this subject, but it is becoming increasingly apparent that the consumption of energy per household, in some rural areas is dipping further below normative levels estimated on the basis of minimum cooking requirements and existing efficiency of appliances and methods used for cooking in this sector.

It is also obvious that the degree of scarcity is likely to grow in the future, unless there are major improvements in appliance efficiency and a larger availability of existing non-commercial fuels or substitutes. In several forums the question of directing natural gas resources to the fulfilment of these needs have been discussed, but the magnitude of the task is quite daunting. The demand for fuelwood in urban areas is contributing to the physical scarcity of non-commercial fuels in rural areas, and one means by which this trend can perhaps be arrested is to ensure larger distribution of fossil fuels for domestic consumers in cities and towns, whereby the pressure on fuelwood markets, which originate largely in rural areas could be reduced.

**Agricultural Sector**

The agricultural sector has also exhibited very rapid growth in demand for different forms of energy. The ABE's estimates for consumption in 1982-83 as against the WGEP's projections are shown in Table III.

Table III

RLF and Actual Energy Use in Agriculture (1982/83)

| Item | Unit | RLF Projections | Actuals |
|---|---|---|---|
| Electricity | bkwh | 16.20 | 17.79 |
| Diesel oil for pumps* | mt | 2.60 | 2.55 |
| Diesel oil for tractors | mt | 1.10* | 1.065* |
| Specific Consumption/ Electric motor | kwh/ year | 3000 | 3577 |
| Specific consumption/ Diesel engine | t/year | 2.5 | 2.5 |

* Includes consumption by power tillers & crawler tractors.

Source: Advisory Board on Energy

It should be mentioned that the consumption of diesel fuel for pumps estimated as shown above cannot be taken as reliable, since there is really no factual data base for such estimation. In a recent study that the Tata Energy Research Institute attempted for the Oil Coordination Committee, it became apparent that there was a major data gap for estimation of specific appliance based consumption figures, and this gap can only be filled up through a system of periodic surveys designed and conducted on a scientific basis.

There are two major conclusions that can be drawn from a detailed study of the agricultural sector in this country:

(1) The demand for energy in the aggregate will continue to grow rapidly for the sector as a whole to take up a larger share of total energy consumption in the country.

(2) Since the supply of power in rural areas is characterised by various forms of unreliability of supply, a larger number of diesel pumpsets will continue to find preference with farmers, such that the demand for diesel oil would continue to grow rapidly, adding to the existing imbalance in petroleum products. To this may also be added the observation of the ABE that LDO and HSD consumption in pumpsets, and commercial energy consumption in agriculture in general is being under-reported. This is a situation which requires the development of a suitable information base through periodic surveys to be carried out in different parts of the country, and perhaps the Central Statistical Organisation should take up this task in coordination with other departments and ministries.

**Industrial Sector**

In the case of the industrial sector, while overall energy consumption has been lower than projected by the WGEP, the major factors responsible for this are inadequate supply in some years during this period and a lower rate of industrial growth. Table IV shows the consumption of major forms of energy in the industrial sector as compared to the projections of the WGEP:

**Table IV**

**RLF and Actual Energy Use in 1982/83**
**RLF**

| Fuel | Unit | Projections | Actuals | Variation |
|---|---|---|---|---|
| Electricity | bKwh | 85.0 | 61.62 | - 23.38 |
| Oil (Furnace Oil) | 106 tonnes | 4.5 | 4.00 | - 0.50 |
| Coking and Blendable Coal | " | 34.00 | 23.20 | - 10.80 |
| Non-Coking Coal | " | 40.9 | 33.90 | - 7.00 |

Source: Advisory Board on Energy

In the case of electricity consumption the lower rate of growth in consumption is accounted for by lower than anticipated overall intensity of electricity use. This no doubt has taken place largely on account of inadequate supplies of power resulting in a forced lower intensity of electricity use, particularly in the more energy intensive industries and lower output in these particular industries. An industry by industry analysis of actual electricity consumption in the year 1982-83 carried out by the ABE explains the lower rate of consumption of power as against the WGEP's projections as resulting from lower output levels, without any major decline in the intensity of electricity use. What has happened in the aggregate is that intensity of power used in industry has not grown as rapidly as projected by the WGEP.

In the case of coal and oil use in the industrial sector, while there was lower consumption at 33.9 million tonnes against a projection of 40.9 million tonnes in the case of coal, the consumption of petroleum products was 4.6 million tonnes inclusive of furnace oil, LSHS and LDO. Taken together in terms of million tonnes of coal equivalent, the intensity of coal and oil used in the industrial sector was somewhat lower than the projections of the WGEP (0.819 KgCE/rupee of value added as compared to 0.9 KgCE/rupee). This improvement over earlier projections can largely be attributed to efforts at more efficient use of petroleum products.

The conclusion, however, is quite unmistakable that lower consumption of energy in the industrial sector was brought about largely by a low level of industrial output as well as constraints in the supply of different forms of energy, particularly power.

**Transport Sector**

In the case of the transport sector, the level of traffic projected by WGEP, the National Transport Policy Committee (NTPC), and the actuals or estimates of consumption in 1982-83 are shown in Table V.

**Table V**

**Traffic forecasts and Actuals** (for 1982/83)

| (i) **Railways** | **WGEP** | **NTPC** | **Estimated/ Actual** |
|---|---|---|---|
| Passenger Traffic | | | |
| (Intracity) bpkms | 44 | 50 | 45.8 |
| (Intercity) bpkms | 160 | 160 | 181.1 |
| Freight Traffic btkms | 200 | - | 177.8 |

| (ii) **Road** | **WGEP** | **NTPC** | Actual |
|---|---|---|---|
| Passenger (bpkms) | 370 | 370 | 585 |
| Passenger (bpkms) Car,2-wheeler, taxi etc. | 77.7 | - | 62 |
| Passenger (bpkms) Bus | 293.3 | - | 525 |
| Freight (btkms) | 114 | - | 148-179 |

Source: Advisory Board on Energy

From these figures it can be seen that the level of passenger traffic has been higher than estimated by the WGEP in the case of railway transport and much higher than estimated both by the WGEP and the NTPC transport. Another observation which is clear is that there was obviously a shift in favour of greater freight transport by road which outweighed the somewhat lower than projected freight transport by rail. Again, it appears that the income elasticity of demand for passenger transport was underestimated by both these

Committees as also perhaps the price elasticity which was in evidence as a consequence of low real prices of passenger transport constrained by several factors which restrict them to popular low tariffs.

The methodology for projecting demand in the transport sector needs stronger conceptual underpinnings and an explicit inclusion of income and price factors. For instance, one of the forecasts made by an official body two years ago taking into account a larger fleet of fuel efficient cars in the future actually predicted a decline in the consumption of petrol on the basis of a fixed norm of kilometers per vehicle. It must be understood that with more fuel efficient cars resulting in a lower cost per kilometer, the demand for passenger car utilisation will go up in accordance with the price elasticity of demand for these services and the kilometres per car for a Maruti will not be the same as for an Ambassador with the same owner in both cases. Here again is an area where much greater rigour is required to model the demand for transportation services and, therefore, the derived demand for different forms of energy.

## 3. THE SUPPLY SCENARIO

The prospects of supply of different forms of energy are directly dependant on the input of various resources for creation and operation of supply capacity. There are, however, several issues related to management of the energy sector which would have a direct impact on energy supply. While allocation of resources is determined largely by the planning process, there are reasons why perhaps some institutional innovations need to be considered in the present context, by which capital and other inputs required for the production of energy could be mobilised from outside the public sector as well. In the aggregate, total supply would depend on the rate at which investments are made in establishing new capacity and the operating efficiency which determine production from such capacity.

It is increasingly clear that the energy supply industry, particularly for conventional fuels, is becoming increasingly capital intensive. An indication of this can be seen from the fact that the average cost per kilowatt of new thermal power projects went up from Rs.2144 per kilowatt in 1974-75 to Rs.4691 per kilowatt in 1981-82. In real terms this increase amounts to an increase from Rs.1239.3 per kilowatt in 1974-75 to Rs.1667 per kilowatt in 1981-82 in 1970-71 rupees. The current cost in nominal terms is around Rs.10,000 per kilowatt. There is reason to believe that this average cost is climbing even at the present time. In effect, the capital cost of every form of energy has been increasing over the last decade, and there is economic incentive, therefore, for substitution in favour of less capital intensive and more labour- as well as fuel-intensive technologies for energy production, assuming that fuel costs will not rise as rapidly as capital and labour costs in the medium term. There is also the reality of inadequate capital for investment in the coming years.

Given this outlook, there would be serious pressures on supply of energy of all forms during the next 5-10 years. In the case of electric power, ongoing projects would largely determine the extent of additional capacity that would materialise in the next five years. There were schemes at the end of the 6th Plan period which are due to materialise in the 7th Plan and later, amounting to a total generating potential of over 30,000 MW. The timely implementation of these projects would be of critical importance, if we have to reach a total capacity of between 65,000 to 70,000 MW at the end of the 7th Plan period. Even this level would be lower than the desired level, if the plant load factor of thermal power plants does not improve substantially and efficiency of end use does not improve significantly. Given the fact that industrial output is likely to pick up and demand in the household and agricultural sectors is likely to grow faster than that of other sectors in the economy, there would be growing pressure on the power sector throughout the 7th Plan period.

The 7th Plan also envisages increased production of oil, of which a small share is expected to come from new oilfields. Concern has been raised in some sections on the realism of this plan, and certainly this is a matter for some discussion and analysis, but the supply scenario for oil during the 7th Plan would, in general, not provide too much cause for alarm, particularly in view of a continuing easy market situation for global oil. What adds an interesting dimension to the hydrocarbon supply picture is the increased availability of natural gas, the utilization of which has to be seen in a longer term context, given the fact that major investments are required in infrastructure and facilities to utilise this gas.

Coal output has improved in recent years, but it is unlikely that there would be a dramatic improvement in transportation of coal in the near future or a substantial improvement in coal quality. This would continue to affect adversely the performance and output from coal based thermal power plants.

The supply of non-commercial fuels is too large and complex a subject to be dealt with in this paper, and while there is evidence of renewed interest in afforestation and increased supply of fuelwood, it is unlikely that interventions on the supply side will produce a major impact in the short-term. It can, therefore, be concluded safely that in the next 5 years the scarcity of fuelwood would continue to get more acute, thereby producing pressure on commercial fuels at least in those segments of society where incomes are higher and there is adequate purchasing power, and on commercialisation of non-commercial fuels.

Given the outlook presented above there are certain compulsions which short- and medium- term energy policy needs to address, and these can be very briefly dealt with in the following section.

## 4. ISSUES OF RELEVANCE TO MEDIUM-TERM ENERGY POLICY

1. Given the constraints in public sector resources for the energy sector, we have to make a departure towards lower capital intensity of energy supply and higher utilisation of existing investments. This can be brought about through infusion of new management expertise and practices.

2. The weaknesses in supply of electric power are seriously affecting markets for other forms of energy. This is particularly true in the case of captive power capacity in the industrial sector and large spread of diesel pumpsets in agriculture. These two developments, (coupled with growth in transport), have caused an unusually high rate of growth in demand for diesel fuel. Alternatives for boosting the output of power for these two sectors could involve changes in institutional mechanisms for the growth of the power sector as well as the use of natural gas in the short-term.

3. The peaking problem in the power sector is likely to get more severe over a period of time. The 12th Annual Power Survey has projected peak and energy demand for the period of the 7th Five Year Plan, and these projections show a decreasing ratio between energy and peak demand from 5.48 in 1984-85 to 5.46 in 1989-90. We believe that this projection actually understates the increasing trend of peak demand relative to energy demand. Given this scenario, there is urgent need for levelling load curves for electric power through more efficient lighting technologies, and, in general higher efficiency appliances. This effort can be supplemented with increased uses of renewable energy, such as using solar water heaters on a large scale in North India.

As an example one could take the case of a high middle class home in a metropolitan area which would typically have a refrigerator, room heaters, airconditioner, a TV set, and electric water heaters. A coincidental peak of 3-4 kilowatts would be quite normal in a household using these appliances. If this peak demand is to be met at the margin, the investment that a power utility would require for generation capacity alone could be of the order of Rs.30,000 to Rs.40,000. In a situation of constrained capital availability, it would make sense to spend a fraction of this amount on technologies and methods for reducing this peak demand.

4. Efficiency of energy use related to peak demand and supply is only one aspect of energy conservation. The guiding factor in medium-term energy policy in the country would have to be greater energy conservation in all sectors - industry, transportation, agriculture and households. Indeed this subject is important enough to perhaps justify this Workshop next year focusing on efficient energy use and policies directed towards it.

5. Almost every committee on energy in recent years has emphasised the importance of matching investments in transmission and distribution and the imperative of bringing down line losses. Quite apart from a shortage of electricity in the aggregate, there is a serious

problem introduced by poor and badly maintained T&D systems which has reduced reliability levels to an all time low in several parts of the country. Unless there is an improvement in the reliability of supply and distribution, the trend towards higher captive power capacity will continue. It is anticipated that within the 7th Plan period itself over 2000 MW of captive power potential will be established, representing enormous diseconomies of scale and inefficient use of fossil fuels.

## 5. ROLE OF NATURAL GAS

The role of natural gas in the medium and long term context has to be viewed against the very broad scenario presented above. While government policy has in the past favoured the reservation of natural gas for fertilizers, petrochemicals and other non-fuel uses, the picture on the supply side and in terms of the potential demand for natural gas has changed substantially in recent years. Indeed it is likely to change even more dramatically in the next decade or so. Several issues, therefore, come to the fore in deciding on the role and potential of natural gas in India's energy future. These are subjects for detailed debate and discussion, which undoubtedly will take place in the next two days, but a few general comments are presented at this stage for consideration:

(i) Natural gas can be viewed as a valuable transition fuel, which may give us the kind of low capital option that is necessary for bridging the gap between demand and supply as it confronts us today and for ensuring that a smooth transition can be brought about to the post-hydrocarbon era with optimal use of this resource.

(ii) Natural gas policy has to be viewed in a dynamic context. Given the fact that the infrastructure and utilization potential for natural gas has long gestation periods, a constant review of resources and the trade-offs between competing uses has to be made continuously to ensure that forward looking choices are made in time to avoid flaring and waste of this valuable natural resource on the one hand and sub-optimal investments for utilisation on the other.

(iii) Natural gas represents more sharply than any other resource the nexus and conflict between utilization for fuel and food. Given the fact that higher agricultural productivity would in the future continue to depend on larger inputs of inorganic fertilizers, the trade-off between using natural gas for fertilizers and as fuel would have to be evaluated in an overall economic framework, to maximumise total benefits from choices involving both uses. This makes the analysis of such choices challenging and complex.

## SECTION II

## AN EVALUATION OF NATURAL GAS UTILISATION OPTIONS

### Introduction

The report of the Working Group on Energy Policy which represents India's latest comprehensive effort towards arriving at a long run energy policy has assigned very little importance to natural gas both from the supply side as a potential source of energy supply as well as from the demand side. This is an indication of the rapid changes that have taken place and in the prospects for supply and use of natural gas in India, which have not been analysed in much depth.

India's energy requirements are met by the age-old traditional as well as modern forms of energy. Though the utilisation of modern forms of energy has grown rapidly in recent years the non-commercial sources of energy, such as firewood, dung, biomass and charcoal still contribute about 40% of total energy consumption.

Though the commercial energy requirements are met primarily by coal, oil and hydro power, the share of gas - both in associated form as well as free gas - has increased quite rapidly in the last few years. While the reserves of oil increased at an average annual rate of 15% over the decade 1974-1984, the reserves of gas increased by over 21% during the same period. The share of natural gas in total primary energy supply has also gone up from 2.46% in 1972-73 to 4.15% in 1982-83.

The prognosticated and established reserves of oil and gas are given in the table below :

**TABLE I**

| | Prognosticated Reserves | Established Geological Reserves (1.1.84) |
|---|---|---|
| Oil | 7.5 MMMt | 2.66 MMMt |
| Solution Gas | 800 MMM$m^3$ | 334.32 MMM$m^3$ |
| Free Gas | 6800 MMM$m^3$ | 549.33 MMM$m^3$ |

Source : Goyal et al : 'National Gas Grid' KDMIPE, ONGC Dehradun 1984

Though nearly 50% of the country's hydrocarbon reserves are seen to be in the form of natural gas, only a little more than 10% of these have been established against 35% of oil (from above table). Gas discoveries therefore hold much greater promise in the future than oil.

The large infrastructure facilities required for gas production and transportation as well as the huge investments associated with it call for a detailed study of natural gas demand to be conducted well in advance of investing in its exploitation. Another peculiarity of natural gas which also stresses the need to forecast demand accurately is the fact that it is virtually impossible to divorce gas production from gas marketing.

In the following few sections, we will attempt to identify various options for utilising gas, study alternative distribution facilities and the economic benefits of gas utilisation in various end-uses.

Options for gas Utilization :

The use of natural gas is attractive as it is a clean fuel, and has insignificant environmental impacts. The composition of natural gas is such that it can be used for either industrial or domestic purposes. Considerable research is being carried out to study the viability of using gas as a transport fuel. Natural gas may also be used for power generation either in captive plants or in peaking plants or even for base load generation.

In the case of industry, gas finds use as a fuel and as a feedstock. As a feedstock gas is used for the production of fertilisers and methanol, demand for which is already established. While it can also go into the production of hydrogen and alcohol these are items of low demand. Natural gas used for the production of fertilisers would substitute valuable oil products such as naphtha and fuel oil. As a fuel, gas can be used in industry to replace the use of either fuel oil or the oil which has a much higher value.

The domestic sector has the option of using natural gas either directly or in the form of LPG which would be obtained from gas fractionation. The LPG fraction of natural gas is approximately 5.6%. This would not only ease the pressure on demand for LPG but also for middle distillates (in this case kerosene).

In the power sector gas can be used with a greater degree of economy than diesel. Captive generation in India, which is mainly based on diesel generation, contributes to over 10% of total generation. For this application gas can either be used by itself in gas turbines or it can be used in bi-fuel or multifuel plants.

Compressed natural gas at low pressures can be used either as town gas or it can be a substitute for diesel in transportation.

## Energy Demand/Supply Projections

The Indian economy has been and continues to be plagued by energy shortages. The periods when India has recently suffered stagnation are also the periods where there was an energy shortage either in the form of a bad monsoon leading to lower power generation or due to transport bottlenecks which restricted the movement of coal.

Energy demand and supply projections do not show any promise of the situation reversing. The following table gives likely shortages for the Seventh Five Year Plan period.

**TABLE II**

**Projected Energy Shortages** ($10^9$ K.Cal)

| | 1985-86 | 1986-87 | 1987-88 | 1988-89 | 1989-90 |
|---|---|---|---|---|---|
| Coal | 63850 | 75800 | 61800 | 38000 | 25300 |
| Oil | 12100 | 28600 | 47300 | 67100 | 75900 |
| Electricity | 9342 | 9006 | 9979 | 11090 | 10616 |
| Total | 85292 | 113406 | 119079 | 116190 | 111816 |
| **Total (MTCE)** | **17.06** | **22.68** | **23.8** | **23.24** | **22.36** |

Source : Working groups of the various departments for drafting the Seventh Five Year Plan.

The share of natural gas in total commercial energy production has increased from 2.46% in 1972-73 to 4.15% in 1982-83 but its share in total primary energy consumption in 1982-83 stood at only 1.9%. Nearly 40% of the gas produced still continues to be flared. Of the gas which is being utilised nearly 45% goes towards fertiliser production, a little over 42% towards power generation, nearly 12% to industry and the balance of only 0.5% to the domestic sector.

The principal limitations to the use of gas are the need for an extensive pipeline grid system and the general unfamiliarity with regard to production and market demand structure vis-a-vis oil.

The Techno-Economic feasibility of Alternative Gas Distribution Facilities :

The main gas producing regions in India are off the west coast and in the north-eastern region of Assam. Off the west coast we have the South Bassein free gas field producing gas upto 20 MMSCMD as well as associated gas from the Bombay High region (12 MMSCMD). The north-eastern region produces about 6 MMSCMD.

As mentioned earlier, gas distribution plays a vital role in the exploitation of gas resources. Since gas is a fuel which cannot be easily stored, once produced it should have a ready market or else it has to be flared or reinjected into the ground. With free gas one has the option not to tap it and leave it in the ground till a market develops for it or till a suitable distribution network is laid. In the case of associated gas this option is closed. As on 1.1.1984 the established geological reserves of free gas stood at 549.33 MMMCM against 334.32 MMMCM of associated gas.

Most of the prognosticated reserves of gas and the gas being produced today lie in the offshore areas of Gujarat. Over 80% of onshore gas lies in the north-eastern region of Assam. It has been estimated that of the total quantity of between 4.2 to 4.6 MMSCMD of gas, which is likely to be available till the end of the century in Assam, 2 MMSCMD would be consumed internally by the oil company and the balance could easily be taken up by the local market. In such a situation the mode of gas distribution would obviously be a pipeline. The chief method for transporting natural gas competitive with pipeline transmission is liquified natural gas (LNG). The supply of gas by either mode has some constraints which are listed below:

TABLE III

| Long-distance pipeline | Liquefield natural gas |
|---|---|
| Heavy initial capital cost. | Heavy initial capital cost. |
| No initial conversion cost or compression cost. | Heavy cost of liquefaction. |
| Minimum purification cost. | Stringent purification requirements. |
| Moderate re-compression costs. | Low unit transportation cost. |
| No lower limit on throughput. Ceiling limit of throughput. | Defined minimum throughput in relation to unit output. Upper limit by unit output. |
| Modest extensibility through additional re-compression stations at modest cost. | No extensibility without complete liquefaction unit or liquefaction tanker combination. |
| Slight inherent storage facility. | Unlimited relatively cheap storage at either end. |
| Inflexible source of supply and delivery. | Ability for both buyer and seller to switch source of supply or delivery point. |
| Overland route with short sea or river crossings. | Both supply and delivery point with access to sea route of competitive length. |

As in the case of the offshore gas from Gujarat which would cater to a much larger market distribution alternatives are not as clear cut as for Assam. Gas can either be brought to land by the shortest sub-sea pipeline and then distributed on land by a pipeline network as is being planned, or alternatively it can be transported as LNG to shorepoints closest to the demand centres and then be transported via a pipeline.

Given India's geographical structure one would conjecture that the latter option does not hold much promise. While there have been some estimates on the cost of long distance transmission of gas via a pipeline, in India similar figures for transport of gas in the form of LNG are not available. Using international estimates for illustrative purposes the cost breakup for transporting gas by the two modes is as follows :

**TABLE IV**

Infrastructure Costs for Gas Transportation ($/Mbtu)

| | Pipeline | LNG |
|---|---|---|
| Gas Gathering | 0.25 | 0.25 |
| Liquefaction | - | 1.10 |
| Transportation | 1.53 | 0.55 |
| Regasification | - | 0.40 |
| **Total Costs** | **1.78** | **2.30** |

The recurring transportation costs of gas as LNG are much cheaper(nearly a third) than via a pipeline. It is the huge financial investments required for setting up the liquefaction and regasification facilities which add to the cost of using LNG. Total costs of gas transported as LNG are therefore nearly 30% higher than that of gas transported via a pipeline.

Economics of using gas in alternative options :

The two major uses for which gas is presently being planned is power generation and fertilisers. Natural gas can be used as a feedstock in the production of nitrogenous fertilisers. The demand/supply projections of nitrogenous fertilisers indicate a shortfall of 803 MT by the year 1989-90 and of 2354 MT by 1994-1995. Since India is basically an agriculture based economy, a shortfall of these proportions (over 30% of planned production in 1994-95) is alarming.

While the likely energy shortages in India in the year 1989-90 would be equivalent to $111.82 \times 10^{12}$ K.Cal (Table II) the shortfall in the electricity sector has been estimated at nearly $10,000 \times 10^{9}$ K.Cals. At 50% plant load factor this would convert to over 2800 MW of capacity. In terms of peak demand the shortage is likely to be of the order of 7600 MW by the same year.

Since gas utilisation is highly dependent on gas availability it is important to have a region specific view of the electricity sector. The likely peak and energy shortages in the five main regions of India are as follows :

## TABLE V

| | 1989-90 Peak Deficit (MW) | Energy Deficit (GWH) |
|---|---|---|
| Northern | 3833 | 3404 |
| Western | 1741 | 932 |
| Southern | 1388 | 1677 |
| Eastern | 804 | - 2033 |
| North Eastern | -168 | - 1650 |

Source : Twelfth Annual Electric Power Survey of India, Central Electricity Authority, New Delhi

The main gas producing areas lie in the western and north-eastern regions of India. The north eastern region has a surplus of power. While the western region is likely to suffer from significant peak shortages, it is the northern region which is faced with the greatest shortage in terms of peak availability. The southern region is also seen to have large deficits of energy but for the sake of detailed analysis, we will first look at the northern and western regions, as the northern region is to be connected to the western gas fields by a pipeline extending over 1700 KMS.

Power : The use of gas for power generation would substitute for fuels like diesel, fuel oils and coal whereas its use in fertiliser production would release coal and fuel oils as well as naphtha. In the case of power generation, natural gas would be the ideal fuel for meeting peak power requirements since bringing the system on and switching it off does not pose as great a problem as in the case of say coal-based thermal power plants. The disadvantage though, which makes this option unattractive, is the difficulty in regulating gas production and flow through the pipelines to suit the fluctuating requirements of peaking operations. Thus even though costs of generating peaking power by a gas plant[1] are just 75% of the costs of generation from a coal powered plant and less than 50% of the costs of generation from a diesel plant, gas is not at present planned to be used for peak load power generation purposes in India.

As there is no fixed price for natural gas in India, the economic costs of gas have been worked out in table VI below on the basis of costs of thermal (coal) power generation.

1. Unofficial discussions with the Central Electricity Authority

## TABLE VI

| | Scenario I | Scenario II | Scenario III |
|---|---|---|---|
| **Coal Plant**[1] | | | |
| a) Capital Cost (Rs./KW) | 9000.00 | 9000.00 | 9000.00 |
| b) Fuel Cost[2] (Rs./KW) | 1664.40 | 1664.40 | 1664.40 |
| c) O & M Cost (Rs./KW) | 262.80 | 262.80 | - |
| d) Total Running Cost (Rs./KW) (b+c) | 1927.20 | 1927.20 | 1664.40 |
| e) Lifetime (Years) | 25.00 | 25.00 | 25.00 |
| f) PW of costs | 24115.03 | 24115.03 | 22053.90 |
| **Gas Plant** | | | |
| g) Capital Cost (Rs./KW) | 3500.00 | 7000.00 | 7000.00 |
| h) Total running costs(Rs./KW) | 2628.46 | 2182.02 | 1919.40 |
| i) Economic Costs of gas (Rs./KW) | 2389.05 | 1983.08 | 1745.00 |
| j) (i) as % of cif price of FO | 107.17 | 88.97 | 78.26 |

Source : 1. Uttar Pradesh State Electricity Board.
2. Average coal Price = Rs. 500/tonne

Three scenarios are presented above - the first assumes the capital cost of a gas based plant to be Rs.3500/KW and the second takes it to be Rs. 7000/KW. Taking the capital costs of a coal plant to be Rs.

9000/KW and the running costs at Rs. 1927.20 (Table VI) the present worth (PW) of total costs was worked out assuming a life time of 25 years and an interest factor of 12% in each case. Given the assumptions on capital cost of gas plants the total economic running costs were worked out and the economic costs of gas (including O & M) were arrived at assuming a specific consumption of 1100 $m^3$/KWH. Further assumptions made were a plant load factor (PLF) of 50% for coal plants and 75% for gas plants. The final scenario assumes that the O & M costs are the same in the case of coal as well as gas plants. In actual fact, all the three derived costs of gas are over-estimated as the O & M costs of a gas based plant are likely to be less than that of coal plants.

The actual realisation in the north-eastern region has been quoted as Rs. 185/MCM. The economic costs of gas are given as a percentage of the cif price of fuel oil in the last row of the table above. While in the first scenario, this percentage works out to 107%, in the next two scenarios, which have a more realistic estimate of the capital costs of a gas plant, the price of gas is seen to be 89% and 78% that of fuel oil. If one were to attach a premium on foreign exchange to the price of fuel oil, then these percentages would turn out to be much lower.

Fertilisers : In the case of nitrogenous fertiliser production, the main feedstocks are naphtha, fuel oil and natural gas. The all India production of nitrogenous fertilisers increased at the average rate of 7.2% per annum in the decade 1970-71 to 1980-81. Since then in the period 1980-81 to 1983-84, it has increased at the average annual rate of nearly 18%. Actual production of nitrogenous fertilisers in 1983-84 was approximately 6.87 Million tonnes. In addition, over 1.3 million tonnes of nitrogenous fertilisers and 325,000 tonnes of ammonia for the production of nitrogenous fertiliser were imported. The imported ammonia would account for 0.54 MT (approx 8%) of nitrogenous fertiliser produced domestically.

Over 70% of nitrogenous fertiliser capacity in India is based on naphtha and fuel oil. The breakup of sectoral consumption for these oil products together indicates that nearly 3.6 million tonnes out of a production of 11.3 million tonnes are consumed by the fertiliser sector - over 30%. Just for purposes of comparison India imported 4.05 million tonnes of petroleum products in the year 1983-84.

Nearly 43% of the natural gas produced in 1983-84 was flared - i.e., 256.2 MMCM. Let us assume, on the basis of current gas utilisation trends, that 45% of this flared gas had been utilised by the fertiliser sector. Given that 860 $NM^3$ of gas are required to produce one tonne of Ammonia and that 0.6 tonnes of Ammonia are required to produce 1 tonne of urea this gas (115.3 MMCM) would have been able to sustain a production of over 2 million tonnes of urea per annum - which is more than our import of nitrogenous fertilisers directly and indirectly (in the form of ammonia) for the same year.

The costs of production of fertilizer from naphtha and fuel oil based plants as well as the economic costs of gas derived backwards are given in the table below :

**TABLE VII**

| | NAPHTHA | FUEL OIL |
|---|---|---|
| Cost of Production (Rs./MT) | 4776 | 5874 |
| Cost of Production excluding cost of Natural Gas | 2653 | 2653 |
| Cost of Natural Gas/MT of urea | 2123 | 3221 |
| Consumption of NG($NM^3$)/ MT of urea | 516 (670.8) | 516 (670.8) |
| Price of Natural Gas Rs./000$M^3$ | 4114.3 (3165) | 6242.2 (4801.7) |

The figures in brackets give the consumption of natural gas at 30% lower efficiency. Even at this rate it is seen that natural gas based fertilizer production will be economical upto a gas price of Rs. 3165/MCM. Since nearly 40% of gas is being flared it can currently be assigned zero opportunity cost. In the case of naphtha and natural gas based plants the production processes are almost identical and minimal investments are required for the conversion of existing fertiliser plants based on naphtha to natural gas. This is yet another feasible option that can be adopted for the use of natural gas.

Natural gas can also be used for domestic purposes as a substitute for Liquified Petroleum Gas (LPG). The $C_{3}/C^{4}$ fraction (5.6%) of natural gas forms LPG. Taking 1983-84 figures again, of the 2562 MMCM of gas which was flared if 0.5% were to go for domestic use on the basis of current tends) this would amount to 12.81 MMCM. The LPG fraction of this would be 640MCM which is equivalent to 346 thousand tonnes of LPG. For comparative purposes the total LPG production in India during the same year from both domestic and imported crudes was 514 thousand tonnes.

Taking the costs of Auraiya as representative of LPG extraction costs we see that for a plant capacity of 5.0 MMSCMD the annual LPG production is 140 thousand tonnes. The capital costs are equivalent to 974 lakhs per annum. Assuming a life time of 30 years and an interest rate of 12% per annum the annualized costs work out to Rs. 21.82 crores or approx. Rs. 1559 per tonne of LPG produced. When compared with present prices of LPG at Rs. 2634 to Rs. 2928 per tonne this option is quite attractive.

Another alternative is the use of natural gas in the form of compressed natural gas (CNG) for transportation purposes. While no work on this has been done in India in Italy over 250,000 vehicles are run on CNG. In the United States too a number of fleet operators use CNG[1].

Table VIII gives some summarized cost data based on data adapted from the existing U.S. 500 vehicle LNG System.

1. Gunter Schramm 'The Economics of Gas Utilization in a Gas Rich Oil Poor Country : The case of Bangladesh' The Energy Journal, January 1983.

## TABLE VIII

**Representative Capital and Operating Costs of a CNG-Powered Vehicle Fleet Operation**

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Data :

1 U.S. gallon of gasoline = 0.115 mcf of gas

Operating Costs:

Compressor electricity costs,[a] 11kW X \$0.07/kWh = \$0.77/hr

$$\frac{\$0.77/\text{hr}}{2\ \text{mcf/hr}} = \$0.39$$

Maintenance Costs: $$\frac{\$2{,}000/\text{yr}}{2\ \text{mcf/hr} \times 6{,}000\ \text{ht/yr}} = 0.17$$

| | | |
|---|---|---|
| Total Operating Costs | | \$0.56 |
| Cost for conversion and refuelling equipment per vehicle | \$ 1,000 | |
| Pro-rated costs of refilling facilities (for 500-vehicle fleet) per vehicle | \$ 2,000 | |
| Total pro-rated cost per vehicle | \$ 3,000 | |
| Monthly equipment costs (12% interest, repayment period 48 months for vehicles, 96 months refill station): | \$ 59/month | |
| Average monthly consumption = 30 mcf (259 gal. of gasoline equivalent): pro-rated equiment cost/mcf | | \$1.97 |
| Total systems costs/mcf | | \$2.53 |
| Economic opportunity costs of gas | | \$0.60 |
| Opportunity costs of gasoline (8.7 U.S. gals. equivalent ) \$350/ ton, f.o.b. Chittagong)[b] | | \$7.18 |
| Net economic gain from using CNG | | \$4.05/mcf |

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Data Source : Gas Development Corporation, Chicago, mimeo, 1981

[a] Electricity costs were adjusted to account for higher Bangladesh costs but lower kWh requirements due to assumed take-off from high-pressure (960-psi) gas lines.

[b] Bangladesh is a net exporter of naphtha (i.e. gasoline) stocks, because of insufficient demand for gasoline.

| | |
|---|---|
| Total operating costs of gasoline-powered vehicle | 100.0 |
| Fuel costs as a share of total vehicle operating costs | 40.0 |
| Net savings from CNG (0.56 x 0.40) | -22.4 |
| Net loss in carrying capacity 200 lbs/average utilization factor of carrying capacity 60% (0.6 x 200/4,000) | +3.0 |
| Net loss in operating hours, 1/2 hr per 10-hr day | +5.0 |
| Net reduction in total operating costs from using cng | -14.4 |

The advantage of a CNG based transportation system is that it is clean-burning and extends engine life. But the disadvantages of the weight of high pressure cylinders, limited range and carrying capacity make this option attractive only for short distance or local transport. The use of CNG for rail transport needs to be examined.

Supply prospects and Demand potential:

The previous few pages establish the economic feasibility of using natural gas in diverse applications. The established geological reserves of associated and free gas as on 1/1/1984 stood at 334.32 BCM and 549.33 BCM respectively. The 20 year perspective plan of the Oil and Natural Gas Commission envisages an annual production of 20 BCM by 1990-91, 34 BCM by 1995-96 and 45 BCM by 2000-2001.

Table IX gives nitrogenous fertiliser demands for the same three periods as well as the gas requirements for setting up additional fertiliser capacity.

**Table IX**

| (i) Year | (ii) Nitrogenous Fertiliser Demand (MT) | (iii) Addl.Fertiliser Cap. required * | (iv) Gas Requirements for (BCM) |
|---|---|---|---|
| 1990-91 | 8.2 | 3.95 | 2.04 |
| 1995-96 | 10.4 | 6.15 | 3.17 |
| 2000-2001 | 12.5 | 8.25 | 4.26 |

* Assuming current capacity of 4.25 MT to remain constant over the next 15 years.

If one were to suppose that all new fertiliser plants set up to meet the additional capacity requirements would be using natural gas a feedstock then the natural gas demands of this sector would be as shown in column (iv).

Table X gives the all India demand projections for electricity - the second major competitor for use of natural gas. While the use of natural gas for power generation should really be looked at regionally the figures provided below are more for illustrative purposes.

Column (ii) gives the electricity demand in GWH whereas column (iii) gives the equivalent of this in terms of capacity requirements. Adopting the same norms as the Twelfth Annual Power Survey from which these figures were obtained the plant load factor (PLF) for 1990-91 was taken at 50% and for the later two periods at 62.4%. Present generating capacity in India stands at 42583 MW. Assuming this capacity would continue for the next 15 years and taking into account the 24478 MW which have been sanctioned and will be completed by the end of the Seventh Five Year Plan the incremental capacity requirements are worked out as in column (iv).

**Table X**

| (i) | (ii) Electricity GWH | (iii) Demand MW | (iv) Incremental Cap.Requirements(MW) | (v) Natural Gas Available | (vi) Gas Demand |
|---|---|---|---|---|---|
| 1990-91 | 295503 | 67466 | 405 | 17.96 | .59 |
| 1995-96 | 470573 | 86087 | 19026 | 30.83 | 27.78 |
| 2000-2001 | 752594 | 137680 | 70619 | 40.74 | 40.74* |

* the available 40.74 BCM would sustain a plant of capacity 27904.

Column (v) gives the gas availability situation net of that amount required by the fertiliser sector as given in table - above. Column (vi) gives the gas required to sustain plants of capacity given in column (iv). It is seen that while for the year 1990-91 only .59 BCM need to be set aside for incremental power generation in 1995-96 this goes up to 27.78 BCM still leaving a surplus of over 3 BCM. For the year 2000-2001 it is seen that all the available gas would be used up to sustain a plant capacity of 27904 MW which even though only 40% of required capacity is significant. Since natural gas based power plants have short gestation periods and can therefore be set up fairly quickly the 15 year grace time which we get by using this energy source would enable us to plan for and set up power plants with longer gestation periods - be they hydro or thermal or nuclear.

If one were to assume that the surplus gas (17.37 BCM) in 1990-91 was allocated to some alternative use and hence was not available for future periods it would imply that the share of gas plants in required capacity would go down to a little over 48% in 1995-96 and to about 22.6% by 2000-2001. While this would put some pressure on setting up alternative capacity it would be considerably lower than had gas not been utilised by the power sector.

## Conclusions

The economic value of gas works out to be the highest in fertiliser use and as such, the obvious policy would be to saturate gas demand of the fertiliser industry first, before moving on to other applications of natural gas. But if one were to take a multi-dimensional view of the whole issue, then other considerations would enter in the ranking of gas utilisation options. For example, by taking into consideration the spatial factors one may find that there is a considerable demand for fertilisers in the southern part of the country but it may well be that the cost of transporting gas for this specific purpose or even the cost of producing gas based fertilisers close to the natural gas source and transporting the fertiliser material are both not "economically viable".

The economic value of gas in power generation is considerably lower than that in fertiliser production - but one should consider the chronic power shortages which have been experienced in India in the recent past and the impact of this on the industrial sector outputs, prices, income levels etc.. By including all these chain effects in our analysis, we may find that the returns from the utilisation gas from power generation are much higher. In addition, the shorter gestation periods of gas based power plants add to the attraction of its use for this purpose in the resource constrained economy like India's. Yet another factor which needs to be borne in mind is the increasingly poorer quality of coal being produced and supplied to the power industry and the true social costs of coal supply and transportation, which are normally understated.

Similarly, even though a detailed study of using compressed natural gas (CNG) for the transportation sector has not been carried out in India, the experience from other countries shows some definite advantages in using CNG in place of the traditional transport fuels. Keeping in mind the disproportionate increase in demand for middle distilates and the resulting increase in imports of these, it may be worthwhile to carry out a detailed feasibility study for using CNG in the transport sector in India.

While the use of natural gas for domestic purposes also seems to be viable, a more detailed study needs to be carried out to assess the costs and feasibility of distribution of this gas through a pipeline network. Here one would also need to study the secondary effects of substituting LPG/kerosene with natural gas in urban areas. One obvious impact would be felt in terms of a decreased demand for scarce firewood due to greater availability of the substitute cooking fuels - LPG and Kerosene.

Finally, it needs to be pointed out that while there do exist estimates of future natural gas availability and production rates it is important to know when and where this gas will be made available in order to plan an optimal utilisation package.