International Energy Agency: Focus on Asia Pacific

GAS-FIRED POWER GENERATION IN INDIA

Challenges and opportunities

Paper
October 2005

The views expressed in this Working Paper are those of the authors and do not necessarily represent the views or policy of the International Energy Agency or of its individual member countries. As this paper is a Work in Progress, designed to elicit comments and further debate, comments are welcome, directed to the author dagmar.graczyk@iea.org.

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-six of the OECD's thirty member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To assist in the integration of environmental and energy policies.

The IEA member countries are: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, the Republic of Korea, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission takes part in the work of the IEA.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission takes part in the work of the OECD.

Gas-Fired Power Generation in India -- Challenges and Opportunities

Overview

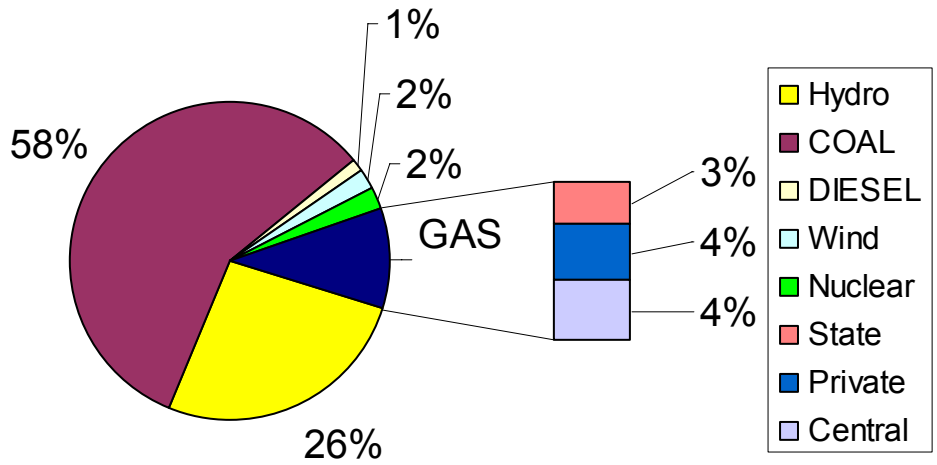
1. India's fast growing economy needs to add 100,000 MW power generating capacity between 2002–2012. Given limitations to the use of coal in terms of environmental considerations, quality and supply constraints, gas is expected to play an increasingly important role in India's power sector. This report briefs NMC Delegates on the potential for gas-fried power generation in India and describes the challenges India faces to translate the potential for gas-fired power generation into reality.

The Power Sector

Status of India's Generation Capacity

2. India's installed power generating capacity on 31 January 2005 was 115,545 MW reflecting a 44 percent increase in capacity in the decade between 1993 and 2002. While the increase in installed capacity is substantial, it fell short by almost half of the targeted capacity additions set for the same period. Gas-fired generation accounts for only 10% of total installed capacity whereas almost two-thirds of capacity is coal-based. The share of private generation is only about 10% of total installed generation, with gas-fired private plants accounting for 4,160 MW or 34% of total installed private capacity, and for over 35% of total gas-fired capacity. The remaining 90% are owned by the public sector, of which about two-thirds are owned by the central government sector and one-third by the Indian states government sector. The breakdown of installed capacity by fuel is shown in Figure 1 below:

Figure 1: Fuel Share of Installed Capacity (31 January 2005)



3. In addition, over 2,300 auto-production plants, owned by the industrial and commercial sectors, with a total installed capacity of 18,740 MW were reported on 31 March 2004 of which about 15% are gas-fired. Only captive units with more than 1 MW capacity are taken into account in statistics, thus, potentially, there could be even more private gas-based generation capacity

4. India's power generation resources are unevenly distributed and far away from major load centers. The northern region has huge potential for additional hydro-generation with an assessed exploitable potential of about 100,000 MW. Given high capital cost coupled with long gestation periods and extensive environmental requirements, this potential is unlikely to be realized quickly. Coal resources are located mainly in the eastern and central region. Power demand centers are mainly in the western and southern region, close to the country's gas fields, with the exception of the greater New Delhi area. Thus, optimal utilization of resources requires huge cross-country transmission capacity. However, India still lacks a fully developed national high-voltage transmission grid connecting its different regions. Overloading of inter-regional transmission lines frequently results in prolonged periods of black-out. The current inter-regional power transfer capacity is about 9,500 MW. Powergrid, India's inter-state public transmission company is implementing a plan to establish an integrated National Power Grid by 2012 under which the existing capacity will be tripled.

Power Sector Planning

5. Planning for the Power Sector is part of the responsibilities of the Planning Commission which prepares India's five-year development plans. India is currently implementing its 10th Plan (2002-2007). The 10th Plan targets an 8% annual growth in gross domestic product and recognises the fact that underperformance of the energy sector can be a major constraints in delivering the targeted growth rate. Power demand is projected based on the targeted annual economic growth rate plus the targeted annual rate of electrification. To meet the projected power demand in 2012 an additional 100 GW generation capacity is required. According to the 10th Plan, an additional 41 GW will be installed of which 7,109 MW will be gas-fired generation. The remaining capacity will be installed during the 11th Five-Year Plan (2007-2012). The private sector is expected to contribute about 20% of the capacity increase. As of end June 2005, the mid-term for the 10th Plan, 11,499 MW of additional capacity have been installed, or about 27% of the total plan target. This makes it doubtful that the entire plan target will be met during the remaining years of the 10th Plan.

Findings of the 10th Plan Mid-Term Appraisal

6. In the mid-term appraisal of the 10th Five-Year Plan issued by the Planning Commission in July 2005, the anticipated capacity additions during the 10th Plan are consequently revised downward to 31,290 MW, or 76.1% of plan target. Of the expected over 7,000 MW of private capacity, almost 43% will be added as planned. The Planning Commission states that the problems the private sector experiences, for instance reaching financial closure of projects in the absence of a payment security mechanism from the distribution end and overcoming the difficulties of obtaining fuel-supply linkages for both coal and gas, are responsible for the shortfall in private capacity additions.

7. To put these numbers into perspective, it is helpful to note that during the 9th Plan (1997-2001) only 47% of the planned increase in generation capacity was achieved. Even more significant, only 29% of the expected private investment materialized. As the main reasons for the shortfall, the Government identified, among others, the absence of adequate arrangements for ensuring payment security, delays in land acquisition, environmental clearances, and unresolved issues relating to fuel supply arrangements for generation stations. The first and last arguments are of particular relevance for private investors as they have displayed a preference for gas-fired generation.

The Organization of the Power Sector

8. Under India's federal structure, the power sector is designated a "concurrent subject". All major issues affecting the power sector thus require concurrent action by the central government and state governments. The central government's Ministry of Power provides overall guidance to the sector through the Central Electricity Authority (CEA). It also either owns or is the largest shareholder of central power utilities such as the National

Thermal Power Corporation (NTPC), and the Powergrid Corporation of India (Powergrid) which are engaged in generation and interstate power transmission. The Rural Electrification Corporation and the Power Finance Corporation (PFC) are Government-owned institutions dedicated to financing power sector activities. The Power Trading Corporation (PTC) was established as part of power sector reforms with the intention to facilitate trading power for large independent power producers (IPPs) targeted on multi-state purchases.

9. State governments largely control the rest of the sector through State Electricity Boards (SEBs) and electricity departments (EDs). These SEBs and EDs provide distribution facilities within a state and share responsibility with the central power sector agencies for power generation and transmission. The Indian power sector is set up as a single-buyer model; the SEBs and EDs are the sole buyers of the power produced by the central power utilities. With the power sector reforms in the mid-1990s an increasing number of the states have re-organized their SEBs. Typically this includes the vertical unbundling of the SEB into separate companies for generation, transmission and distribution; however, a few states also opted to partially or entirely privatize generation and distribution while keeping transmission as a state monopoly. However, the reforms did not fundamentally change the market model which remains principally a single-buyer one but which now consists of several monopolies in those states that have unbundled their SEBs.

Power Sector Reforms

10. In order to raise investments to meet the physical targets of power generation and full connectivity of its citizens, the power sector must quickly address its major constraint, namely its lack of financial viability caused by exorbitant system losses (estimated to be well over 40% on an aggregated all-India basis), operational shortcomings, and an average tariff below cost of supply. The Government is committed to addressing these problems through fundamental sector reform with the aim of making the sector commercial and competitive.

11. The Electricity Act, 2003 is an enabling framework providing long-term legal confidence to potential investors. It replaces and consolidates all existing provisions for the power sector. The Act includes provisions related to independent sector regulation, need for a national tariff policy, reduction of subsidies and cross-subsidies, vertical unbundling of State Electricity Boards (SEB), commercialization and corporatization of sector entities and the need to pursue rural electrification outside the main grid through decentralized supply systems.

12. The Act opened the sector for power trading. It recognizes transmission as a separate activity and permits private sector participation in transmission. In mid-2004 CERC operationalised open access in interstate transmission. These new business opportunities were quickly accepted by the Indian private sector with several licences for power trading and transmission being awarded. The Act seeks to effectively insulate the tariff setting process from political considerations and limits the roles of the Central and State Governments to providing overall policy guidance. Accordingly, regulatory responsibility for the sector is vested in the Central Electricity Regulatory Commission (CERC) and the State Electricity Regulatory Commissions (SERCS) whose establishment has been made mandatory. At the end of 2004, 13 states have unbundled/corporatized, and two have also privatized distribution; 24 states had established SERCs and tariff orders have been issued in 18 states. The Act also allows for introduction of a multi-year tariff framework. In 2004 CERC announced a five-year tariff order stipulating a flat 14 per cent return on equity for all central public sector undertakings and mega private projects.

13. It is important to remember that a large portion of India's population does not yet have electricity connections. The Government has set an ambitious plan to electrify the entire

country by 2012 through a two-step process. By 2007, it plans to provide power to over 90,000 villages that are not yet electrified (about 15% of all Indian villages). About three-quarters of these villages would be connected to the grid and the remaining 18,000 villages in remote areas through decentralized non-conventional technologies. The level of Indian households that are electrified is much lower; only 44% of rural households are electrified, reflecting the enourmous tasks the Indian Government is facing to meet its aim of providing electricity to the entire population.

The Long-Term Potential for Gas-Fired Power Generation in India

14. In addition to preparation of the five-year plans, the Planning Commission jointly with relevant Ministries is occupied with longer-term planning. The "Hydrocarbon Vision 2025" issued in the year 2000 is considered the first major policy paper on the future role of gas in India's economy. The Vision identified natural gas as the fuel of choice for the Indian economy and projects future gas demand in the economy broken down by different demand drivers. According to the Vision, in the most optimistic scenario, Indian overall gas demand will grow from 20 bcm/y in 1999 to 114 bcm/y in 2010 and to 143 bcm/y in 2025 while the share of gas in the economy will grow to be 14% and 20% respectively; provided sufficient supply is available.

15. To determine future gas demand in the power sector, the Vision analysed the competitiveness of gas against other fuel options at different plant locations throughout the country for a given technology. The projections of the Vision take into account CEA's Fourth National Power Plan (1997-2012) which includes a list of proposed generation capacity addition by fuel and the "Natural Gas Development Master Plan" prepared in 1999 and financed by the Asian Development Bank. The Vision comes to the conclusion that at a cost of $4/mmbtu gas demand (in 1999 US$) for power generation in the year 2025 would be 56 bcm/y for a total installed capacity of 42,309 MW. At a price of $3/mmbtu, installed capacity would reach 57,420 MW and gas demand would reach 76 bcm/y. For both scenarios power accounts for about half of total demand for gas in each reference year.

Table 1: Hydrocarbon Vision Projection for Gas Consumption for Power Generation

	2007	2012	2025
Scenario I: Gas at $3/mmbtu			
Installed Capacity (MW)	30,761	43,449	57,420
Gas Demand (bcm/y)	43.5	61	76
Scenario II: Gas at $4/mmbtu			
Installed Capacity (MW)	17,190	23,298	42,309
Gas Demand (bcm/y)	24.5	33	56

(Source: Planning Commission, Hydrocarbon Vision 2025)

Major methodologies and assumptions used in gas demand projections

16. Taking the Hydrocarbon Vision as the base case for long-term gas demand projections in India, it is useful to compare its methodology and findings to those used in other projections made.

Table 2: Various Gas Demand Forecasts for Indian Power Sector

Made By Whom	When	Unit	2010	2012	2015	2020	2025	2030
IEA World Energy Outlook	2004	bcm/y	22			44		66
		MW	22,000			45,000		72,000
FACTS	2003	bcm/y	27		35.5			
		MW						
India Vision 2020	2002	bcm/y				27		
		MW						
CRISIL	2003	bcm/y	24		41			
		MW						
TERI/FACTS	2001	bcm/y	25		29			
		MW	24,800		28,202			
Revised Hydrocarbon Vision	2001	bcm/y					38	
		MW					28,500	
Natural Gas Master Plan (ADB) for gas prices >$3.5	1999	bcm/y		34				
		MW		24,300				
& low and high power capacity additions		bcm/y		57				
		MW		41,100				

17. Table 2 shows the major differences in the projections of gas required for power generation. Projections made by the Government in the Hydrocarbon Vision (Table 1) and the ADB study (Table 2) are the most optimistic ones. The methodology used by the Vision is closely related to the one employed by the ADB study. The ADB Study and Vision 2025 were undertaken more or less within the same timeframe, used very similar input data and similar methodology and models.

ADB Study

- Technology choices

18. The general methodology employed in the ADB study is the netback approach where the competitive price of gas against other fuels at 42 plant locations was calculated and costs for associated transportation and distribution deducted to arrive at the well-head price. The

study analyzed the switching potential of existing gas fired capacity that is currently using alternative fuels due to gas supply shortages and future demand originating from new capacity additions. For new capacity the ADB study used the imputed value approach which equalises the cost of generation for gas-based CCGT technology with the cost of generation from other alternative technologies for the selected locations throughout the country.

- *Future Coal Pricing Assumptions*

19. Within this methodology, assumptions about coal prices become of critical importance. Coal is the most important source of commercial energy in India, accounting for over 55 percent of commercial TPES and providing over 60 percent of all fuel consumed for electricity generation. Coal will continue to play the dominant role in meeting Indian's energy needs and will remain the the primary fuel for power-generation, even if its share is expected to decline.

20. The ADB study has used two base scenarios for future coal prices, one in which the domestic coal market continues to be regulated and domestic coal prices remain below international parity, and a second where the Indian coal sector is deregulated and domestic coal prices approach import parity (taking account of calorific values). In addition, the study also includes a third coal price scenario under which the domestic coal industry becomes competitive resulting in coal prices below and approximating minimum economic prices at which producers will still supply.

- *Findings*

21. The ADB study found that the affordable price of gas-fired power generation varies significantly by region and assumed pricing structure for coal. Continuation of regulated coal prices results in gas-fired generation being competitive in all regions, but the East, at prices at or above $3 - $3.5/mmbtu. However, if coal prices were to reach import parity, gas-fired generation would be affordable throughout India at $4/mmbtu. Thus, the ADB study used prices of $3.5/mmbtu and higher as the most realistic gas price scenario on which to base projections.

Reasons for Differences in Gas Demand Projections

22. It is noticeable that most studies result in considerably lower demand projections than the Hydrocarbon Vision. Partly this is the result of the benefit of hind-sight, whereby changes to the policy framework, actual versus planned capacity additions and supply side developments could be taken into consideration. But partly the more conservative estimates of recent studies reflect recognition that the key determinant for future gas-based capacity additions is price sensitivity of end-consumers and not solely the country's fast growing appetite for energy and electricity in particular.

23. The major reasons behind the differences in projected gas demand for power generation are a result of the extent to which sensitivity to gas pricing, domestic gas availability and total gas supply stability were taken into consideration. Coal is the major competitor fuel for gas and thus assumptions about future coal sector policies and in particular about the path and extent of coal sector deregulation, are critical variables. Price sensitivity to gas prices differs by region with locations close to the coal mines in the east of the country showing much higher price sensitivity than those on the west coast, located close to the domestic gas supplies and existing and proposed LNG terminals. Another reason for the differences in projected gas demand for power generation is linked to whether the studies assumed that the Government's five-year plan goals of capacity addition will be met or not and whether IPPs will come on-stream as publicly announced.

24. Generally, most projections provide more of an insight into the potential for gas use in India's power sector then about the likely capacity additions, as they assume, within the framework of certain methodological differences, that (i) there will be sufficient gas supplies (domestic or imported), (ii) the necessary transport and distribution infrastructure is in place, (iii) gas supply prices are acceptable to domestic consumers and (iv) the regulatory and policy framework in the power and gas sectors are conducive to investments.

***How does the Power Industry View the Future for Gas-Fired Generation*?**

25. The best manifestation of the views in the power industry on the prospects of gas-fired generation is the number of projects implemented and planned. The private sector has been invited to invest in power generation since the early 1990s but IPPs still account for only about 10% of total installed capacity. However, private power generators have revealed a preference for gas-fired generation which accounts for over one-thirds of IPP capacity and is concentrated in the Western and Southern region. The geographical concentration of gas-based plants reflects the current centres of gas supply, the concentration of industrial locations and the availability of transmission infrastructure. Since the approval of the Electricity Act in 2003, eleven IPPs for over 4,000 MW capacity have reached financial closure and eight more for over 10,000 MW capacity are under discussion. A large number of these projects will be gas-fired. Most prominent among them was the announcement in 2004 by industrial giant Reliance to construct a 3,500 MW gas-fired project in the state of Uttar Pradesh, originally planned to be operational in 2006. However, the date for commissioning appears increasingly unlikely as uncertainty over gas supplies continues to exist.

….in Principal Very Positive….

26. In terms of installed gas-fired plants the magnitude of capacity for the private and the central sector is almost equal and both are over one-third larger than gas-fired capacity owned by the states. Enthusiasm for gas-fired generation is dampened by increasing concerns about gas supply security, as is the case for the Reliance project. Domestic gas production is insufficient to meet the growing gas demand in the Indian economy.

27. Total Indian gas production in FY 03/04 was 33 bcm/y, of which 80% or 26 bcm/y came from the public sector. Total available gas was 31 bcm/y whereas total gas demand was around 44 bcm/y. Even for a moderate demand forecast, the demand-supply gap is expected to reach about 62 bcm/y in the year 2012. Power generation accounted for about 37% of total gas consumption in India during FY 03/04.

...but Growing Concerns about Gas Supply Security

28. The power sector is already starting to experience shortage of gas supply. According to a statement by the Ministry of Power in May 2005, 38 gas-based power stations with a total capacity of 9,536 MW had to operate at a plant load factor (PLF) of only 58% during FY 04/05 due to shortage of gas supply. The stations require a total of 17 bcm/y to operate at a PLF of 90% (a performance level set by the Government) but were delivered only 10.5 bcm/y. The mid-term review of the 10th Plan notes with concern that the cumulative gas production during the plan period will show a shortfall of 8 bcm/y against the plan target. In percentage terms the shortfall is only 4.7%. However, when viewed against the cumulative production addition of 36.5 bcm/y set for the 10th Plan, the shortfall is a substantial 22.8% - and will have significant impact on gas-fired capacity additions.

The Policy and Regulatory Framework to Encourage Gas-Fired Power Generation

29. The Government is actively encouraging the use of gas by industrial units, in transport and power generation with a view to promote clean and modern fuels in the economy and to reduce air pollution. Private investment in generation has been promoted by the Government since the first round of power sector reforms in 1990. Since then several additional initiatives and enabling regulations and laws have been approved at centre and state level. Among them was the creation of the PTC charged with acting as a one-stop buyer of power from mega-sized IPPs for onward sale to multiple-buyers. However, it was the approval of the Electricity Act, 2003 that provided a consistent regulatory framework and more investment certainty for private and captive generators. Relevant provisions

relate to power trading, direct sales and deregulation of captive units. Sales agreements for duration of below one year, and in situations where open-access has been granted, can be directly negotiated between buyers and sellers and tariffs are not subject to regulatory approval.

- Moves Towards a Wholesale Market

30. While India still has a long way to go towards creating a competitive market in generation, activities of PTC have increased rapidly since its creation. PTC's annual trading volume increased from 1,600 MU in 2001/02 to 8,887 MU in 2004/05. This volume represents less than 20% percent of the total generation in the same year. The company is simultaneously engaging in the acquisition of long-term clients from the captive producer and industrial consumers segments and in exploiting short term trading opportunities arising from supply and demand mismatches in various regions of the country. India is also encouraging establishment of merchant plants which are authorized to sell directly to industrial consumers, though tariffs are levied with a surcharge, or they can sell to trading companies or to distribution companies and SEBs without an extra surcharge being levied on to the tariff.

31. Auto generation units can now be set up without the approval from any authority (except for statutory clearances) and can sell their surplus power to the grid, though tariffs are subject to regulatory approval. The Act also removed the requirement of generation projects to receive techno-economic clearance from CEA and introduced non-discriminatory open access in inter-state transmission for generators.

32. These policies encourage wholesale trading and open up new opportunities for gas-fired power producers. Gas-fired power stations that in particular cater to industrial consumers or to co-generation, can afford substantially higher gas prices than those plants dedicated to supply the public power sector. Estimates about the acceptable delivered gas price based on comparison to alternative fuels range from $3.63 to $4/mbtu for incremental capacity to over $4.6/mbtu for existing but underserved capacity, though the state-specific merit-order dispatch regimes could result in alternate prices.

33. The merit-order dispatch regime is a central feature of the current generation market design. However, this is not an uncontroversial issue in the ongoing reform discussion. The SERCs and CERC are trying to establish how to move the incentives provided to generators from those linked to the plant load factor (and thus connected to fuel charges) to those linked to availability (and thus accounting for fix charges) to avoid disadvantaging specific fuel based plants. Gas fuel costs vary greatly depending on the sources of gas supply (public or private) and any future investments in gas-fired generation, whether IPP or public plant, will have to be made on the basis of gas prices determined outside the reach of domestic Indian policy setting. Another topic of discussion relates to the tendency of SERCs to levy a variety of charges and fees onto actual delivered power costs (surcharges, cross subsidy charges, open access fee etc) which tend to slow down reform progress and are of particular concern for IPPS.

34. At the distribution end, the Act forsees the phased introduction of open access at the discretion of the State Regulatory Commissions. A surcharge for the current level of cross subsidy and an obligation to supply would be part of the conditions for distribution liscencees.

35. The Government is actively supporting the use of gas in public power generation through provision of subsidized gas. However, current gas pricing policies are a two-edged instrument. On the one hand subsidized public gas has been a crucial enabler for introduction and growth of gas-based generation. On the other hand the subsidies have perpetuated distortions at the retail end of the power sector; thereby reducing

competitiveness of gas-fired generation. At the upstream side in the gas sector the administered pricing mechanism (APM) discourages intensified exploration and production in existing public gas fields and public gas companies have increasingly taking up positions in joint venture undertakings, which can sell their gas outside the APM.

- The Choice of Technology

36. Changes in Government policies have influenced technology choices for power generation. With initiation of power sector reform, the Government permitted import of equipment and reduced customs duties and other tariff barriers for innovative gas-fired technology. Given the lower capital cost and shorter gestation period of gas-fired technologies new private entrants into the sector frequently opt for gas-fired plants. India's domestic industry originally did not have the technology needed for CCGT but the Government policy encouraged new entries into the Indian power equipment market. However, fuel choices for generation capacity additions are also strongly linked to confidence in fuel supply and the assured availability of gas, the absence of which has lately emerged as a hindrance for rapid growth of gas-fired generation.

Is Gas-Fired Generation Competitive in the Indian Context?

37. The use of gas in power-generation was initially promoted by the Government primarily with a view to environmental considerations. Over 60% of India's power generation is coal-based but domestic coal supply is generally of low quality with low calorific values and a high degree of ash content.

38. Most of the gas-fired IPPs and large captive plants are located in the Western Region, home of major domestic gas fields and large industrial complexes. Industrial consumers are keen either to set up their own captive plants or to buy power directly from private producers. For those large industrial power consumers quality and un-interrupted supply are more relevant than price. Besides, given the typical power retail tariff structure in Indian states with high cross-subsidies between different consumer groups, large industrial consumers pay considerably more for power than their long-run marginal cost would suggest, thus, making power purchases from gas-fired IPPs and gas-fired auto-production financially attractive - in addition to providing the benefit of enhanced security and quality of supply.

….at the Right Price, Yes!

39. The established view on the Indian gas and power sector is that a delivered price of gas of about $3 mmbtu is the critical threshold for demand from the public power sector. At a price beyond $3.5 mmbtu gas is seen as too expensive for public power production. This "optimal" gas input price was arrived at by working backwards from the average power retail price, adjusting for distribution and transmission cost and fixed generation cost to arrive at a variable fuel cost of about US cents 2.3/kWh.

40. A report published in 2004 by the "Expert Committee on Fuels for Power Generation" under the aegis of the CEA took a different approach to assess the competitiveness of gas for power generation. The expert committee analyzed various fuel options for varying distances between the location of the fuel source and the load centres for base load (80% PLF) and peaking plants (30% PLF). The study came to the conclusion that for base-load operations, domestically supplied gas-fired plants located along the existing Hazira-Bijaipur-Jagdishpur (HBJ) pipeline (connecting the north-western coast with the northern market) is the cheapest generation option at all distances. Domestic-coal fired plants at pithead are the second cheapest option while domestic coal-fired plants located close to demand-centres are ranked third

41. The findings in favour of gas-fried generation were however qualified with the caveat that the delivered price of public sector gas along the HBJ pipeline is the same at all locations

and will remain constant over time. No comparison for de-regulated domestic gas prices has been carried out. Since the study included LNG as an option, those prices can be used as an approximation of deregulated domestic gas prices. LNG-fuelled plants located close to LNG import terminals rank sixth out of ten options for base-load and second for peaking plants.

The obstacles to realising the full potential of gas-fired generation

42. The two major obstacles against realising the full potential of gas-fired power generation in India are gas price sensitivity and availability of gas.

- ***Gas Price* Sensitivity**

43. For fiscal year 2004-05, the aggregated average India-wide power tariff (excluding New Delhi and Orissa State) was US cents 6.3/kWh which covered 76% of average cost of supply. According to the Expert Committee Report generation-send out cost based on subsidized gas supplies and levelised along the HPJ-pipeline work out to US cents 3.4/kWh. In comparison, power generated from imported LNG would be US cents 4.2/kWh for a delivered LNG price of $2.50/mmbtu and US cents 5.2/kWh for an LNG price of $3mmbtu. The delivered cost of LNG in the state of Gujarat is currently $4.5mmbtu – translating into a generation send-out cost of over US cents 5.7/ kWh. However, it is important to highlight that average power tariffs vary greatly between states and that states levy a variety of different taxes and surcharges on the final price to consumers. Thus, the economics of gas-fired power generation have to be evaluated on a case-by-case basis bearing in mind the states to which the power is expected to be sold. Moreover, as discussed before, the cross-subsidies inherent in the power tariff structure make gas fired production very interesting for commercial and industrial auto producers who often pay rates that are almost double average tariffs. Auto production capacity accounts for over 10% of total Indian power capacity and is expected to grow following the provisions made in the Act, 2003.

- ***Gas Supply***

44. As regards the demand and supply gap of gas; the issue needs to be reviewed from three different angles. The first angle is the fact that the share of public gas is expected to go down from 80% of total supply during 2004 to about 33% by 2012. The second angle is the discovery of substantial gas finds over the last three years pre-dominantly by the private sector. While those finds are considered significant enough to alter the demand-supply balance, they can not be expected to be sold at subsidized rates. Thirdly, India is planning to import both LNG and pipeline gas to fill the supply-demand gap but they will be competing on an international market that has recently seen a move to become a so-called sellers market, and is increasingly commanding prices much higher than the APM regime in India.

45. Uncertainty about gas supply is increasingly becoming a hindrance to increasing gas-fried generation capacity. Recently, reports surfaced in the Indian press that public lending institutions are reluctant to fund gas-fired power projects in the absence of secure gas-supply contracts.

- ***Gas Regulatory Framework***

46. There is obvious need for the government to develop a comprehensive legal and regulatory gas sector framework and an adequate gas transmission infrastructure. Finally, as discussed above, there are strong inter-linkages between the coal, power and gas sector. All three sectors are in need to undergo further sector reform to unlock their potential to allow them playing an important role in India's fast development. However, reform in the three sectors should be carried out in a coordinated manner that addresses the interdependencies in the sectors and avoids creating new distortion.

The Gas Sector

47. Petroleum and gas have emerged as the most dynamic energy sectors in India. The importance of gas in India's energy mix is expected to increase sharply. In 2000, gas represented 7% of India's energy mix, equivalent to a consumption of 22 bcm/y. The World Energy Outlook (WEO) 2002 projects the share of gas in Indian TPES to reach 13% in 2030, equivalent to 97 bcm/y. The sector has seen several policy developments in the last few years that have substantially altered the investment framework even if deregulation and creation of a comprehensive legislative framework are far from completed. However, India's gas sector is still primarily publicly owned with private companies currently limited to upstream E&P activities and LPG retailing. The up-stream sector is largely controlled by the Oil and Natural Gas Corporation (ONGC) while transmission and distribution/marketing is in effect still a monopoly of the Gas Authority of India (GAIL). Gas has been sold at subsidised price under the APM. An exception to this is the Gujarat Gas Company Limited (GGCL), a 60% subsidiary of British Gas, and a success story of private sector involvement in India's downstream gas sector. GGCL is engaged in gas transportation and distribution in Gujarat State and is now the largest private sector gas distribution company in India. To ensure stable gas supplies, GGCL sources its gas from public as well as private sector companies. GGCL has recently expressed interest to expand its activities into co-generation business of power due to the significant synergies between the two sector

48. Public gas companies, jointly with Government officials, research think-tanks and industry representative groups, are involved in planning for the long-term gas economy, including preparing projections. Most public companies use these official data for their own project and investment planning, thus, closing a circle. Private investors in the gas sector work in close collaboration with the public sector on which they rely to transport and often also buy their gas, and thus, also tend to use public data in their planning.

New Domestic Gas Finds

49. The launching of the New Exploration Licensing Policy (NELP) in April 1997 has successively improved investment conditions for foreign and domestic investors in exploration and production which was previously restricted to Indian state-owned firms. Five rounds of bidding have been held since January 1999, the last, NELP-V in 2005. Several major gas finds were made in fields allocated under the NELP. It is worth noting that almost all major finds under the NELP have been made by private companies or public-private joint ventures often with relatively new and small private entrants into the sector. These finds have the potential to fundamentally alter India's gas supply and demand balance and to substantially supplement the countries dwindling gas reserves. The most prominent gas find was the discovery by the Reliance–Niko consortium in late 2002 of about 10 to 14 tcf of recoverable gas reserves in the Krishna-Godavari (KG) basin in Andhra Pradesh State on the East Coast. Since then several more sizeable discoveries have been made in the same basin and expectations for a second discovery of a size similar to Reliance's find are high. Those expectations seem to have been justified by a discovery by the Gujarat State Petroleum Corporation (GSPC) jointly with two private partners in June 2005 which could even substantially exceed the Reliance find. GSPC's find has not yet been certified by an independent technical party and thus, the extent of recoverable reserves remains uncertain. There is also uncertainty as to when gas from the recent discoveries will start to flow and no firm timetable has been presented.

Closing the Supply Gap

50. Questions have been raised about the impact of the domestic gas finds on the demand-supply scenario and if they might render gas imports uneconomical. None of the new

domestic gas finds are yet in production. Also, private investors like Reliance are authorized to sell gas at market prices putting it in direct price competition with gas imports. Thus, even though domestic gas supply will increase, gas price competitiveness in public power generation remains an issue.

51. Reliance is now planning to start production from their K-G field by mid 2008 with an initial flow of around 5 bcm/y to be build up gradually to up to 13.5 bcm/y. The maximum flow from Reliance's K-G field could be 20.5 bcm/y. GSPC announced that is expects to start commercial production by end 2007 with an initial flow of 4 bcm/y to be increased to between 18–22 bcm/y in 2010. The maximum flow from GSPC's field could be 29 bcm/y in 2017. However, none of these production schedules and volumes is yet confirmed and further testing will need to be undertaken. Questions also remain about the transport of the gas as there is currently no pipeline that could transmit the gas cross-country. GAIL and Reliance have been in strong competition as to who will build the pipeline to transmit gas from AP to demand centres at the west coast. At the same time, the state government of Andhra Pradesh has announced its intention to set up a gas pipeline grid in the state jointly with GAIL.

52. Assuming that the production from the K-G basin as well as from other recent discoveries comes on stream as scheduled, and that gas flows from existing public fields decline as projected, India's total gas production could increase to about 51 bcm/y. Even in this optimistic gas supply case there would still remain a demand-supply gap of around 25.5 bcm/y in 2012– leaving ample scope for gas imports.

Gas Imports

53. India is strategically well located to import gas via pipeline from either Myanmar and/or Bangladesh and via Pakistan from either Middle Eastern or Central Asian sources. Pipeline imports could be the most economical way given geographics; butl none of the different pipelines options has materialized due to geo-political concerns which would need to be priced into the cost of the delivered gas. This has led India to actively pursue import of LNG.

LNG

54. India entered the LNG economy in 2004 with the arrival of the first tanker at Petronet's 2.5 mt/y Dahej terminal. Construction of the terminal was surrounded by speculation if India could really afford the LNG and if sufficient buyers could be found. The company however announced that the entire quantity was sold to industrial customers operating outside the subsidised gas pricing regime and put the selling price of LNG between $4.87 mmbtu to $4.93 mmbtu, depending on state taxes. While Petronet's Dahej facility appears to have avoided most of the pitfalls projected, the overall future of LNG in India is much less clear, in particular in light of recent large domestic gas finds.

- How Many Terminals are Viable?

55. Although India will continue to depend on LNG to close its demand gap, the LNG euphoria of the late 1990s has lately been replaced by a more realistic assessment of market potential, legal and regulatory framework conditions and affordability issues. Several LNG projects have been shelved, or put on hold. The remaining three active projects, all located on the west coast, include the Dahej facility whose capacity is expected to gradually increase to 10 mt/y by end 2008. Petronet is also moving ahead with plans to construct a 2.5 mt/a LNG facility in Kochi, on the south-western coast. Gas supplies for Dahej and Kochi will be coming from Qatar and Iran.

56. In June 2005, India signed a breakthrough deal with Iran comprising a mixture of LNG sales and upstream oil investments. India would import 5 mt/y LNG from Iran over a 25-year period starting in 2009. Based on a pricing formula combining a fixed with a variable

price component, the cost would result in an FOB price of $3.1/mmbtu which would increase to a landed-cost of $3.51/mmbtu including shipping.

57. India's second operational LNG terminal is the Shell-Total 2.5 mt/y facility in Hazira. The Hazira terminal received its first delivery from Australia's North West Shelf project, in which Shell has a share, in April 2005 and its exclusive buyer was Gujarat State Petroleum Corporation (GSPC). No confirmed information is available on the likely sources of gas supply for the next deliveries; or whether any longterm off-take contracts have been signed with gas buyers. It is most likely that Shell will opt to operate Hazira as a "merchant" LNG plant, using short-term sales contracts and sourcing LNG on demand.

58. The Dabhol LNG facility, part of the Enron complex, has a capacity of 5 mt/y. Due to legal complications construction of the facility has not been completed. However, recently substantial progress has been made towards a resolution of the dispute. The Indian consortium consisting of NTPC and GAIL, who took over the Dahbol complex and renamed it "Ratnagiri Gas and Power" expects that the LNG terminal can become operational within a short period. GAIL is already trying to identify potential supply sources for Dabhol which would allow to maintain a generation send-out cost cost of US cents 5.2/kWh, implying a gas price of $3./mmbtu. However, given current high international prices it is rather unlikely that GAIL will obtain long-term supplies at this price – questioning the viability of power purchases by the power-starved Maharashtra State Eletricity Board, the sole buyer foreseen. All together there could be potential LNG imports on the magnitude of 20 mt/y by 2012-2015, if all the projects discussed above were indeed to materialize on time.

Pipeline Imports

- from the West

59. Since late 2004, discussions of different pipeline options to import gas have intensified. From the West, India considers importing gas through the proposed $7 billion, 2,700 km on-shore Iran-Pakistan-India pipeline. Based on current information, India would receive about 25.5 bcm/y of gas from the pipeline while Pakistan would take-off 11 bcm/y. Talks on the pipeline are ongoing and an agreement could be reached by the end of 2005. A second pipeline option from the West would bring gas through the so-called $3.2 billion, 1,700 km TAP(I) pipeline from Turkmenistan via Afghanistan and Pakistan to India. The pipeline would be designed to carry up to 30 bcm/y of which a maximum of 10 bcm/y could be taken-off by India. However, none of the two pipelines has made any substantial progress and no discussions of gas pricing have taken place. Though it has been reported that Iran would expect the price of piped gas to be identical to the price of their LNG contract – which would make it considerably less attractive for India.

- and from the East

60. From the East, India is promoting plans to import 11 bcm/y of gas from Myanmar through Bangladesh via a $1.5 billion, 900 km-pipeline. However, as in the case of the pipeline from Iran, initial indications about gas pricing have not been well received in India. It is understood that Myanmar expects India to pay at least the same price as Thailand to whom it has been selling gas for several years. The Thai price of $3.8/mmbtu would result into a delivered price of gas at the Indian border of more than $5/mmbtu after accounting for transport cost and transit fees to be paid to Bangladesh.

61. If all of the LNG and pipeline projects materialize India could in fact be over-supplied with gas by 2015. LNG import capacity could reach about 29 bcm/y and adding pipeline imports, total gas import volume could reach 77 bcm/y by 2015. This would be in addition to potential domestic production (private and public) of around 51 bcm/y for total supply of 127.8 bcm/y – as opposed to a base case demand scenario of about 80 bcm/y and rather optimistic demand scenario of 114 bcm/y according to the Hydrocarbon Vision 2025.

62. However, filling the demand-supply gap will be a necessary but not sufficient condition to turn India into a modern gas economy. The gas sector is facing additional challenges that need to be addressed in a comprehensive and timely manner.

Major Gas Sector Challenges

63. India is facing three major challenges on its way to become a well-functioning gas market: (i) lack of sufficient transmission infrastructure, (ii) lack of a coherent legal and regulatory framework for the sector; and (iii) continous questions about the affordability of gas.

- Transmission Infrastructure

64. India is currently relying predominantly on its 1,800 km HBJ pipeline connecting the north-western coast with the northern market. In order to connect the new LNG terminals with consumers in the Indian heartland and to allow gas from the recently discovered sites at the East Coast to be brought to consumers around the country, India needs to almost triple its existing pipeline capacity over the next five years. Construction of a "National Gas Grid" to connect gas supply points, from LNG as well as NELP fields with consuming centres, is one of the major priorities. GAIL has unveiled plans for construction of over 7,000 km of pipelines for a cost of about $4.5 billion by 2008. A fully developed gas grid would allow gas-fired power generation to spread throughout the country; away from the current locations along existing pipelines and would allow for fuel substitution from petrol based products to gas.

- Legal and Regulatory Framework

65. India currently lacks a coherent natural gas policy and regulatory framework. Issuance of a draft LNG policy paper announced for 2003 has been postponed and the draft *"Petroleum and Natural Gas Regulatory Board Bill", 2004* is still pending. In September 2003, the Government issued a draft "*Policy for the development of Natural Gas Pipeline Network"* that foresees construction of the future gas transportation network on a common carrier principle with requirements for third-party access under public ownership and management. GAIL was nominated as monopoly builder and operator of cross-country gas pipelines. The existing HBJ trunk pipeline is exempted from the common carrier principle. The draft policy does not foresee any private cross-country pipelines with the exception of those pipelines for which project proposals have already been approved. Tariffs for the national transmission grid would be approved by an independent regulator.

66. The draft policy stirred substantial debate among industry players and in particular the private sector raised questions about a conflict of interest resulting from the different roles of GAIL as producer, transporter and retailer of gas. In response to critics, GAIL announced plans for a separation of its different business units into independent profit centers by 2008 as a first step and with a view to divest at a later stage. Discussion of the third draft is ongoing. Critics have also pointed out that the current approach at sector regulation is unlikely to entice urgently needed foreign investment into the sector and that the lack of a consolidated legal and regulatory framework might weaken the growth potential of the sector. In response, private investors shareholders in the gas sector have created an informal group called "The Gas Industry Group". The GIG has as its objective to work jointly with the Government in the design of a sector regulatory framework conducice to promote gas sector gas and has recently offered its view on the draft pipeline policy and a draft framework for local gas distribution.

- Affordability of Gas

67. Questions about the ability-to-pay for gas and the urgent need for pricing reform in the gas and power sector are a major concern. The key challenge for rapid development of the gas sector is the capacity of the Indian power generators to pay their gas bills. This capacity in turn depends on setting electricity tariffs at cost-recovery levels and reduction of

transmission and distribution losses to improve the financial viability of power generators. The problems GAIL is encountering in its attempt to source LNG for the Dabhol-Ratnagiri plant at $3.5/mmbtu, the unofficial Indian ceiling price, and warnings by the Ministry of Power against planning new gas-based capacity at gas above that levels, underline the dilemma India is facing. India needs power and gas-fired generation is seen as crucial to meeting that need. Yet financial problems in the power sector prevent the required gas-fried generation capacity additions from materializing in the short term; as pointed out by the Planning Commission in its 10th Plan Mid-Term Review.

- LNG Pricing Structure

68. Various taxes and duties at centre and state level are being levied on LNG aggravating the affordability problem. Also, domestic transport of LNG in the HBJ pipeline is more expensive than shipment of LNG from Qatar to India, reflecting cross-subsidizes in transmission pricing to promote gas consumption in remote locations. A calculation by the Ministry of Petroleum and Natural Gas showed that delivered LNG prices could be reduced by $0.5/mmbtu (over $1/mmbtu in Gujarat) if taxes, duties and other levies would be rationalized. While central taxes and duties were rationalized in response to the report, not all states follow suit, leaving LNG imports burdened with unequal financial attractiveness throughout the country.

Market Environment for Potential Investors in Gas-Fired Power Plants

69. Potential investors in gas-fired power generation need to analyze the issue of affordability and gas shortages from two different perspectives. Affordability of gas is primarily an issue for public sector consumers, in particular the power and fertilizer sectors. Gas shortages and allocation of domestic gas are primarily issues for other users, in particular the industrial sector who often use Naphtha and other liquid fuels at much higher prices, and IPPs and captive power generators

Gas Allocation

70. Since potential gas demand is significantly higher than gas supply, the Government allocates public gas at subsidized rates to different states and individual users on recommendations of the Gas-Linkages Committee (GLC) which is an inter-Ministerial Committee with representatives from the Planning Commission and the Ministers of Finance, Power, Chemicals & Fertilizers and Steel. Priority in gas allocation is given to the power, fertilizer and transport sectors. The GLC determines the quantities of gas to power plants as part of the investment and planning process before they become operational. During times of temporary shortage the GLC is also responsible for any re-allocation of gas amongst consumers, if so required. However, with initiation of sector reforms, direct marketing of gas has been permitted and new gas companies, like Petronet and the JV operators of the Panna-Mukta-Tapti fields, have recently entered the market. Public gas is provided at subsidized rates through the so-called "Administered Pricing Mechanism" (APM) while private and JV gas is sold at market prices.

Gas Price Deregulation

71. The Government was committed to deregulated petroleum pricing in 2002 with the abolition of the APM. However, for the gas sector the Government decided to continue providing public gas under the APM. APM prices are delivered prices of $2.95/mmbtu including transportation and taxes, independent of customer location. This price was set in October 1999 and was in theory to be linked to 75% of the price of a basket of imported fuel oils. However, in practice the Government kept the prices at the level fixed in 1999. Realizing that low gas producer prices act as a disincentive for public gas companies to invest in existing fields that are beyond their peak production or to explore in more difficult, deeper and offshore fields, the Government set up a committee in 2004 to review gas prices. In May 2005 the Government agreed to a 12 percent increase in gas prices for

the power and fertilizer sector while all other sectors, except transport (CNG) and very small consumers will now also have to pay market prices that currently amount to $3.86/mmbtu for delivered gas.

72. Private and joint venture gas producers, who currently account for 20% of domestic gas production are paid market-determined prices on the basis of 100% parity with the basket of imported fuel oil and receive about $3.11/mmbtu.

Two gas markets?

73. In effect, the Government's policy is creating a dualistic market for gas; one with strict quantitative allocations at subsidized prices controlled by the public sector and another one based on market principles controlled by the private sector and JV operators. Moreover, as discussed above, the share of public gas in India's overall gas supply position is expected to reduce while the share of private gas is expected to increase accordingly – shifting the balance towards an open and competitive gas supply market. However, this in turn raises again the question of affordability of gas for public power producers but might also provide the necessary pressure to move ahead quickly with power sector reform, particular in distribution and tariff setting. The price was set in 1997 had not been revised since then. After a prolonged discussion between the operators of the PMT JV, GAIL and the MPNG in early 2005, the price was bench-marked against the price for regasified LNG currently being imported into India and set at $3.86/mmbtu. Moreover, the PMT were also given permission to sell their production directly to end-consumers. However, upon request by the Government with a view to the shortage of gas for public power and fertilizer producers, the PMT JV sold about half of their production to GAIL at the R-LNG benchmark price and the remainder at a higher, negotiated price directly to end consumers.

74. In practical terms the development of a dualistic market can be illustrated by the following examples. When NTPC issued a tender for supply of 4.5 bcm/y of gas for two gas-fired plants located on the western coast, it received widely varying bid prices. Petronet offered LNG at over $4/mmbtu, a price similar to the one offered by Malaysia's Petronas. Reliance Industries offered to deliver the gas from its K-G field at a delivered cost of $2.97/mmbtu for 17 years resulting in a power generation cost of around US cents 4.5/kWh with a fuel component US cents 2.3/kWh. The price offered is clearly below the current market price and it is unclear if it is reflective of Reliance's cost-plus price. However, the NTPC contract would account for a substantial amount of potential gas supply from Reliance K-G field and offers long-term fixed returns which could assist Reliance to raise funding for the planned transmission pipeline. Still, Reliance has so far not signed the contract with NTPC. Conversely, the proposed Reliance Energy sponsored 3,500 MW gas-fired plant to be set up in Uttar Pradesh has not been successful in obtaining bids at similar prices. The plant had originally invited bids for the delivery of 6 – 6.5 bcm/y for 20 years starting in 2006. The commissioning date has been pushed back relieving Reliance Energy of the task to secure gas supplies at affordable prices for the public power sector. Similarly, NTPC's has so far not been successful to attract bids below $3/mmbtu for its proposed gas-fired plant in the southern state of Kerala. GAIL is involved in sourcing the required 2 mtpa of LNG but was not yet able identify sources at the prices required by NTPC.

75. It is important to remember that NTPC as well as Reliance are planning to supply power from their plants to the public sector and thus, they are particularly sensitive to gas prices. However, as discussed above, the Electricity Act, 2003 allows power trading and direct sales implying that gas-fired power generation with market-determined gas-prices is

attractive, even if volumes are potentially smaller. Private power producers are also tasked with securing long-term gas supplies which are, at least for the moment, limited by import facilities and sufficient domestic gas production. Still, recent domestic gas finds and the prospects for LNG imports are encouraging.

Conclusions

76. The potential for use of gas in India's power production is large. India has one of the strongest economic growth rates in the world and has sufficient potential to maintain this high growth rate over a sustained period of time. India has also recently entered a new era in its gas industry with the large discoveries of indigenous gas and the arrival of the first LNG tanker.

77. The power sector will be growing in tandem with the economy and India will be able to slowly but steadily integrate its entire population into the commercial energy economy with will further boost long-term demand for electricity. Given limitations on the use of coal for power generation due to its environmental consequences, quality and supply constraints, gas will play an increasingly important role in India's power sector.

78. However, India faces several challenges to translating this potential for gas-fired generation into reality. The major constraint is the distorted retail pricing structure in the power sector that currently limits the competitiveness of gas-fired generation at a level of $3.5/mmbtu. Another major constraint is the provision of subsidized gas to public gas-fired plants which limits required investments in further gas exploration while at the same time perpetuating the distorted retail tariff structure in the power sector.

79. Domestic gas production from existing fields by public entities is expected to fall continuously. The supply gap will be filled through imports at market prices and through new domestic gas sources that will be pre-dominantly supplied by companies operating on commercial principles, leaving the Government with no choice but to undertake a fundamental reform of the pricing system in the power and gas sector – or to continuously fund uneconomic pricing of gas and power directly from its budget or indirectly through public sector gas and power companies.

80. India will also need to aggressively expand its gas transmission and distribution network, while at the same time putting into place the required legal and regulatory framework for the gas sector.

81. The challenges faced are not insurmountable but do require a strong commitment by all sector players. As regards retail prices of gas products, the Government might postpone making unpopular decisions about energy prices but with the current situation in the international oil and gas market, it will quickly become apparant that India can not operate its gas and power sectors de-linked from trends in international energy market. The later a decision on retail prices is made, the higher the increase will be or, alternatively, the higher the subsidies will have to be in the interim, either crowding out capital investments in the sector or resulting in a higher fiscal deficit.

Conversion Table

1,000 cf	=	28.3 cm
10 tcf	=	283 bcm
14 tcf	=	396 bcm

10 mcm/d	=	3.53 bcm/y
1 mt	=	5.00 mcm/d
1 mt	=	1.82 bcm/y

www.iea.org