The Future of Natural Gas in India: A Study of Major Consuming Sectors

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The Program on Energy and Sustainable Development at Stanford University is an interdisciplinary research program focused on the economic and environmental consequences of global energy consumption. Its studies examine the development of global natural gas markets, reform of electric power markets, international climate policy, and how the availability of modern energy services, such as electricity, can affect the process of economic growth in the world's poorest regions.

The Program, established in September 2001, includes a global network of scholars—based at centers of excellence on five continents—in law, political science, economics and engineering. It is based at the Freeman Spogli Institute for International Studies.

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About the PESD Study: Natural Gas in the Energy Futures of China and India

PESD has been studying the emerging global market for natural gas through a series of integrated research projects. To date, these studies have focused on the geopolitical implications of a shift to a global gas market, the factors that affect gas pricing and flows as LNG links the U.S. and European markets across the Atlantic basin, and how gas projects fare in privately-owned independent power projects (IPPs) in emerging markets. A series of books, major articles, and working papers on the PESD website report results from those studies.

One of the major open questions in looking to the future of the global gas market is the role of China and India. Both countries, today, use relatively small amounts of gas, but they could become major global consumers in the future. The role of natural gas in Chinese and Indian economies is of critical import both domestically and for global energy and environmental issues. The competition between coal and natural gas in these two markets has tremendous implications for local air pollution and for climate change since gas emits less than half the CO_2 of coal in most applications where they compete, such as in the generation of electric power. Rising demand for imported gas in China and India will also shape the LNG market in the Pacific Basin and could lead to the construction of major international pipeline projects to monetize gas supplies in Russia and the Middle East. The present paper is one in a series that looks at the Indian market in detail.

Disclaimer

Executive Summary

The last thirty years have seen a shift in the global energy fuel mix towards an increased role for natural gas. Attractive for its cleaner and more efficient combustion relative to other fossil fuels, gas has assumed a significant role in power generation, industrial applications, residential heating and in some cases as a transport fuel as well. Traditionally, gas has been consumed in the major industrialized countries (in Western Europe, East Asia, and the United States) and most supplies have come from domestic sources and others nearby in the region. Increasingly, however, these regional markets are becoming linked to one another through long distance transport of natural gas in the form of liquefied natural gas (LNG). Changes in supply and demand in one economy can have an effect on prices around the world, although this "LNG revolution" is still unfolding slowly.

This study focuses in particular on the evolution of natural gas demand in India over the next 20 years. It considers the major gas-consuming industries in India – electricity generation, fertilizer production, and industrial use – and explores how fuel choices in these sectors may respond to a range of market and policy conditions.

Our findings confirm that the size and growth of the Indian gas market will be driven by a few key policies. Within the electricity sector, natural gas competes largely with coal, and the liberalization of the Indian coal sector, which is haltingly underway, could squelch the rise of natural gas. Such reforms are likely to make coal a bit more expensive in India, but they will also liberalize large new coal supplies (both from the country and through imports). Head-to-head, a competitive coal sector will out-compete gas for most electric power applications because coal is so much cheaper as a fuel. Failure to reform, on the other hand, could reduce available coal supplies and expand the window of opportunity for natural gas. Regional air pollution controls – in our study, modeled as restrictions on oxidizing sulfur emissions – are also important, and could provide a strong advantage to natural gas over coal. For example, in our scenarios, a plausible tightening of sulfur emission rules could nearly double demand for gas in the power sector by 2025. Lastly, the expected rationalization of the Indian electricity grid could provide an opportunity for natural gas to play a larger role in power generators that provide electricity during the few hours of the day of maximum demand – so called "peaking" power generators.

Within the domestic fertilizer industry, which uses natural gas as a primary (and highly subsidized) feedstock, India's fertilizer import policy is the probably the single most important factor affecting future gas demand. While India currently maintains a domestic self-sufficiency goal for nitrogenous fertilizer production, this policy is very costly, as it precludes much cheaper fertilizer imports from countries where natural gas can be sourced cheaply and fertilizer sold to India on long term contracts. Despite being a relatively high cost producer of fertilizer, India produces essentially all of the nitrogenous fertilizer it uses – imports are limited to only meeting unforeseen supply shortfalls. Producers in the nearby Persian Gulf can make fertilizer at less than half the real Indian cost because cheap natural gas is abundant in the Gulf. A future shift to a greater role for imports would dramatically reduce domestic gas consumption and lessen the subsidy burden on the central government. We estimate that without reform, subsidy to the fertilizer sector could rise to as much as US$8 billion by 2025. However economically sensible, such fertilizer reform efforts have historically been stymied by powerful interests within the fertilizer and farming lobbies under the banner of "food security." The Indian government's political ability to increase imports in the face of these interests will have large implications for domestic gas consumption.

For industrial users, natural gas competes with liquid (oil-based) and solid (coal-based) fuels. In general, where gas competes with oil, firms find it cost-effective to switch if they can obtain gas supplies. These consumers have historically had difficulty securing gas supplies, which were allocated through a political process that gave priority to electricity generators and fertilizer producers. New supplies coming online through domestic production and imports afford much greater access to gas for industrial consumers who will readily consume them even though this new gas is 2-3 times more costly than traditional price-regulated supplies. As a result, industrial demand will largely be limited only by the magnitude and structure of Indian economic growth. For gas suppliers, this is the most lucrative market and is a major growth opportunity. (At current gas prices, however, gas is not competitive with coal in industrial applications; most analysts think that gas prices, which are linked to oil in most of the world's markets, are unlikely to reduce much in the future.)

Today, India's total gas demand is about 30 bcm, which is relatively small (about half the size of the entire California market.) In total, this market could grow 4-5 times in size over the next 20 years, depending on the policy variables and other factors discussed above.

How this market evolves could have important implications globally. India has found large amounts of gas off its eastern coast, and still more gas is likely to be uncovered in that locale. If the infrastructure to produce and pipe them to market is developed, these new gas sources will offset the already declining sources in Western India that the country has relied on to date. In addition, India is importing significant amounts of LNG and likely to use even more of that fuel in the future—while LNG is costly, for many applications this source is competitive and it is relatively easy to scale up LNG supplies by adding additional contracts and terminals.

However, if demand for gas outstrips these supplies, India will likely look towards its neighbors for natural gas to fuel its growing economy – pursuing pipelines from Iran or LNG from Middle Eastern suppliers. Our analysis suggests that domestic supplies and planned LNG terminals should be sufficient to meet Indian gas needs for the next 10-15 years. In an earlier study we found that one of the most important factors explaining success or failure of international gas pipelines is the ability of the project to obtain a reliable source of gas demand.[1] The Indian market seems poised to repeat this experience if there is a major push for a large international pipeline from Iran while actual local demand for gas in India is not sufficiently large to justify the project. If these new gas supplies are used, at the margin, for making nitrogenous fertilizer then such a project also would be exceptionally expensive compared with the option of importing fertilizer directly.

The competition of natural gas with other fossil fuels with higher carbon intensities (especially coal) is also highly relevant to global climate change mitigation efforts. Our study shows that annual carbon dioxide emissions from the Indian electricity sector could vary by over 100

[1] Victor, David, Amy M. Jaffe, and Mark H. Hayes (2006). *Natural Gas and Geopolitics From 1970 to 2040*.

million tonnes of CO_2 in response to policy levers like regional air pollution controls (favoring gas) and domestic coal industry reforms (favoring coal). For comparison, such a volume of CO_2 is about a third of the entire annual reduction that the European Union will be making in the next five years as part of its effort to comply with the Kyoto Protocol. For international policymakers looking to reduce India's greenhouse gas emissions, these "non-climate policies" suggest leverage points through which the Indian government can address high priorities for its domestic constituency while reducing carbon emissions at the same time. Such policies might be a much more productive and politically viable way for Western countries to initiate engagement with India in the global effort to combat global warming. By contrast, shrill demands for India (and China, along with other emerging markets) to cap their emissions of greenhouse gases have not been successful to date because they pose climate protection in opposition to economic growth. The alternative strategy suggested here would begin by finding places where India's objectives resonate with slowing growth in CO_2.

1. Introduction

The Indian natural gas market is in the midst of a major shift from a centrally managed system to one with a greater role for market forces. Since the first major gas supplies began flowing in the mid-1980s, gas has been produced entirely by the national oil company, Oil and Natural Gas Corporation (ONGC), and transported and marketed by the state-owned Gas Authority India Limited (GAIL).[1] This gas was sold at low prices set by the central government that, at the time, had a large surplus of gas and sought to stimulate consumption. Along the major pipeline that GAIL constructed to link the gas fields in the west with the interior of the country up to Delhi, the government urged construction of large fertilizer plants, gas-fired power plants, and other gas-consuming industries to ensure that the full volumes of gas were consumed.

In this state-controlled system, gas was allocated through a political process to priority users in the fertilizer and electric power sectors. Low prices encouraged excessive consumption, however, and soon demand for gas outstripped supply. Other potential gas consumers, especially those in industry (such as steel, glass making, and petrochemicals), received the remaining gas after the priority consumers had used their allocation. Although cheap, these gas supplies were unreliable and frequently cut off without compensation, causing many consumers to build plants capable of running on multiple fuels.

Retail price caps hindered investment in new gas production and infrastructure. ONGC was, first and foremost, an oil company that had little interest in gas, and private oil and gas companies had little access to the Indian market. A gas shortage quickly emerged and, by the end of the 1990s, by some estimates, nearly half of India's gas demand was unmet.[2] In response to this supply shortfall, the Indian government passed a series of broad reforms designed to increase the production and availability of gas. Most prominent among these was the enactment of the New Exploration Licensing Policy (NELP), which allowed private companies to bid for oil and gas exploration blocks, and to construct liquefied natural gas (LNG) import terminals. These private investors were guaranteed attractive tax rules and the freedom to sell their gas at whatever price the market would bear.[3]

These reforms have yielded fruit. In 2002, Reliance Industries Limited (hereafter "Reliance") announced a 14 trillion cubic foot (Tcf) gas field off the east coast of India, increasing India's available gas reserves by nearly 50%. Other large fields have since been announced by the Gujarat State Petroleum Corporation (GSPC)[4] and ONGC respectively.[5] In 2004, India's first

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[1] Small quantities of natural gas are produced in the northeastern state of Assam by another national oil company, Oil India Limited. However, these supplies are isolated from the major gas market and relatively small, and have been largely excluded from the discussion and analysis in this paper.

[2] Government of India (2000). "Hydrocarbon Vision, 2025."

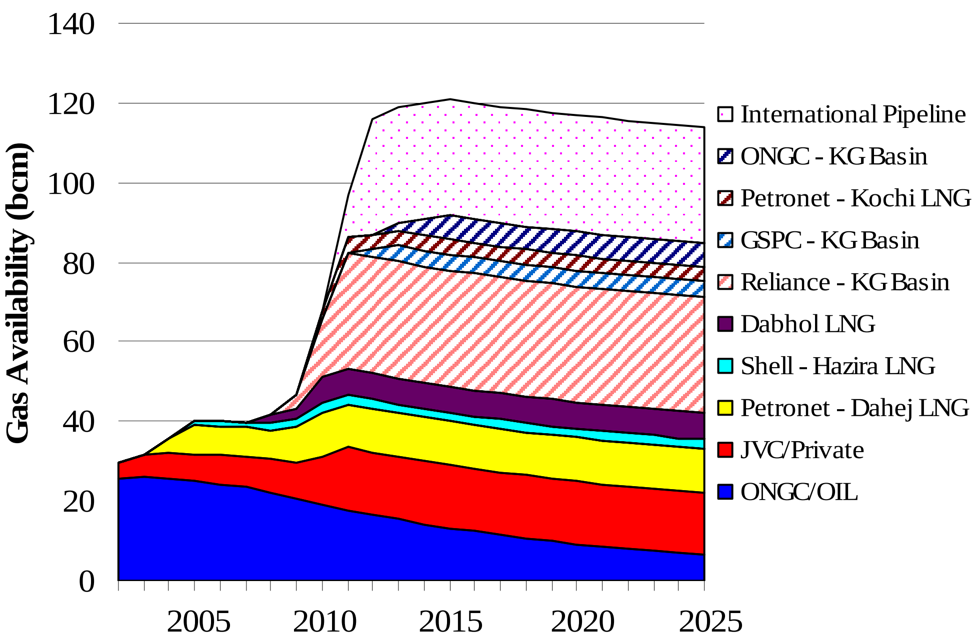
[3] For more detail on India's private gas market, see Jackson, Mike (2005). "Natural Gas Sector Reform in India: Case Study of a Hybrid Market Design."
Available at: http://iis-db.stanford.edu/pubs/20931/WP43.pdf

[4] GSPC is India's only state-government owned oil and natural gas company – with 95% equity held by the government of the state of Gujarat.

[5] As none of these fields have begun producing and selling gas into India, the exact size of these fields is a subject of intense debate and speculation in India. No attempt was made in this study to resolve this question – researchers simply assumed official company statements about field sizes and production capacity to be accurate.

LNG facility (Petronet – Dahej LNG) began operations, with a second (Shell – Hazira LNG) opening in 2005. Figure 1 stacks the expected supplies from these projects, in addition to the existing (declining) fields currently in production. The assured supplies are shown at the bottom; more speculative supplies (e.g., a much discussed, but heretofore unbuilt international pipeline, such as from Iran) are at the top of the stack. The figure assumes no major new domestic gas finds in the coming years, but given the significant exploration underway within India, it seems likely that other domestic supplies will materialize.

Figure 1: Projected Natural Gas Supplies by Supplier



Source: Author's estimates based on official government data and company statements. These figures reflect the significant downward revision of the size of the ONGC and GSPC fields

These new private gas supplies are being sold at prices well above those previously seen in India. While ONGC gas was delivered at state-regulated prices around $2.50/mmbtu, new private supplies cost upwards of $5/mmbtu. Some supplies have sold for much higher – in 2006, many observers were shocked when India purchased a spot cargo of LNG from Algeria a price of $9.28/mmbtu.[6] Despite these high prices, private suppliers have found eager buyers because, for some users, even expensive gas is more desirable than no gas at all.

In this new private market, the main consumers of expensive private gas have been those unable to secure subsidized supplies from ONGC – mostly industrial consumers who have a particularly acute interest in reliable gas supplies because they must keep their factories running reliably. Fertilizer producers and electricity generators, by contrast, have reliably secured access to low-

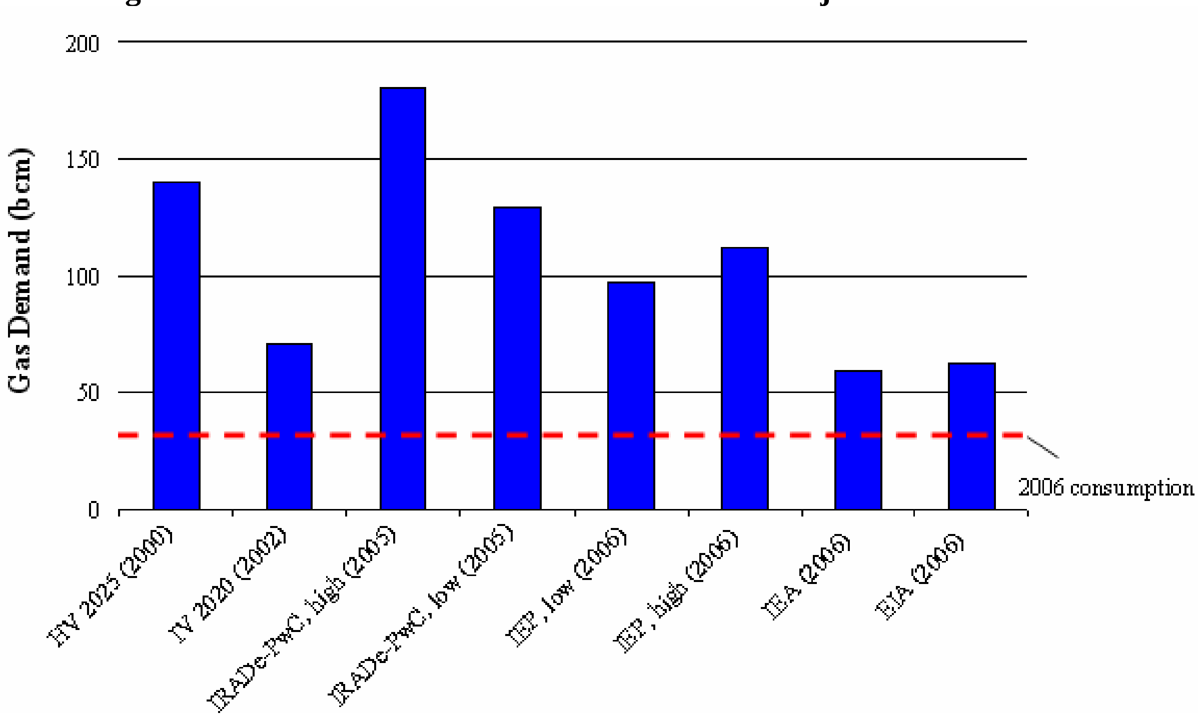
[6] The Hindu Business Line. "GAIL Sells Entire Quantity of LNG Spot Cargo Bought from Algeria." June 3, 2006. Available at: http://www.thehindubusinessline.com/2006/06/03/stories/2006060303990200.htm

cost gas due to their political clout. In effect, the market has bifurcated. Politically connected users in the fertilizer and electric power sectors still obtain their gas at low government-regulated prices. Other users get their gas from private suppliers at market prices. As the low-price supplies become scarcer and less reliable, a larger number of users are forced to shift from the public to the private market.

2. Study Methodology

This dual pricing and supply regime for gas, as well as the possibility of significant new supplies in the near future, have made it extremely difficult to project future demand for gas in India. Figure 2 summarizes several recent major projections for Indian gas demand in the year 2020. As the figure shows, these projections have varied widely – about threefold from 60 bcm to nearly 180 bcm. This wide range in projections is largely driven by different expectations of future economic growth, natural gas pricing and availability, and varying modeling methodologies.

Figure 2: Review of Indian Natural Gas Demand Projections for 2020

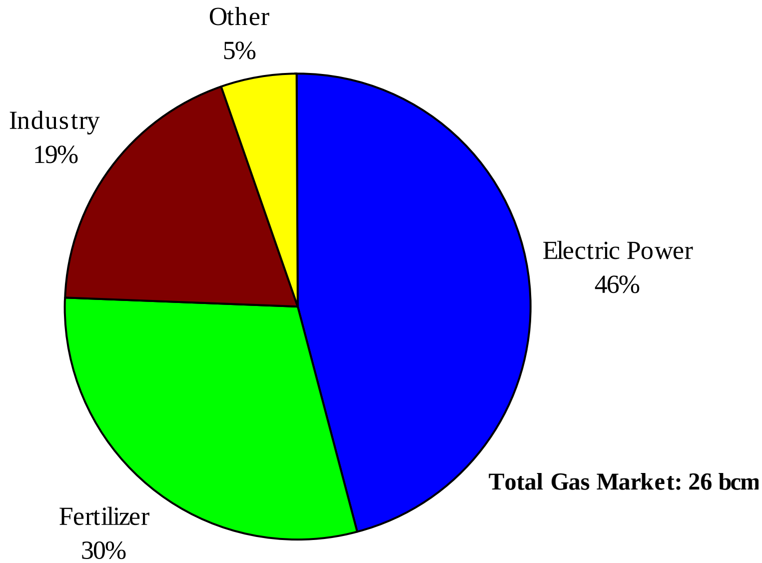


Sources: HV 2025 – Government of India (2000). "Hydrocarbon Vision – 2025."
IV 2020 – Government of India (2002). "India Vision 2020."
IRADe-PwC – Integrated Research and Action for Development and PriceWaterhouse Coopers (2005). "Fueling India's Growth – Vision 2030."
IEP – Government of India (2006). "Integrated Energy Policy – Report of the Expert Committee."
IEA – International Energy Agency (2006). "World Energy Outlook, 2006."
EIA – Energy Information Administration (2006). "Annual Energy Outlook, 2006."

The PESD Indian gas market study aims to understand the major drivers of natural gas demand, and explain how the Indian gas market might develop under different political and economic scenarios. In this way, it hopes to explain the variation in projections and explain how Indian gas demand could vary by wide margins under a range of plausible policy and development scenarios.

Unlike the PESD China gas market analysis,[7] which focuses on major geographical regions as the unit of analysis, the India study examines three key consuming sectors for the country as a whole: electricity generators, nitrogenous fertilizer producers, and industrial consumers.[8] As shown in Figure 3, these three consumers account for approximately 95% of current demand. Our study excludes attention to users such as CNG for transportation and domestic consumption because they play a minor current (and likely future) role in the total market. The widely publicized Supreme Court mandated shift of the Delhi bus fleet to compressed natural gas (CNG) for example, consumes about 1% of India's gas.[9]

Figure 3: Natural Gas Consumption in India (2006)[10]



We focus on major consuming classes, rather than geography, as the unit of analysis because natural gas pricing and allocation decisions are made at the national level in India. The most important variations are across consuming industries – in particular, in the policies that concern supply of low-cost price-regulated gas. In addition, the most important policy reforms relevant to gas demand in these industries are the product mainly of national political choices (e.g. coal sector reform and fertilizer import policy). While there are regional differences in gas transmission infrastructure – at present, the Indian gas transmission infrastructure serves only the northern corridor of the country, between the offshore fields on the western coast, through the state of Gujarat and into Delhi – over the next 15 years a rudimentary infrastructure is likely to

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[7] Jiang, BinBin (2007). "The Future of Natural Gas vs. Coal Consumption in Beijing, Guangdong and Shanghai: An assessment utilizing MARKAL." Program on Energy and Sustainable Development, Working Paper #62. Available at: http://pesd.stanford.edu/publications/china_gas_markal/

[8] Industrial consumers in this figure includes natural gas used both as a chemical feedstock and as a fuel for process heat. More details will be discussed later in the paper.

[9] Ministry of Petroleum and Natural Gas, Government of India (2007). "Petroleum Statistics." Available at: http://petroleum.nic.in/petstat.pdf.

[10] Ministry of Petroleum and Natural Gas, Government of India (2007). "Petroleum Statistics." Available at: http://petroleum.nic.in/petstat.pdf.

emerge in much of the rest of the country, at least in the major industrial regions that are the most attractive candidates for gas supply.

In preparing this study, PESD worked with three research partners in India to analyze these three primary consuming sectors. Within each of these sectors, it is clear that a range of different policy and market developments could significantly affect demand for gas. Thus, each study modeled variation in major demand drivers through scenarios. The results of these scenarios help to frame an analysis of possible futures for gas demand and to identify the factors of greatest importance for policy leverage. Table 1 below summarizes the major drivers modeled in the analysis within each study (more details on methodology can be found in the sections to follow and in the individual sector analysis papers).

Table 1: Summary of Natural Gas Study Sector Scenarios

Demand Driver	Current Conditions	Plausible Future Scenarios
Electricity		
Natural gas pricing	Some plants have access to cheap government-regulated gas	Gas supply curve allows plants to exhaust available low-cost supplies and forces them to purchase market-priced gas
Environmental controls	Piecemeal regulation of regional air pollutants in some cities	Tighter limits of sulfur emissions
Coal pricing and reform	Coal is state-controlled industry with low prices and infrastructure imposed cap on available supplies	Reforms allow much greater use of pit-head coal plants ("coal by wire") and imported coal, and raise coal prices towards international levels
Fertilizer		
Import controls	India is nearly 100% self-sufficient in nitrogenous fertilizer	Allowance of 5% or 30% dependence on imported fertilizer
Price and availability of gas	Most plants have access to cheap government-regulated gas	Cheap gas supplies decline and gas prices move to market levels
Farm gate urea prices	Prices to farmers have increased slowly but remain below international levels	Farm gate prices increase more rapidly towards international levels
Industrial		
Availability of gas	Many industrial consumers lack political access to gas supplies, and consume other fuels	Significant gas supplies are available to consumers willing to pay international prices
Economic growth	Economic growth is strong in India	Economic growth could accelerate, decelerate, or remain the same

3. Electricity Sector Demand

PESD worked with the Indian Institute of Management – Ahmedabad (hereafter "IIM") to analyze the Indian electricity sector. IIM used a bottom-up energy-economic model, MARKAL, to analyze the electricity sector—the same modeling framework that is used in the PESD China gas study. Inputs to the model are demand for energy services, conversion and end-use technology performance (power plants and boilers), and supply curves for primary energy resources (coal, oil, and natural gas). The model then determines the economically optimal arrangement of primary fuels and conversion technologies to meet the specified energy service demand.[11]

To explore the issues outlined in Table 1, we developed a reference projection that offered the researchers' view of the most plausible "reference" projection. This reference projection allowed examination of factors such as the gas supply curve and competition between the power sector and other sectors of the economy for scarce gas supplies. We then examined a number of reform scenarios, two of which are summarized here. One examines policies that affect the price and supply of coal, the main rival to gas for generating power. The other explores the consequences of a possible tightening of local environmental controls.[12]

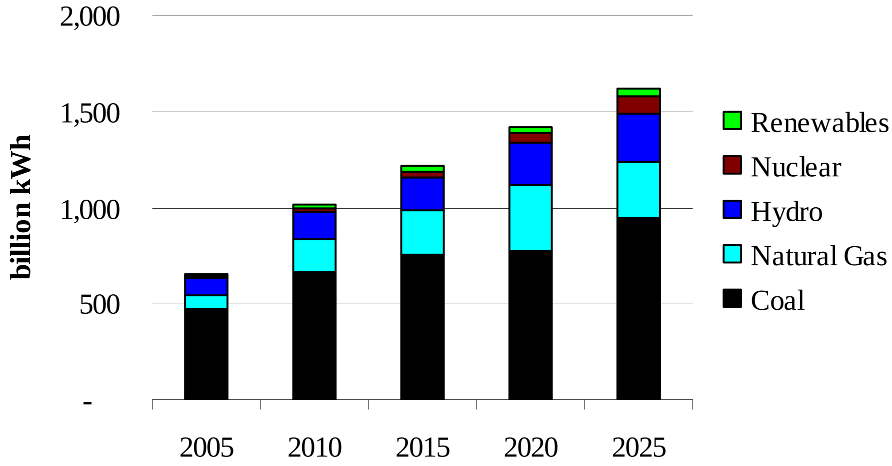
Reference Projections

Our reference projection for the fuel mix in the Indian electricity sector is summarized in Figure 4. While most of the remainder of the analysis in this paper focuses on the competition between natural gas and coal, there are two assumptions of note to point out for nuclear and hydroelectric power. Our analysis assumes only marginal increases in nuclear power over the coming decades. India is presently in discussions with the United States to develop a framework that would provide nuclear technology and fuel to help India's nuclear sector expand, but the impacts on the power sector are highly uncertain and will likely only be seen towards the end of the time period analyzed in this paper, if at all. In the case of hydroelectric, while our projections may appear bullish, they remain well below official government projections and goals, largely due to the perceived difficulty in siting and transmitting large amounts of hydroelectric power.

[11] Rather than a prediction of exact natural gas demand in each scenario, MARKAL indicates the least cost solution to realize the energy mix. In some cases, it is necessary to constrain technological penetration to reduce knife-edge effects where an entire electricity grid might switch to an advanced technology IGCC the minute it becomes cheaper. The results thus provide an indication more of how energy demand could be met most cheaply, rather than the most likely outcome.

[12] For a more in depth description and analysis of the electricity sector study, see Shukla, P.R. and Subash Dhar (2007). "Natural Gas in India: An Assessment of Demand from the Electricity Sector." Program on Energy and Sustainable Development, Working Paper #66.

Figure 4: Projected Electricity Generation Mix, 2005-2025



As the projections indicate, coal is expected to maintain its dominant position in the Indian electricity mix (69% in 2005 vs. 58% in 2025). Cheap domestic coal, as well as the increased availability of imports, makes it very difficult for alternatives like natural gas to compete with coal in this market. The share of natural gas does increase from 11% to 18% of the electricity market – much of this fueled by the new gas supplies projected to come online by 2010 from Reliance and other private suppliers. Natural gas assumes a large role in generating peaking power, as the model expects that the Indian load curve will shift from baseload-dominated power of today to a load curve with greater daily variability.

Over the modeling time period, cheap government gas is expected to decline in availability (which reflects the decline of the major ONGC fields and increased consumption from the politically better-connected fertilizer sector), resulting in gas prices that increase sharply after 2020. Tests of the model's sensitivity to higher economic growth scenarios suggest that gas consumption in the power sector will *decrease* as the economy booms. This finding reflects the expectation that high economic growth leads to high demand from industrial consumers, who outbid power generators for available gas supplies. As gas becomes more costly as domestic supplies are exhausted, coal is increasingly favored in the power sector, reflected in the decline in gas' share of power generation between 2020 and 2025.

The model projects a modest degree of technological change in power generation. The most significant is a shift from subcritical to supercritical coal technology beyond 2010. Based on the economic comparison, the model predicts nearly all incremental coal-fired capacity uses supercritical technology, because this burns coal more efficiently without incurring a dramatically higher capital cost. While our model seems optimistic in its expectations of supercritical deployment, supercritical technology is already being mandated in several central government-promoted 4,000 MW coal plants called the ultra-mega power projects (a more complete discussion of the ultra-mega power projects is found in the "Coal Reforms" section of this paper).

Reform Scenarios

Our study evaluated a series of policy reforms that are expected to significantly impact demand for natural gas in the Indian electricity sector. Some of these major reforms are discussed in the sections that follow.[13]

Coal Sector Reforms

The Indian coal sector has historically been run entirely through Coal India Limited (CIL), the national government-owned coal company of India. CIL has been widely criticized for years as an inefficient behemoth incapable of expanding production capacity to meet India's growing coal demand. This poor performance can largely be explained by CIL's inability to charge market clearing prices for coal, as these have been set by the central government and kept low to encourage consumption on the theory that higher consumption of primary energy would boost economic growth and employment.

The domestic coal industry is also plagued by infrastructure bottlenecks – most visibly on the Indian railway system that offers irregular delivery of coal to consumers. Given that India's major coal resources are located in the eastern part of the country where energy demand is low, and must be transported to the south and northwest, where demand is high, these railway constraints have restricted growth in coal and electricity production in India.

In general, Indian coal has very high ash content (often 40%), and the country has made inadequate investment in coal washing and other techniques that could upgrade coal quality. This has exacerbated the problems with railroad infrastructure, since a large fraction of the material transported is not actually combustible, and has also forced India to import high quality coking coal in recent years.

Catalyzed by these woes, the Indian coal sector has begun a serious overhaul that could revitalize the sector. The central government has taken steps to increase competition by opening some mines to private and foreign companies. So far, these openings have been restricted to investors that build pithead power plants, but there are indications that even these restrictions could be lifted. In 2005, CIL began selling some of its coal via competitive auction rather than through a government-managed "linkages" allocation process. The auctions are yielding considerably higher prices and revenue for CIL as well as more efficient allocation of coal resources. There are indications that the Indian railways are improving, although sustained railroad reform will likely remain an ongoing challenge.[14]

The government has also significantly reduced duties on imported steam coal, to be used in power production. Between 2003 and 2004, import duties on steam coal were reduced from 31% to only 5%, in response to the coal shortages facing India during that time. These coal imports

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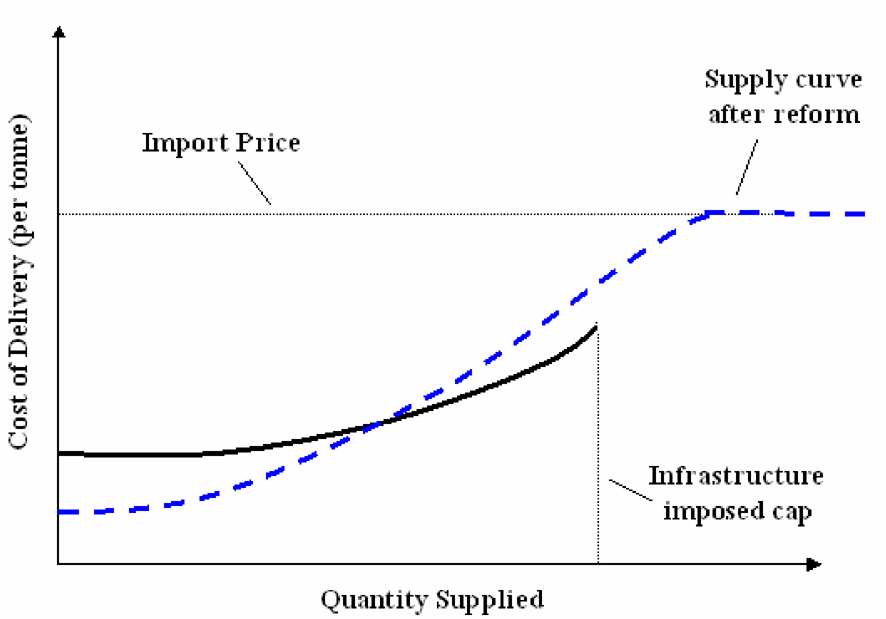
[13] The complete modeling results, including other policy scenarios and sensitivity analysis, are described in Shukla, P.R. and Subash Dhar (2007). "Natural Gas in India: An Assessment of Demand from the Electricity Sector."
[14] For more discussion on Indian coal sector reforms see Ministry of Coal, Government of India (2005). "Report of the Expert Committee on Road Map for Coal Sector Reforms."
Available at: http://www.coal.nic.in/expertreport.pdf

could help link Indian coal prices to the world market, and would likely raise prices in India towards international parity.

These reforms to the coal sector are most visible through the Indian government's role in promoting nine 4 GW coal plants, called the Ultra-Mega Power Projects. Some of these projects would be constructed at the pit-head in the eastern regions of the country, while others would be located on the coasts and fueled by imported coal. The first two projects, one coastal and one pithead, were auctioned to private domestic companies (Tata Power and Reliance) in 2007, with the hopes of beginning operations by 2012.[15]

Figure 5 provides a conceptual supply curve to show how these reforms are likely to impact the pricing and availability of coal in India. At present, before significant reforms are implemented, the solid-line supply curve illustrates that coal prices are low but the volume that can be delivered is constrained by inadequate investment in infrastructure (which, itself, is a function of low prices for delivered coal) – on the railways that transport the coal and the ports that could import it.

Figure 5: Impact of Indian Coal Sector Reform

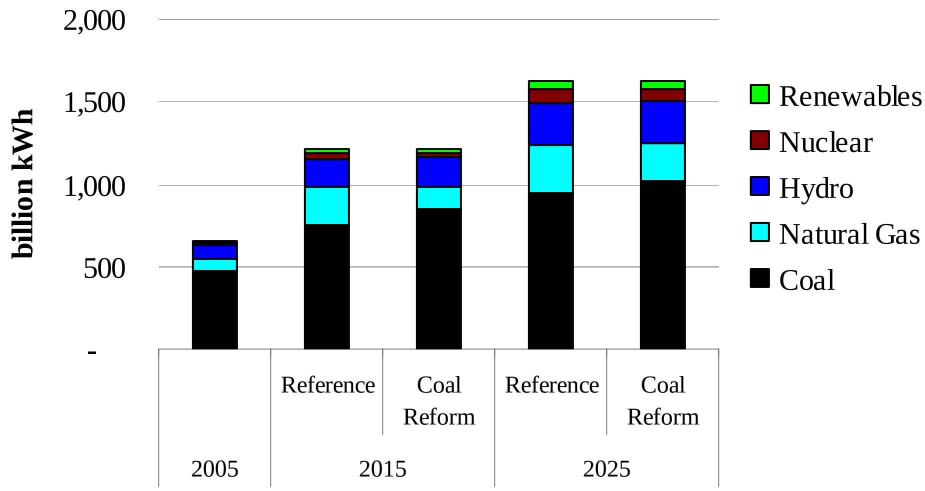


As the figure indicates, coal reforms (dotted line) are likely to reduce the cost of some supplies (mainly from pit-head generation applications) while, at the same time, increasing the volume of coal that can be delivered at higher prices that eventually equilibrate with international levels due to a larger role for imported coal. In effect, the marginal price of coal will rise but so will volumes available.

[15] The Ultra-Mega Power Projects are being run by the Power Finance Corporation, a central government-owned financial institution aimed at promoting efficient investment in the Indian power sector. The most up to date information on the progress of the projects can be found on their website at: http://pfc.gov.in/

A comparison of the coal reforms scenario with the reference scenario is provided in Figure 6 below. As the figure indicates, the reform scenario creates a shift towards coal, owing to the increased availability of domestic coal resources. However, that shift is modest because over the time horizon that is relevant here, the infrastructure cap is a "soft" one—it has some impact on constraining supplies but not a dramatic one. This is largely due to the fact that some reforms (notably eased restrictions on coal imports) have already been enacted and are included in the reference scenario. If a similar study were conducted in the late 1990s, when significant reforms appeared less likely, coal capacity would likely be much more constrained in the reference scenario due to this infrastructure imposed cap.

Figure 6: Comparison of Electricity Mix Between Reference Scenario and Coal Sector Reform Scenario



Stringent Environmental Reforms

Another modeling scenario focused on the impacts of restrictions on regional air pollutants – our study focused on sulfur dioxide (SO_2), which is of acute concern to Indian policymakers and also allows comparison of results in India with China, where our models adopted similar controls. Regional air pollutant controls are already in place in the most polluted and sensitive areas of the country – such as Delhi, Mumbai, and Agra – and more are likely in the future.

We modeled a stringent environmental scenario by constraining SO_2 emissions to 40% below the reference scenario projections. The Chinese study adopted the same limit, as well as additional scenarios with even tighter limits. The model results presented thus indicate the least cost solutions to meet these sulfur constraints on the power sector.

As Figure 7 indicates, natural gas plays a much more prominent role in the electricity mix under this scenario, nearly doubling in capacity. In addition (not pictured), nearly half of the coal capacity under this scenario is equipped with flue-gas desulfurization in order to comply with the sulfur restrictions.

Figure 7: Comparison of Electricity Mix between Reference and Stringent Sulfur Scenarios

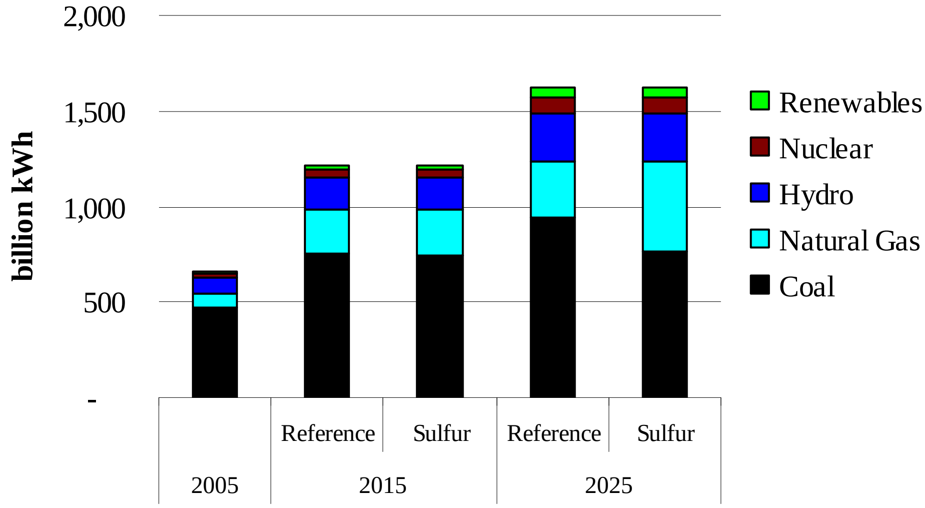
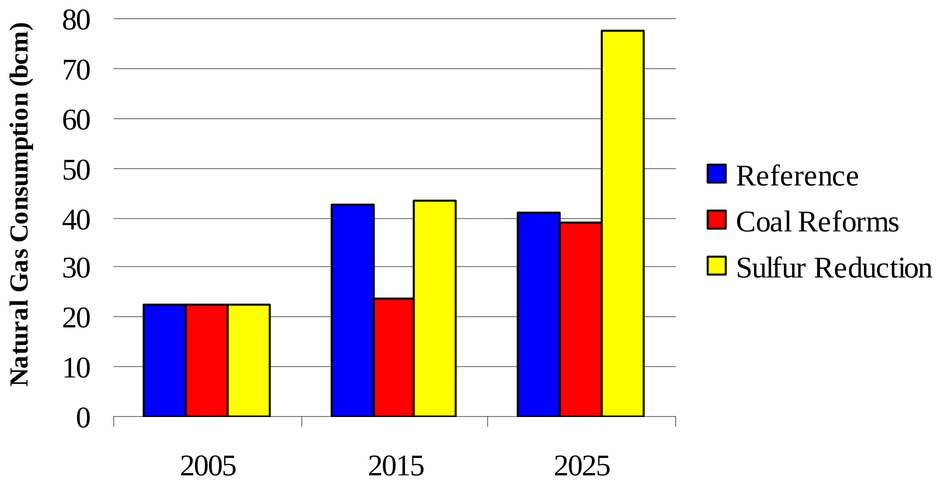


Figure 8 summarizes natural gas consumption under these scenarios. The coal reform scenario results in significantly less gas being consumed through 2020 as reforms relieve the infrastructure constraints on coal availability, indicated in the figure by very low gas consumption in 2015. The differences between the coal reform scenario and reference scenario lessen by 2025 as it is assumed that infrastructure constraints on coal delivery are relieved even in the reference scenario, largely through increased imports of coal.

Figure 8: Natural Gas Consumption Across Major Modeling Runs



The sulfur reduction scenario provides a much brighter future for natural gas – nearly double the demand of the reference scenario by 2025. While half of the sulfur reductions are met by the installation of flue-gas desulfurization on the new coal plants, about 40% of the reductions are realized by fuel switching from coal to natural gas.

Issues for Further Analysis

As is normal, modeling tools require simplifications that can limit the analyst's ability to examine the full range of issues. We note one, in particular, that merits further analysis as it could dramatically affect the role of gas in the power sector. Due to perennial insolvency and politicization of electric power in India, the country's supply system is fragmenting. Politically connected users rely on the grid, often with low tariffs, but the most lucrative industrial customers are leaving the grid system and relying increasingly on "captive" power systems. Reforms in 2003 have, in part, accelerated this tendency, which some analysts welcome because it offers the prospect of competition for the grid system. Where gas is available, these captive customers have often relied on gas because it is clean and flexible and less costly than oil. Many captive suppliers also use biomass – especially in the agricultural sector – and diesel.

More analysis is needed that looks to the future for captive power. On the one hand, continued economic troubles in the power sector along with wider availability of gas distribution infrastructures could accelerate the use of gas for captive power. On the other hand, efforts already under way to raise electricity prices and depoliticize the sector through more insulated central electricity regulatory bodies could encourage new centralized generation while reducing power consumption. By bringing solvency and increased reliability to the sector, captive generation could actually be reduced, potentially improving the prospects for coal.

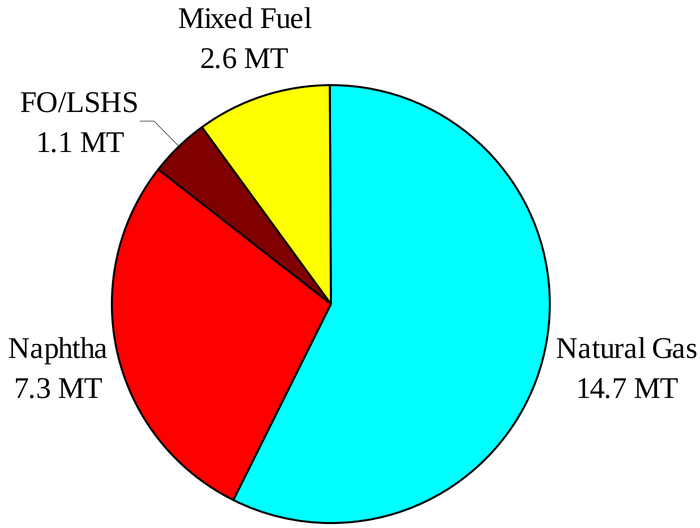
4. Fertilizer Sector Demand

The highly political nature of the Indian fertilizer sector renders an economic optimization model, like the one used in the electricity sector, essentially useless. Approximately two-thirds of India's 1.1 billion people derive their livelihood from farming, and these highly vocal masses have created a populist governing regime for the agricultural sector in India, resulting in policy based less on economic efficiency than on meeting the short-term perceived needs of the masses. Essentially all ruling coalitions must orient their agriculture-related policies to this simple electoral math.

Nitrogenous fertilizers are no exception.[16] Since the 1970s, India has maintained a cost-plus pricing regime for domestic fertilizer producers, guaranteeing them an attractive rate-of-return over their production costs. Through the 1980s and early 1990s, Indian policymakers encouraged construction of fertilizer plants along the HVJ pipeline that connects gas fields in the west with the major consuming centers in the interior to Delhi, and provided these plants with inexpensive natural gas. As a result, India has been able to achieve 100% self-sufficiency in nitrogenous fertilizer production. However, due to frequent shortages of gas in the pipeline, much of India's fertilizer production was built with the flexibility to utilize gas (when available) or oil-derived naphtha (which, as a liquid, is easier to transport and store on site). Figure 9 summarizes Indian fertilizer production capacity by feedstock.

[16] Unless otherwise noted, the term "fertilizer" in this paper refers to nitrogenous fertilizers.

Figure 9: Fertilizer Production Capacity by Feedstock (2005)[17]

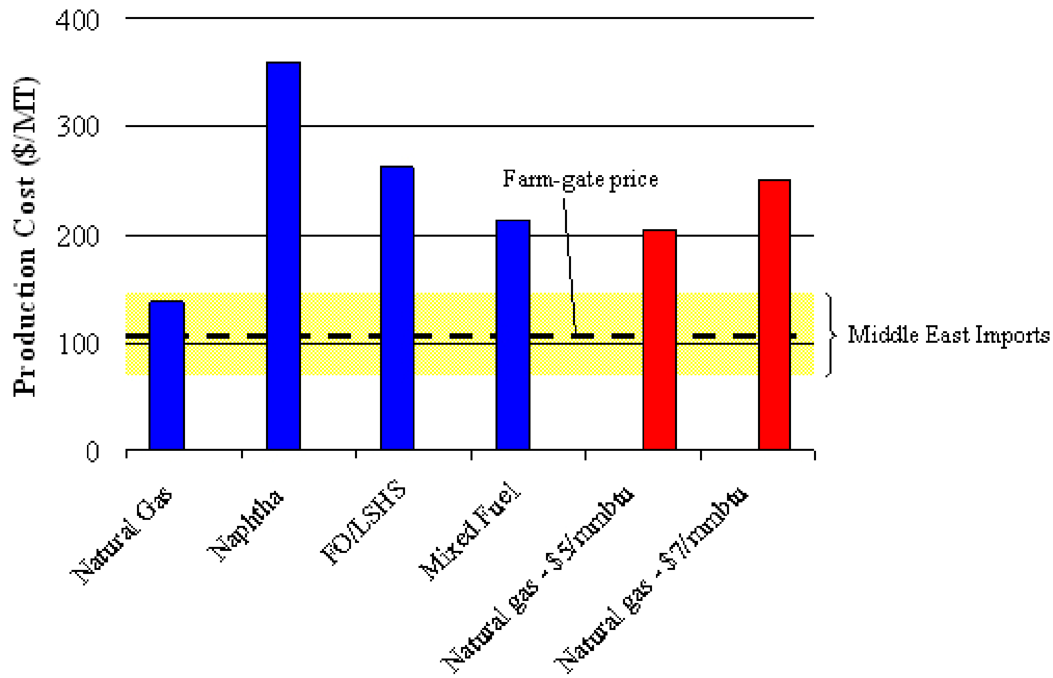


Farm-gate prices for nitrogen fertilizers have also been maintained well below the cost of production, with the difference between production costs and farm-gate prices paid by the central government as a subsidy. As the quantity of this subsidy increased through the 1990s to over $2 billion, Indian policymakers have sought greater fiscal probity, and the central government has sought ways to reduce this burden.[18]

Figure 10 summarizes the average production cost of fertilizer by feedstock in India, along with the farm-gate and import parity prices. As indicated by the figures, there is a wide range in fertilizer production cost based on fuel, and nearly all Indian fertilizer is more expensive to produce than current world standards for new plants.

[17] See Integrated Research and Action for Development (2007). "Demand for Natural Gas in the Indian Fertilizer Sector."
[18] Department of Fertilizers (2005). "Annual Report, 2004-05."

Figure 10: Fertilizer Production Cost by Feedstock



Source: *Natural gas, naphtha, FO/LSHS, and Mixed Fuel costs from Government of India, Planning Commission (2006).*
Natural gas at $5 and $7/mmbtu from IRADe (2007). "Natural Gas Demand from the Indian Fertilizer Sector."
Middle East Imports based on delivered prices from an Indian project to import fertilizer from Oman, the so-called OMIFCO project, which commenced operations in 2005.
Farm-gate price is Rs. 4,850/tonne.

The main driver of the production cost differences is the cost of hydrocarbon feedstocks. In India, prices of many petroleum products, including naphtha and fuel oil, have been decontrolled by the central government and are at parity with international prices – with a range of $12-15/mmbtu. However, because the central government continues to pay the difference between production costs and farm-gate prices, naphtha-based plants have little incentive to switch to natural gas – at subsidized or even private market prices. Policy discussions underway today focus on mandating a switch to gas from naphtha to help reduce the subsidy burden to the central government.

As Figure 10 indicates, fertilizer sourced from the Middle East on a long term contract would be the cheapest option for India. One such plant has been set up in Oman as a joint venture between the Oman Oil Company and two Indian fertilizer cooperatives, and commenced operations in 2005. The plant sources gas at a price below $1.00/mmbtu, and plans to sell fertilizer to India on a long term contract at a price between $80-150/tonne.[19] Despite the cost advantages of this strategy, the political realities in India, anchored in a strong desire for food security and self-sufficiency, suggests that domestic production will continue to be favored over international supply options.

[19] Government of India, Indian Budget 2005-06.

Study Design and Reference Projections

Because domestic fertilizer production is protected by import restrictions, gas demand from the fertilizer sector will be almost entirely a function of total fertilizer demand and the degree to which imports are allowed, with imports comprising as much of supplies as permitted. As a result, demand can be estimated by back calculating from overall fertilizer demand and the allowed role of imports in the future. PESD worked with Integrated Research and Action for Development (IRADe), an economic policy think tank in Delhi, to construct such a model and determine demand for gas and allocation of subsidy under a range of proposed policy reforms.

The modeling exercise began with a projection of future demand under a reference scenario, which was the researchers' view of how the market might develop in the absence of major future reforms. Demand for fertilizer was projected to 2030, and using Indian fertilizer industry efficiency norms, natural gas demand was calculated from this figure. With new gas supplies coming online from Reliance and private suppliers in the near term, and the Department of Fertilizers stated policy of switching all plants to natural gas, it was assumed that all future fertilizer production beyond 2010 would be met by natural gas, rather than naphtha or fuel oil. Given the obvious cost savings – even expensive private gas supplies are significantly cheaper than naphtha and fuel oil – we find it hard to see how this policy would fail to be enacted, and therefore include a switch to a fully natural gas fueled fertilizer market in all of our scenarios, including the reference projections.

The reference projections assume a 95% domestic self-sufficiency requirement, a mix between government supplied cheap gas and private gas, and slowly increasing farm gate fertilizer prices. Comparisons between assumptions used in the reference projections and two other projections described in this paper are provided in Table 2 below.[20]

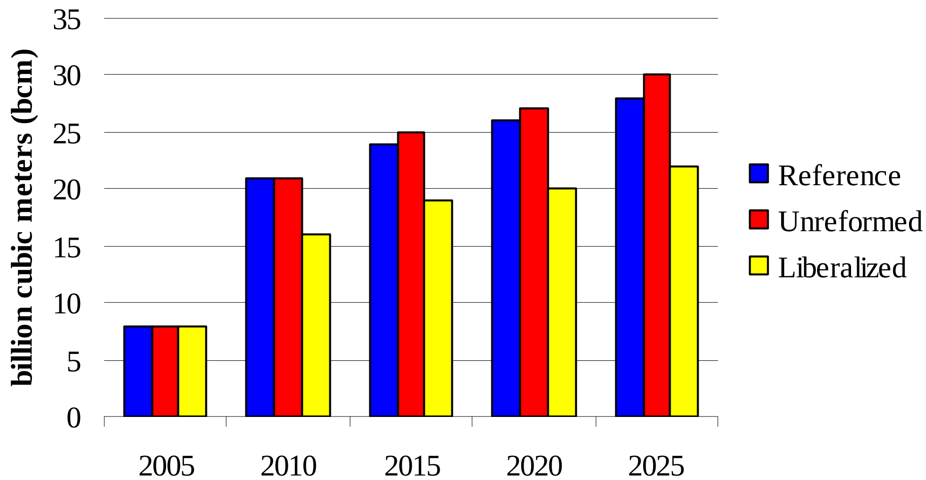
Table 2: Summary of Major Fertilizer Demand Scenarios

	Self-sufficiency requirement	*Farm Gate Prices*	*Natural Gas Pricing and Availability*
Reference	95%	Increasing by 10%	Mix of cheap government gas and private
Unreformed	95%	Remain constant	Unlimited cheap government gas
Highly Reformed	70%	Increasing by 10%	Mix of cheap government gas and private

The impacts for natural gas demand from these scenario runs are provided in Figure 11. As expected, we found that the strongest driver of natural gas demand in India is likely to be fertilizer import policy because imports are expected to outcompete domestic production to the extent they are allowed into the market. Our model found that rising farm-gate prices decreased demand for fertilizer only marginally. The large jump in gas demand observed between 2005 and 2010 in all scenarios is driven by the switch of all plants to natural gas by 2010.

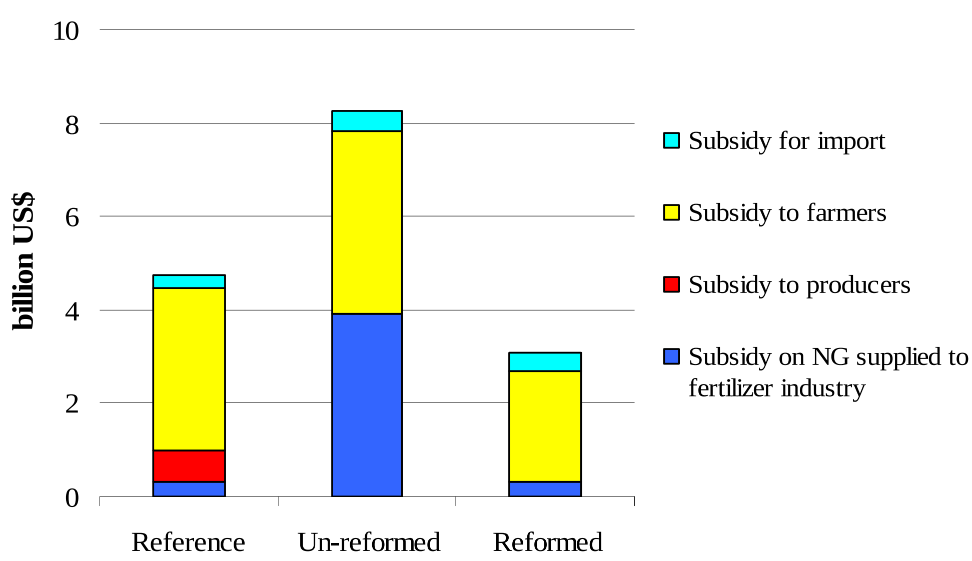
[20] Other variables were modeled in the study, all of which can be seen in Integrated Research and Action for Development (2007). "Demand for Natural Gas in the Indian Fertilizer Sector."

Figure 11: Gas Demand from Fertilizer Sector under Different Scenarios



The fertilizer model also tracked the quantity and allocation of subsidy needed to be paid by the central government under each scenario. Figure 12 summarizes the allocation of subsidy under the three scenarios described in Table 2. As the figure indicates, the quantity of subsidy paid by the central government varies considerably under each scenario, as does the allocation of the subsidy. For example, while the unreformed scenario is politically more tenable than a highly reformed scenario among the agricultural sector, it results in a subsidy burden for the central government that is probably too high to sustain. Alternatively, while the highly reformed scenario does reduce the subsidy burden the most, it requires India to purchase significant quantities of fertilizer from overseas, and may encounter stiff resistance from domestic producers and constituencies arguing for self-sufficiency in fertilizer production.

Figure 12: Distribution and Allocation of Subsidy Under Different Scenarios



The second illustrative example is the cost of self sufficiency. The researchers compared the cost of India's goal for 95% self sufficiency with a concerted strategy to build fertilizer plants in gasrich countries and import fertilizer under a long term contract – whereby the cost of imports could be significantly cheaper. The modelers determined that the government would save Rs. 50 billion (approximately $1.3 billion) per year through pursuing a more liberal import strategy associated with moving from 95% to 70% self sufficiency. Even greater reliance on long term fertilizer imports would yield even greater savings in total subsidies paid by the central government. While self sufficiency is an attractive goal, it does come with a very significant cost.

In conclusion, we find that gas demand from the Indian fertilizer sector will be driven by two main factors. The first is the willingness of the central government to allow imports of fertilizer. The Oman project – being located in a foreign country, but partially owned by Indian companies – offers a compromise between the desire for self-sufficiency and the need to reduce the cost of production. Should this model prove politically tenable on a larger scale, gas demand growth from the fertilizer sector could be significantly reduced. If the current political fashion towards self-sufficiency remains, then the Indian fertilizer sector could consume very large quantities of gas into the future.

The cost of these scenarios to the central government could help drive the political outcomes. Massive subsidy burdens have forced liberalization throughout the Indian economy over the past fifteen years, and it could be that India simply cannot afford to follow the unreformed path as demand for fertilizer doubles over the next twenty years. In such a scenario, gas demand from the fertilizer sector would likely decline as farm-gate fertilizer prices increase or cheap imports gain market share.

5. Industrial Gas Demand

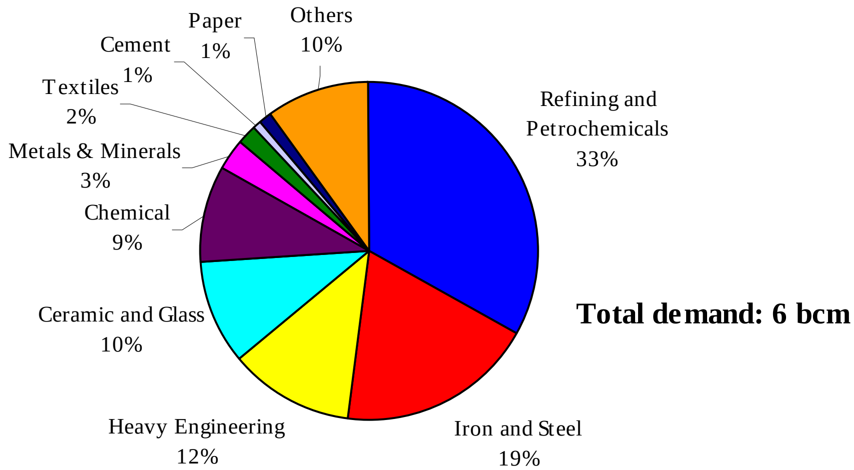
Industrial consumers that are connected to gas supply infrastructures (and thus have access to gas) could potentially emerge as major consumers of natural gas in the future. These consumers, historically, have had difficulty securing reliable supplies of natural gas, but with the increased availability of gas in the near future, industrial consumers will have the option to purchase gas from private suppliers (who source gas from domestic fields or LNG) at higher prices than those that prevail in today's government-regulated supply system. In India today, the major consumers of LNG cargoes thus far have been these industrial consumers, who have been willing to pay for expensive gas rather than be left with no gas at all.

PESD worked with analysts from A.T. Kearney in India to determine the economic viability of natural gas for industrial consumers in 2025. Researchers projected industrial demand for hydrocarbons to 2025, and then, through interviews within nine major industries, determined what demand could be met economically by natural gas, incorporating conversion cost, fuel cost, gas infrastructure constraints, and other relevant variables.[21]

[21] For a more detailed discussion of the modeling framework and results, see A.T. Kearney (2007). "Demand for Natural Gas in the Indian Industrial Sector." Program on Energy and Sustainable Development, Working Paper #68.

Figure 13 below summarizes the major natural gas consuming industries in 2006. As the figure indicates, the refining and petrochemicals industry consumed the most gas in 2006, followed by iron and steel. We will reexamine these two industries in our analysis of the modeling results.

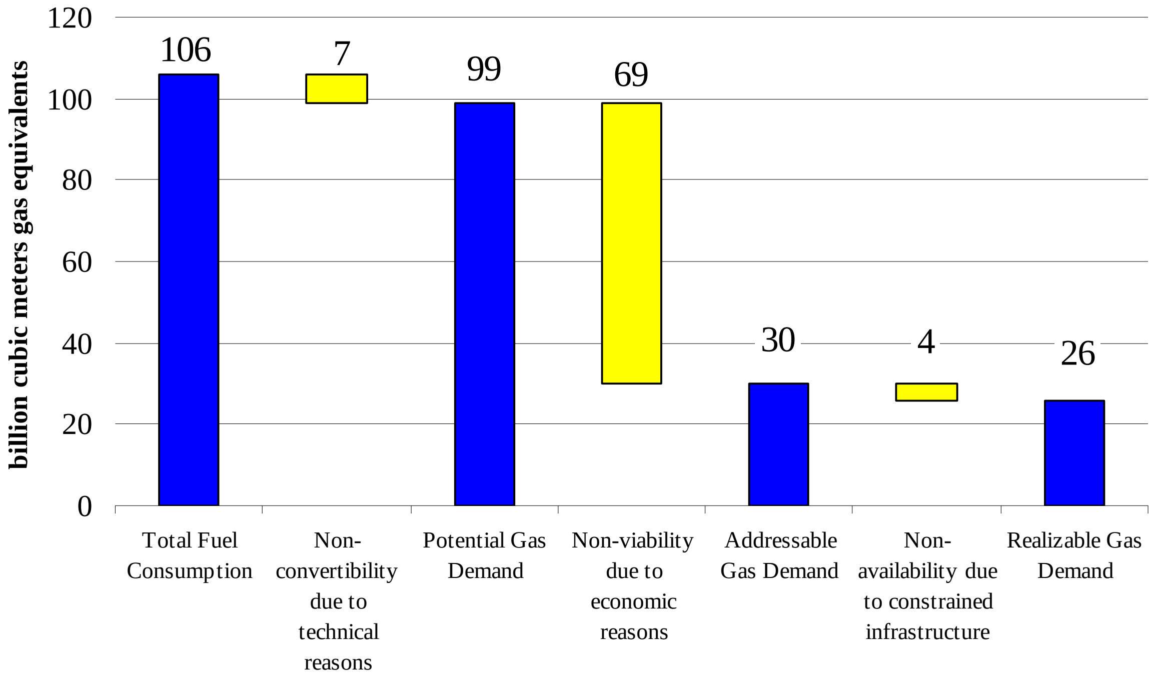
Figure 13: Distribution of Industrial Gas Demand, 2006



Modeling Results

Through focused interviews with these nine major industries, the A.T. Kearney study projected total demand for industrial fuels in 2025, and calculated the amount of this demand that could be met economically by natural gas. Figure 14 summarizes these results.

Figure 14: Projected Realizable Industrial Natural Gas Demand, 2025

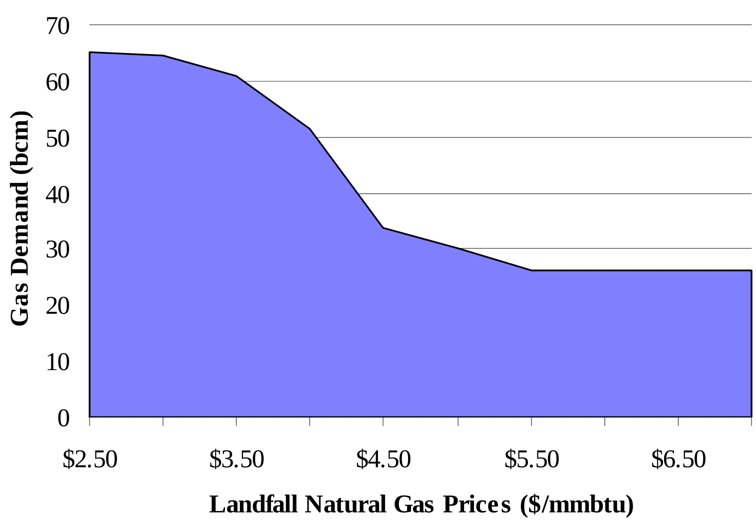


Note: Assumes a delivered natural gas price of $5.50/mmbtu.

As Figure 14 makes clear, natural gas is technically capable of meeting all but a small amount of industrial energy demand (coking coal in the iron and steel industry, for example, cannot be switched to natural gas). The major constraint on natural gas use is the high price of natural gas relative to the alternative, cheap coal. The major opportunity for growth in natural gas demand is in displacing petroleum use, where gas prices paid in the private market are a bargain for consumers currently paying prices over $10/mmbtu for oil.

These results are reflected in Figure 15, which projects a demand curve for natural gas in 2025.

Figure 15: Industrial Natural Gas Demand Curve, 2025



The demand curve for industrial gas suggests two important findings. First, significant additional natural gas could be consumed by the industrial sector if gas prices were low enough that gas could compete directly with coal. That scenario would require gas prices much lower than those seen in India today, which is implausible since industrial consumers do not have the political clout to obtain government-regulated gas. However, if tight environmental controls were applied to coal-based industrial boilers then gas might find itself in a much more competitive position relative to coal in the industrial sector. We haven't explicitly modeled a more stringent environmental control scenario for industrial consumers, although we are exploring that possibility for future study.

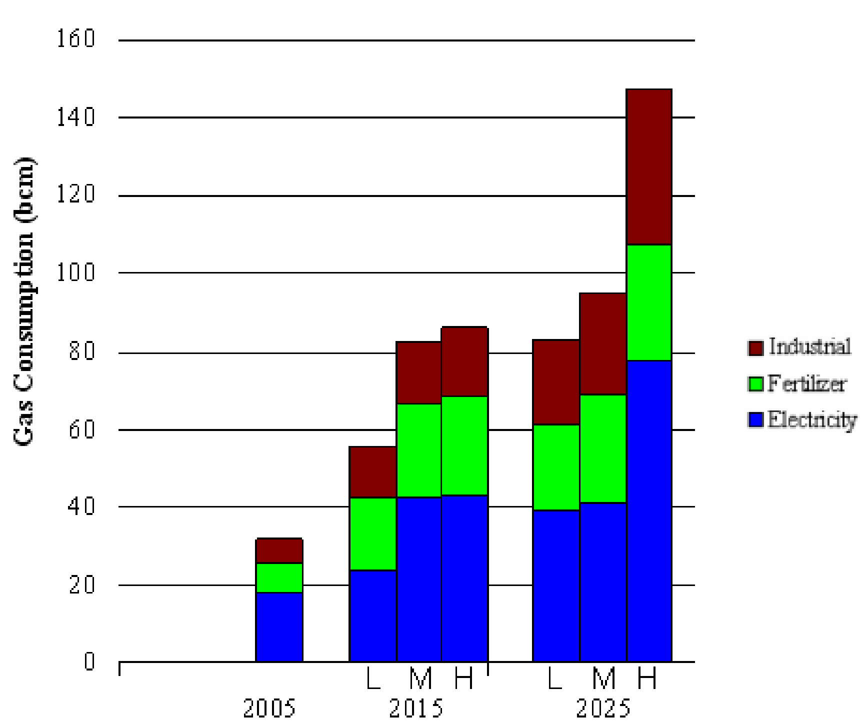
Second, demand for natural gas is highly inelastic at prices above about $5.00/mmbtu. This is largely because in this price range, most switching is from oil to natural gas; even at very high natural gas prices, gas is more economic than oil. This supports the finding that most of the growth in gas consumption comes from refining and petrochemicals, where coal use is low. Conversely, steel and iron producers' share of the industrial gas demand declines to 2025, because most of their consumption continues to be met by cheap eastern coal. This would suggest that Indian industry should not be constrained on price in accessing LNG from overseas because they are able to pay prices seen around the world today. Furthermore, it explains why Indian LNG importers have been able to import and sell gas at very expensive prices on the spot market, as seen with the recent high-cost purchase of LNG from Algeria.

6. Implications for Total Indian Gas Demand

Because natural gas pricing and allocation is segmented by consumer in India, adding up the projected consumption of gas from each major consumer provides a close approximation of the projected size of the overall gas market in the future. We assume fertilizer producers will be able to access as much gas as they can consume (though some runs assumed higher prices). We then removed this consumption from the available gas to the power sector to construct a gas supply curve exclusively for the power sector. And because industrial consumers operate in a market connected largely to global LNG markets, we assume that LNG supplies are likely available if industrial consumers pay prevailing global market prices.

Figure 16 stacks our projections for gas demand under our reference, high, and low scenarios. These projections are meant to provide bounds on our projections of Indian gas demand. For example, the High Gas scenario assumes stringent sulfur constraints in the power sector, protectionist constraints on fertilizer imports, and high economic growth driving industrial gas use. The Low Gas scenario assumes vigorous coal sector reforms, liberalized fertilizer imports, and low economic growth slowing industrial gas demand. Clearly, these High and Low Gas scenarios are provided largely for illustrative purposes – different combinations of High and Low Gas demands from each consumer are plausible ways in which the gas market might develop.

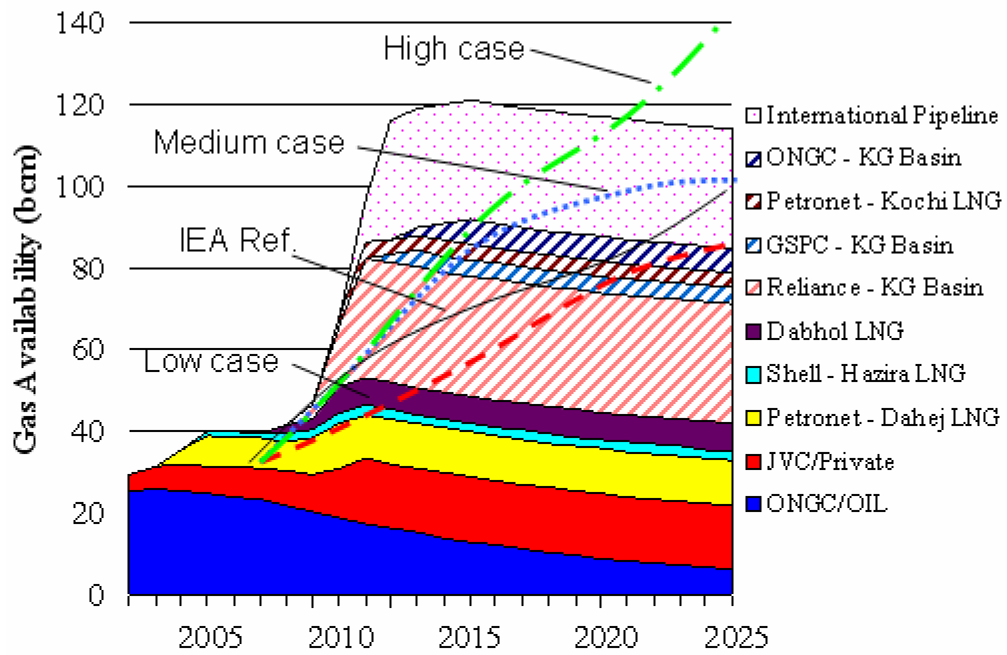
Figure 16: Projected Natural Gas Demand (2005-2025)



**L, M, and H are Low, Medium and High gas demand scenarios respectively.*

In Figure 17, we have plotted these demand projections onto the likely available supplies of natural gas over the next twenty years from Figure 1.

Figure 17: Indian Gas Supply and Demand Projections



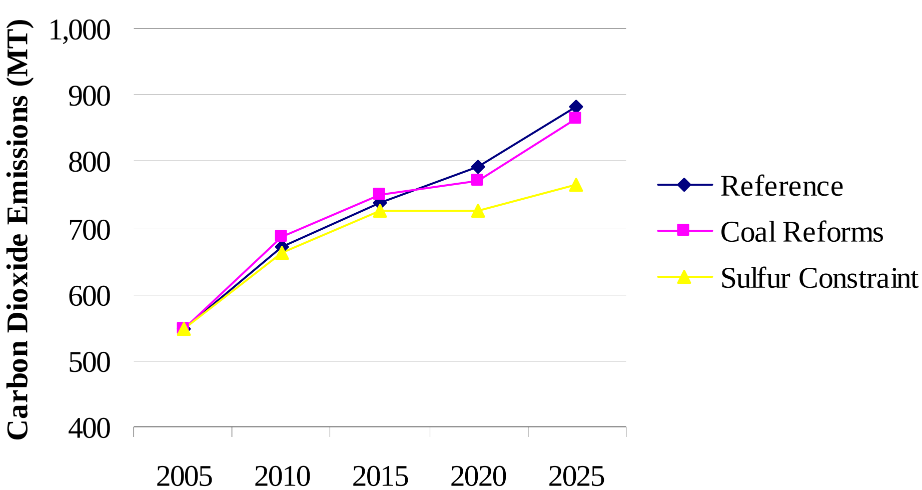
"IEA Ref." from International Energy Agency (2007). World Energy Outlook.

As Figure 17 indicates, the supply projects being developed in India today will be sufficient to supply India's gas demand under all but the most aggressive growth scenarios. A proposed international pipeline – from Iran, Turkmenistan, Bangladesh, or Myanmar – appears to be a risky endeavor, not only because of security of supply concerns, but because it is unclear whether India can reliably guarantee consumption of the gas. Only under the most bullish projections will India be likely to consume the entire output of an international pipeline, and this demand only appears likely post-2020. In addition, given that India has only recently begun aggressive efforts to expand domestic exploration and production of gas, it seems likely that additional domestic supplies, not shown in this figure, will materialize over the next 15 years. With such highly uncertain demand for imports – due to uncertainty in both the domestic demand and supply – smaller LNG terminals, constructed when excess demand is assured, appear to be a more rational supply strategy for India.

7. Implications for Climate Policy and Leverage

Although we did not model an explicit CO_2 abatement scenario, the MARKAL model reported CO_2 emissions from the power sector for each run. Figure 18 summarizes CO_2 emissions under the three electricity scenarios reported in this paper, and finds that emissions vary across the modeling runs. Of particular note is a 115 million tonne CO_2 reduction between the sulfur constraint and reference scenarios. In the context of emissions reduction strategies discussed around the world today, this is quite significant. For example, it is approximately triple the reductions already monetized in India through the Clean Development Mechanism of the Kyoto Protocol.

Figure 18: Carbon Dioxide Emissions under Electricity Scenarios



8. Conclusions

The study suggests a number of key findings on the role of China and India in the global gas market, and offer insights into the competitiveness of natural gas in these two countries over the next two decades.

1) Demand size and uncertainty could influence supply infrastructure decisions

In India, the role of imports is highly uncertain. As Figure 17 indicated, should demand for gas grow significantly across the three major consuming industries, India should be able to consume large quantities of imports – and potentially guarantee the offtake of a major international pipeline post-2020. But if consumption falls below this robust case, or if other new supplies materialize in India (a likely scenario given the aggressive exploration underway through the NELP), it seems unlikely that India could ensure demand for a large international pipeline.

Interestingly, while most attention on international pipelines to India has focused on security of supply – mainly on Iranian credibility and Pakistani security risks – previous studies by researchers at PESD found that many gas supply projects in the past were disrupted not because of the supplier withholding gas to extort a higher price, but because the offtaking country's demand didn't materialize as expected.[22] Because of the highly uncertain import requirement from India and the extremely high capital cost of an international pipeline, we find it questionable whether a major international pipeline would be economically feasible. Instead, we see LNG as the more logical supply option because each project is much smaller and can be built modularly as demand becomes certain.

2) Gas demand is highly dependent on policies outside the gas sector

While there has been considerable attention to the role of gas pricing, supply, and infrastructure in understanding the future of the Indian gas market, our study found that policies not generally considered energy policies had the largest impact on overall gas demand. In the case of the electricity sector, gas demand was largely driven by sulfur controls (providing an incentive for cleaner burning natural gas) and by reforms to the coal sector. For the fertilizer sector, overall gas demand is most dependent on fertilizer import policies, which are tied up in concerns about agricultural self-sufficiency. For industrial consumers, private natural gas supplies are available and attractively-priced relative to alternative fuels, so gas demand will likely track overall economic development and growth rather than any particular pricing or allocation policies, since gas (where available and feasible) clearly outcompetes oil but is generally most expensive than coal.

3) The electricity mix in India is unlikely to change dramatically

Our models solved for the least-cost solution to meeting India's demand for energy services. Across the scenarios, it is very difficult to foresee a scenario in which coal does not remain the dominant fuel for electricity generation. Coal is simply too cheap, abundant, and entrenched to

[22] Victor, David, Mark Hayes, and Amy M Jaffe (2006), ed. "Natural Gas and Geopolitics."

leave unused (India has the world's fourth largest coal reserves), and the domestic coal industry maintains tremendous political clout through Coal India, Ltd, one of the largest employers in India. Aggressive sulfur reductions do shift the electricity mix to a greater role for natural gas, but much of the overall sulfur reductions are met by installing end-of-pipe solutions for coal plants, like FGD.

4) Coal sector reform may undercut climate change objectives

When available, coal outcompetes natural gas in the power sector and industrial use. The experience in India through the 1990s and early 2000s suggests that coal use could be constrained because of lack of investment in new production capacity or the resolution of transportation bottlenecks. Such constraints on coal could lead to a much larger role for natural gas.

But coal sector reforms being undertaken are likely to dramatically expand the availability of coal. In India, liberalization of the coal sector is expected to introduce new mining technology, stimulate more efficient operations from CIL, and bypass transportation bottlenecks (through coal-by-wire and imports). While coal prices will increase as a result, they are not expected to increase enough to allow natural gas to outcompete coal as a fuel for baseload power.

5) Non-climate policies could have a large impact on carbon emissions

While India is unlikely to accept binding carbon dioxide emissions reductions targets in the near future, very large CO_2 reductions might be realized as a side benefit from other policies enacted for reasons aside from climate concerns. For example, a national sulfur reduction policy could have huge implications for carbon emissions. The modeled coal to gas switch observed in the power sector in response to a mandated 40% reduction in sulfur is associated with about 115 million tonnes of avoided CO_2 emissions. Indian policymakers have already begun to regulate regional air pollution in Delhi, Mumbai, and in the region near the Taj Mahal because of the short term health and safety impacts of the pollution. Expansion of this policy could provide a significant carbon emissions reduction as an unintended benefit. While these reductions alone are small in relation to the total size of the global climate change challenge, they could nevertheless play a meaningful role in addressing climate change in a country that has been reluctant to take on any binding targets for its emissions.