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▶ Positioning the Indian Coal-Power Sector for Carbon Mitigation: Key Policy Options

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Executive Summary

Coal-based generation appears likely to remain the linchpin of the Indian power sector at least for the next few decades, given the large domestic coal resources and the absence of any other significant domestic energy sources in the country. Coal power will, thus, help increase the availability of electricity, particularly in rural areas, which is an urgent development priority for the country. Given the enormous financial resources required to achieve this objective, the power sector has strong incentive to deploy cheaper, well-proven generation technologies.

At the same time, climate change increasingly is recognized as an important issue for India, given the range and magnitude of the possible impacts. Even as India and other developing countries await stronger action by industrialized nations, policymakers have begun to explore ways to advance the country's development agenda while reducing greenhouse gas (GHG) emissions. Recently, the Indian Prime Minister constituted a Council on Climate Change to "coordinate national action for assessment, adaptation and mitigation of climate change." There is, however, widespread agreement within the country that its low per-capita emissions and development imperatives necessitate a deliberate approach to GHG mitigation.

The major challenge facing India is how to reconcile rapid growth in the coal-power sector with the increasing urgency to address climate concerns. Appropriate actions and policies that offer climate co-benefits in the present could lay a foundation for an eventual, broader carbon mitigation strategy in the future, and help transition the coal-power sector to a cleaner and more sustainable path. With this in mind, we suggest several immediate steps that can help reduce carbon emissions from the Indian coal-power sector in the short term while offering significant development benefits:

- Improve efficiency of all elements in the existing power system: generation, transmission and distribution, and end-use;

- Aggressively deploy higher-efficiency pulverized coal combustion technologies, such as supercritical and ultra-supercritical technologies;

- Create a program for systematically assessing emerging technologies that may become important for the medium- to long-term future of the coal power sector, and develop a strategic national plan for development, adaptation and deployment of suitable technologies;

- Establish and enforce emissions standards for sulfur oxides (SO_x) and nitrogen oxide (NO_x), and provide incentives for installing pollution-control technologies, such that carbon capture from Indian power plants is economically feasible in the future, should the country decide to exercise that option; and

- Invest in a focused effort on detailed geological assessment of on-shore and off-shore carbon storage sites in India.

A number of other activities can play a major role in the successful implementation of the technical and programmatic elements listed above. First and foremost, the institutional and financial health of the sector needs to be strengthened; while there has been some progress on power-sector reforms over the past decade, it is important to learn lessons from these recent experiences and tailor India-specific policy solutions. Given the dominance of the government in nearly all aspects of coal and coal-power sectors, it is essential that the different government ministries and agencies share a common sense of vision for the sector, and improve inter-ministerial and regulatory coordination.

Given the interdependence between the coal and the coal-power sectors, it is also important to develop a better understanding of coal resources, and to fashion a set of coherent policies for sustainable growth in the coal sector. Technology analysis and innovation systems in the Indian coal-power sector also require institutional changes and a significant infusion of financial resources. In addition, more attention is needed in the area of domestic policy research and analysis—such analyses are crucial for devising long-term energy policies and successfully implementing them. While many of these activities necessarily will be carried out by government organizations, significant attention also needs to be paid to issues of transparency and wider stakeholder and public participation. The priority should be to ensure that these technology programs and the resulting policies are robust and that they adequately respond not just to the climate challenge but also to the wider challenges facing the Indian power sector.

Finally, international action and cooperation play a crucial role in accelerating India's technology analysis, innovation, and deployment, as well as broader climate change policies. The advancement and deployment of low-carbon energy technologies in industrialized countries (through concrete policies and actions) can reduce the technical risk and the costs associated with these technologies, which in turn, will determine the options available to developing countries. In addition, industrialized countries could help with technology assessment and analysis to facilitate the selection of appropriate technologies for India. At the same time, it is also important to note that an excessive and premature push on power-sector GHG mitigation in India, particularly by international agencies, might be counter-productive, especially if it is not clear what technologies make sense for India from a long-term perspective and if their technological and economic feasibility is not well demonstrated.

The domestic and international steps outlined in this paper could greatly advance the development and implementation of a GHG-mitigation strategy in the Indian coal-power sector, while allowing the sector to contribute suitably to the country's energy needs. The key to success will be adopting a deliberate approach, with short- and long-term perspectives in mind, that allows for the development of an integrated energy and climate policy.

Introduction

As a developing country with a large number of people living in poverty, India must work to enhance its economic development as a first step to uplift the poor. Economic development and the fulfillment of basic human needs such as education, sanitation, health and communication are dependent on the availability of modern energy services. Indeed, improved standards of living in developing countries such as India are closely associated with an increase in energy demand.[1] Thus, a principal challenge for India is to determine a coherent and forward-looking set of polices to provide the country with clean energy to meet its development goals.

On a per-capita basis, India's energy consumption is low compared not only to industrialized countries but also to many developing countries (such as China) and to the global average.[2] In terms of electricity use, per-capita consumption in India was only 480 kWh in 2005, just over one-quarter that of China and just over one-twentieth the OECD average.[3] Also, India has long suffered from an insufficient supply of electricity in relation to the demand—in 2005, supply was estimated to be 6 to 8 percent below demand, and peak shortages were as high as 11 to 12 percent (Ministry of Power, 2006a). The quality of power supply in the country is also very poor, with unstable voltages and routine frequency excursions. The lack of adequate and reliable supply of power is often cited as a critical constraint to industrial development in India.[4]

Hence, there is an urgent need for a continued and rapid enhancement of the availability, reliability, and affordability of modern energy services, especially electricity, in India (as in many other developing countries). At the same time, it is important that increased energy use not adversely affect India's energy security or come at high social or environmental costs. Key socio-environmental issues include: the abatement of local pollution (particularly for coal-fired power plants); reducing land-use conflicts (especially, but not only, for hydropower projects); and, more recently, emerging concerns over emissions of greenhouse gases (GHGs), which are the drivers of global climate change.

Reducing GHG emissions to alleviate the impacts of global climate change will be a critical challenge for the energy sector, in particular for electricity generation, not just for India but throughout the world. Global climate change has received significant and increasing attention in recent years, both because of its potential impacts on humans, ecosystems, and economies, and because of the scale of effort needed to mitigate this problem. The United Nations Framework Convention on Climate Change (UNFCCC) recognizes that industrialized countries, with much higher cumulative and per-capita emissions, "should take the lead in combating climate change,"[5] and that "economic and social development and poverty eradication are the first and overriding priorities" of developing countries. The urgent need to tackle climate change is becoming more apparent and more accepted in almost all policy circles in India, and the Prime Minister recently constituted a Council on Climate Change to "coordinate national action for assessment, adaptation and mitigation of climate change." This Council has developed a National Action Plan on Climate Change and the government is moving towards implementing it.[6]

Addressing climate change will require a special focus on mitigation of GHG emissions from coal-based power plants in the country. Currently, more than 70 percent of India's electricity generation is based on coal, and a significant fraction of new electricity supply in India is likely to be based on domestic coal derived from India's significant reserves. Hence, it is crucial for policymakers to begin to assess the implications of continued use of coal for power generation in the context of the GHG mitigation challenge.

While this clearly is not the only challenge facing the coal and coal-power sectors, it is likely to gain in importance in the coming years. The technical and political complexities of mitigating GHG emissions imply that it is critical to start examining future policy options and laying the appropriate groundwork in a systematic and careful fashion, even as India and other developing countries await stronger action by industrialized countries.

This work builds upon a complementary paper, *A Resource and Technology Assessment of Coal Utilization in India* (Chikkatur, 2008), to examine the policy options for managing GHG emissions from the coal-power sector in India.[7] It reviews the context for policymaking in this sector in India and presents policy options based on these contextual factors and on the technological assessment presented in the companion paper.

Context for Climate and Power Sector Policymaking

CLIMATE CHANGE AND INDIA

Climate change is primarily driven by the accumulation in the atmosphere of carbon dioxide (CO_2) from human sources, mostly resulting from the combustion of fossil fuels for energy use. Data from late 2006 indicates that CO_2 levels in the atmosphere now exceed 380 parts per million by volume (ppmv),[8] a significant rise from the pre-industrial concentration of about 280 ppmv.

A warming planet and changing climate will have significant but varied global impacts. Data from recent models indicate a median increase of 3.3°C in annual mean temperature by the end of the 21st century; the projected minimum and maximum temperature rise is 2.0°C and 4.7°C, respectively (IPCC, 2007). Predicted climatic changes with significant implications for India include changes in monsoon precipitation patterns, as well as a rise in extreme rainfall events, coastal storms, and droughts. Such changes in the climate could have enormous human, ecological and economic impacts on the country. For example, more intense rainfall could lead to floods and landslides and contribute to greater erosion. Rising temperatures will lead to reductions in snow cover and melting of glaciers in the Himalayan region, which will have serious implications for water resources in India (and other South Asian countries). Rising temperatures also will lead to changes in disease patterns and affect agricultural productivity. Given that India has about 4400 miles of coastline, more frequent and intense coastal storms could cause enormous damage to human settlements and coastal ecosystems, while resulting in loss of life. Similarly, a rise in sea levels, driven by increases in the global mean temperature, will have significant implications for coastal communities. The vast number of poor in India, who are particularly vulnerable to these kinds of climatic impacts, will be exposed to enormous risk (IPCC, 2001).[9]

Recognizing these impacts, India ratified the United Nations Framework Convention on Climate Change in 1993, and the Kyoto Protocol in 2002. India has no quantified emission reduction targets under the Kyoto Protocol, consistent with the UNFCCC principle of "common, but differentiated responsibilities" for mitigating GHG emissions.[10] Nonetheless, India has been actively participating in the Kyoto Protocol's Clean Development Mechanism (CDM).[11] In addition, India is a party to the Asia-Pacific Partnership on Clean Development and Climate (APP), which encompasses Australia, China, India, Japan, Republic of Korea, and the United States, with the goal "to accelerate the development and deployment of clean energy technologies."[12]

India also has been making an effort to improve its industrial performance, thereby reducing its GHG emissions. Since 1995, the energy, power, and carbon intensity of the Indian economy have all begun to decline (Chandler et al., 2002). Growth of India's energy-related CO_2 emissions declined by nearly 111 million tons from 1990 to 2000 through policy initiatives aimed at economic restructuring, enforcement of clean air laws, and renewable energy programs (Chandler et al., 2002). In fact, India's energy and carbon intensity are relatively low compared with those of other major economies.

While climate change is a problem that faces the global community of nations, there is enormous variation in the contribution of different countries to the problem in terms of current, per capita and cumulative GHG emissions.[13] Although India is now the fourth largest emitter of CO_2 emissions worldwide, its total emissions in 2004 were still about 4.5 and 3.7 times smaller than U.S. and China emissions, respectively. Moreover, India's contribution to annual global emissions remained at about 4.5% between 2000 and 2004; in contrast, China's contribution increased from 13% in 2000 to 17% in 2004, while the U.S. contribution declined from 23% to 21% over the same time period (Marland et al., 2007).[14] On a per capita basis, India's carbon emissions in 2004 were only one-sixteenth that of United States and one-third that of China. From a historical point of view, India has contributed only minimally to the buildup of GHGs in the atmosphere; India's cumulative emissions from 1850 to 2003 are only 2 percent of total global emissions in this time period, in contrast to 30 percent for the United States.[15] Furthermore, India's per capita GDP-PPP was $2750 in 2007, approximately half that of China and about one-sixteenth that of the United States.[16] Hence, it is clear that India's contribution to climate change and its economic status are markedly different from those of industrialized countries, and from those of China, although these two developing countries are often lumped together in climate discussions.

Given the distribution of responsibility, financial capability, and potential climate impacts, as well as the tremendous costs (economic, human, and environmental) involved, issues of equity, fairness, and burden-sharing are pivotal to negotiations on international climate agreements. India has long argued for a per-capita-based allocation framework as the appropriate approach for thinking about GHG emission reduction commitments. Not surprisingly, this argument has not found much traction in the industrialized countries, given their high per-capita emissions. At the U.N. Climate Change Conference in Bali in late 2007, parties to the U.N. Framework Convention adopted a Bali Action Plan launching negotiations toward a comprehensive post-2012 climate agreement. The Action Plan calls for "measurable, reportable and verifiable" mitigation actions. In developing countries, these actions would be supported by "technology, financing and capacity-building, in a measurable, reportable and verifiable manner."

The GHG-mitigation challenge comes at a time when India already faces extremely pressing challenges, such as the urgent need to expand its energy sector to fuel economic and social development and enhance energy access for all citizens. Nonetheless, India, like all other major economies, will also have to alter its GHG-emissions trajectory, despite the fact that India's energy economy will be strained by these efforts. India is already starting to do so through the various National Missions under the National Action Plan on Climate Change. Appropriate mitigation activities for India must be determined taking into account not only its projected emission trajectory, but also its other pressing needs, its financial capabilities, and its current responsibility for climate change. Given India's vulnerability to climate impacts, it is also in India's interest that the global negotiations on climate change yield an ambitious GHG-mitigation regime. The key issue for India is to determine what steps it should take on the climate front even as it works with the global community to craft an equitable treaty that protects the climate system while reflecting the enormous variation in the national attributes of responsibility and capability.

MORE ELECTRICITY FOR MORE PEOPLE

Increasing the availability of, and access to, modern energy services, particularly electricity, is an important element in the effort to increase the standard of living in India, especially in rural areas. Recent government plans aim to increase the per-capita consumption of electricity to 1000 kWh, up from 480 kWh in 2005, as well as to extend the electricity distribution network more rapidly, with at least one substation being located in each community development block[17] of India's rural districts (Ministry of Power, 2005, 2006b). Given the continued pace of high economic growth, the power sector is expected to grow rapidly in the coming decades, especially since electricity lies at the heart of most industrial activity.

By 2005-06, India's total installed capacity (including captive power) was 144 GW, generating about 700 Terawatt-hours (TWh), with thermal-based generation accounting for about 80 percent of total generation (CEA, 2006). During the 10th Five Year Plan (2002-07), about 27 GW of new capacity was added and about 69 GW is planned for the 11th Plan (2007-12) (CEA, 2007b). Long-term scenarios indicate the demand by 2030 to be around 3,600 to 4,500 TWh and total installed capacity (including captive power) to meet this demand has to be about 800 to 1,000 GW, depending on GDP growth (Planning Commission, 2006).

Table 1: Sources of electricity generation.

Year	Electricity Generation (TWh)	Hydro (TWh)	Nuclear (TWh)	Renewables (TWh)	Thermal Energy (TWh)	Thermal Fuel Demand		
						Coal (Mt)	NG (BCM)	Oil (Mt)
2003-04	592	74	17	3	498	318	11	6
2006-07	724	87	39	8	590	379	14	6
2011-12	1091	139	64	11	877	521	21	8
2016-17	1577	204	118	14	1241	678	37	10
2021-22	2280	270	172	18	1820	936	59	12
2026-27	3201	335	274	21	2571	1248	87	15
2031-32	4493	401	375	24	3693	1659	134	20

Shown is a "middle-of-the-road" scenario of electricity generation and thermal fuel demand by resource, based on an average annual GDP growth of 9%. The oil demand includes secondary fuel oil required for power generation.

Source: Planning Commission (2006).

Much of this growth is expected to be based on coal, at least for the next 30 to 40 years, [18] as indicated in Table 1. Use of India's significant domestic coal resources for power generation would enhance energy security— which is an emerging priority in the country. India's domestic oil and natural gas reserves are minimal (about 0.5 percent of world reserves), and over three-quarters of India's petroleum consumption was met through imports in 2004-05.[19]

About 9 GW of new coal-based capacity was added in the 10th Plan period (2002-07), and an additional 48 GW of new capacity is planned for the 11th Plan (2007-12) (CEA, 2007b). According to the Planning Commission (2006) scenarios, coal-based capacity of utility power plants is likely to be in the range of 200 to 400 GW in 2030, up from about 68 GW in 2005. With the large number of coal-based thermal power plants expected to come online, annual coal consumption in the power sector is projected to be in the range of 380 million to 500 million tons (MT) by 2011-12 and 1 billion to 2 billion tons (BT) by 2031-32 (CEA, 2004a; Planning Commission, 2006). Furthermore, a large number of coal plants will need to be replaced as older power plants near the end of their lives. Given that older plants are significantly less efficient than newer plants, decommissioning of the older plants and replacing them with newer, more efficient plants is an important option (Chikkatur, 2005).

The projected high growth of coal power has significant implications for India's GHG emissions, In 1994, coal contributed to about 62 percent of India's total CO_2 emissions of 817 $MTCO_2$, with energy transformation (electricity generation and petroleum refining) contributing 43 percent (MoEF, 2004). Contribution of solid fuels (coal) to total fossil fuel-based emissions is now about 70 percent. Given coal power's rate of growth, it will continue to be the major contributor to carbon emissions from the country (Marland et al., 2007).

POLICY AND INSTITUTIONAL LANDSCAPE

Government Dominance

The Indian power sector remains dominated by government ministries and public sector corporations. Under India's constitution, electricity is a "concurrent" subject, and therefore both the Central and the State governments[20] have legislative and rule-making powers. Generally, the Central government, through the Ministry of Power, sets overall electricity policies, whereas the State governments focus on power plants located within their boundaries, and on regional and local transmission and distribution (T&D) networks. The power sector was placed under State and Central government ownership after India's independence because ensuring an adequate supply of power was considered essential for meeting the country's objectives. Hence, public-sector enterprises have played a dominant role in the Indian power sector.

Although currently about 60 percent of installed capacity is vested in the State sector, NTPC (a Central government-owned utility) has now become a de facto leader in the power sector. NTPC (originally National Thermal Power Corporation) was created in 1975 to accelerate the installation of pithead coal power plants, and to provide additional thermal power capacity to the regional grids. NTPC is now the single largest thermal power utility in the country, accounting for about 20 percent of total capacity (27 GW) and about 28 percent of the total power generated in the country. NTPC also is usually the first utility to experiment with, and deploy, new technologies. For example, the first deployment of supercritical pulverized coal technology is taking place in NTPC-owned plants. It also is actively involved in developing gasification technologies for Indian coal.

The Ministry of Power is primarily responsible for the development of all aspects of electricity generation, transmission, and distribution in India. It is involved in planning, policy formulation, processing of project and investment decisions, project monitoring, human resource development, and implementation of electricity legislation (Ministry of Power, 2006a). It is also in charge of matters related to key organizations in all parts of this sector: NTPC (generation), Power Finance Corporation (finance), Power Grid Corporation of India Limited (transmission), Bureau of Energy Efficiency (efficiency), Central Power Research Institute (research), and the Central Electricity Authority (techno-economic assessments). Thus, the Ministry of Power wields considerable influence on the Indian power sector, despite the existence of an independent regulatory commission, reorganization of State utilities, and a greater push for private-sector involvement since the 1990s.[21] The Ministry of Finance also plays a key role in power-sector policies in determining the allocation of budgetary support for the sector and the terms for financial and investment practices.

In the electric power technology manufacturing sector, the major actor is Bharat Heavy Electrical Limited (BHEL), a holding company formed to take over the management of various industries that were set up in the 1960s for comprehensive power plant manufacturing.[22] BHEL manufactured more than 60 percent of the units installed in the 1970s and nearly all of the power plants constructed in the following decade. BHEL units now account for more than 60 percent of all units installed in India. BHEL also has been the dominant player in technology R&D and innovation for the power sector in the country. The Ministry of Heavy Industry, responsible for planning and growth of the engineering industry in India, is in administrative control of BHEL. It interacts with various industry councils, assists industry through policy initiatives, resolves problems relating to tariffs and trade, and helps in technological collaboration and R&D.[23]

The coal sector also is dominated by public-sector institutions. Planning, exploration and development of coal and lignite resources in India are completely under government control through the Ministry of Coal. The Ministry administratively controls Coal India Limited (CIL), Singareni Colliery Company Limited (SCCL) and Neyveli Lignite Corporation (NLC), which are the country's largest coal and lignite mining companies. Since the nationalization of coal mines in 1975, CIL and SCCL hold the rights to all coal mines held by the Government of India, which account for about 95 percent of all coal produced in the country. The planning for coal exploration and mining is driven by the expected demand for coal in the power and industrial sectors.

Creation and enforcement of environmental regulations is under the purview of the Ministry of Environment and Forests (MoEF). However, this ministry is relatively weak in comparison to the other ministries and it has historically been hamstrung by lack of widespread political and popular support.[24] Often, the ministry's regulations are not enforced strictly, as the production of electricity is given priority over environmental concerns. In fact, much of the enforcement of environmental regulations has come about because of judicial interventions. Nonetheless, MoEF does have significant authority in terms of granting clearances for energy projects.

The MoEF is also the nodal agency for climate change; in principle, this should promote an alignment between climate and other environmental policies. However, MoEF is a relatively weak ministry and is often overextended by other, more immediate local environmental issues, which reduces the amount of attention that can be devoted to the development of climate change policy.

The Planning Commission is the nodal organization to integrate the developmental priorities of the different ministries and to determine a holistic plan that meets the country's objectives.[25] Prior to the 1990s, the objectives, plans and outlays of the Planning Commission's National Plans were considered authoritative, and the various ministries and public-sector units generally attempted to meet the targets set by the Commission. Since then, planning has become much more indicative in nature, and the Commission is attempting to play an integrative role for determining priorities and formulating policy guidelines. It recently released an Integrated Energy Policy document that attempts to devise holistic policies in the energy sector (Planning Commission, 2006). The Integrated Energy Policy report provides a broad overarching framework for guiding the policies governing the production and use of different forms of energy from various sources (Planning

Commission, 2006). Its demand forecast estimates and policy recommendations have been incorporated into the planning process of the 11th Plan.

Thus, the institutional landscape of the power sector in India is dominated by the government through its significant influence on almost all aspects of the power sector and its ownership of key public-sector entities in the power sector. Buy-in from the government is therefore critical for any GHG mitigation activities to take hold in the power sector; and such buy-in is difficult because GHG mitigation is politically sensitive, as discussed earlier.

Tariff-Setting and Financial Weakness

Although government ownership of the power sector in post-independence India was intended to rationally and equitably advance power generation in the country, political considerations began to undermine the financial viability of State Electricity Boards (SEBs). The SEBs were not free to distribute power on a commercial basis, and they were forced by the State governments into providing power for meeting "social objectives" (namely, rural electrification and agricultural development). In the 1970s, politicians keen on exploiting the rural voting blocs gave farmers practically free electricity for irrigating their lands.[26] Thus, in the name of removing poverty and improving food security, many state governments introduced flat-rate tariffs based on electricity connections rather than on metered consumption soon became the norm in rural areas of many States.

With these entitlements, there was a large disparity between the cost of electricity supply and the tariffs paid by customers. The agricultural share of electricity consumption increased from 9 percent in 1970-71 to 24 percent by 1990-91 (Tongia, 2003). Domestic customers in most States also had tariffs that were much lower than actual cost of supply. In order to make up for these losses, the SEBs set higher tariffs for industry, railways and commercial establishments, which resulted in cross-sectoral subsidies.[27] The high tariffs for electricity, combined with poor quality of supply, forced many of the industries to "opt-out" of the grid and generate captive power on their premises, making the SEBs' financial situation even more dire. Given the lack of cash inflow, the SEBs have had to rely on State government subventions, cross-subsidies and other accounting manipulations in order to ensure that they meet their legal obligations (Tongia, 2003).

The financial weaknesses resulting from these politically driven tariff policies contributed to other problems in the power sectors, including a lack of professional management in SEBs, poor quality of electricity supply to the grid, high technical losses during transmission and distribution, increase in theft of electricity, and poor metering. These problems further worsened the financial status of the power sector.[28] The SEBs eventually became financially insolvent.[29] Addressing these problems in the State sector required drastic reforms in the power sector, which have been under way since the 1990s.

Recent Institutional Reforms

The Indian power sector has seen dramatic institutional changes in the past decade and a half. First, in order to deal with the macroeconomic financial crisis in 1990-91, the government began wide-ranging structural adjustment programs. A much-heralded step was adjusting the Electricity (Supply) Act to allow private companies to own power plants and generate electricity as Independent Power Producers (IPPs), while providing lucrative incentives for them. However, despite the initial hype associated with the government's stated intent to increase generation in the private sector, twice as much capacity was added in the public sector as in the private sector during the second half of 1990s (Tongia, 2003). By 2003, only 5.3 GW of IPP projects[30] were fully commissioned (TERI, 2004), and the overall capacity addition in the country slowed down in the mid- to late 1990s. Furthermore, the operating IPPs further eroded the SEBs' finances because of the high price of electricity that resulted from the incentives given to IPPs.

The World Bank, which had previously engaged with the central utilities and had responded lukewarmly to the IPP policy (Dubash and Rajan, 2001), decided to focus on bringing about changes to the Indian power sector through the States. The Bank correctly noted that problems in the Indian power sector were a result of a conflict of interest "between government's role as owner and its role as operator of utilities" (World Bank, 1993). The Bank's response was to promote power sector reforms by offering financial support to states that would implement its policies for restructuring their electricity sectors.[31] Orissa was the first state to embrace the World Bank reforms in 1993. Following the advice of consultants over the next five years, Orissa brought about legislative and institutional changes. Chief among these: a regulatory commission was set up in 1996, and the SEB was split into two generation companies and a grid management company for transmission and distribution. Although the results of power sector reforms in Orissa were controversial (Dubash and Rajan, 2001; Tongia, 2003), the World Bank's push for reforms there led to similar reforms in other states. The Central government consolidated these reforms through the Electricity Regulatory Commission Act in 1998 and Electricity Act in 2003.

The Electricity Act required all SEBs to unbundle and privatize, while introducing at the same time wholesale competition, trading and bilateral contracts with regulation. By forcing the unbundling of vertically integrated companies, the Act intended to separate generation from transmission and distribution, with the hope that generation would be subject to market competition. The Act envisioned a new, market-driven framework where electricity would be just another commodity that can be generated, sold and traded in the market as determined by supply and demand. This is a dramatic shift from the earlier view that electricity is not a commodity but a tool for social progress that requires active participation of the State.[32]

Limited Financial Options

The economics of power plants provide an important backdrop for determining coal power policies. Installation of new power plants requires an enormous financial investment, both for the initial capital expenditure during construction and for operations and maintenance throughout the plant lifetime.

Over the past five years (2002-2007, 10th Plan), about $60 billion has been allocated for the power sector, of which an estimated $40 billion was invested in the sector (CEA, 2007b).[33] More recent estimates indicate that $130 billion will be needed just for generation in the 11th Plan, with the total estimated funds required for the entire power sector in the 11th Plan being about $225 billion (CEA, 2007b; Chikkatur and Sagar, 2007). Estimates of longer-term investments by the IEA (2007b) indicate that, during the period 2006-2030, about $960 billion is needed for the entire Indian electricity sector, of which 45 percent is for generation alone.

Raising such large amounts of funds for the power sector is not easy, especially with the poor financial health of the State government-owned part of the power sector (which accounts for about 60 percent of installed capacity). In spite of the ongoing reforms, in 2004-05, power utilities owned by states had losses of around $4.8 billion and nearly half of the utilities had a negative rate of return on net fixed assets (PFC, 2006). Most of these losses were made up for by government subventions. Generally, investment outlays for public-sector power projects are funded by a combination of funds, including: internal resources of the utilities; financing from State and Central government budgets; multilateral/bilateral loans; loans and bonds from Indian financial institutions (commercial banks, dedicated infrastructure/power finance institutions, insurance companies, etc.); and credits granted by international credit agencies (Jeyakumar, 2004; CEA, 2007b). Most of the required funds in the 9th and 10th Plans have been raised in the domestic financial market, but the required funding for the 11th Plan would need to rely more on international markets. India does not have a large and liquid domestic debt market, and this market is dominated by government securities (CEA, 2007b). There are also regulatory limits on which domestic financial institutions can invest in the power sector—which reduces the overall access to domestic banks and insurance companies. Furthermore, the two government institutions that provide specific financial support for the power sector—Power Finance Corporation (PFC) and the Rural Electrification Corporation (REC)—have limited funding.[34]

Since the early 1990s, there has been a greater push for the private sector to become more involved in the buildup of generation capacity. Initially, the government focused on increasing foreign direct investment for the Independent Power Producers (IPPs), and the IPPs were given lucrative incentives.[35] Yet, most of the IPP projects either stalled in the approval process or did not reach financial closure. Moreover, many of these projects were based on expensive liquefied natural gas (LNG), natural gas (NG) or naphtha, rather using inexpensive, albeit poor quality, Indian coal. Although the Central government fast-tracked eight projects with offers of counter-guarantees, only three have produced electricity thus far (Tongia, 2003). Hence, the private sector was unable to significantly impact the Indian power sector by adding new capacity. With the failure of this policy, the government redoubled its efforts to boost capacity within the public-sector utilities. Only about 9 GW out of the planned 69 GW in the 11th Plan is expected to be in the private sector. Hence, the government will have to spend significantly more. While the overall allocation for the power sector in the 10th Plan was double the expenditure in the 9th Plan, the estimated required finances for the 11th Plan are about four times the estimated expenditure in the 10th Plan.

Given the lack of private-sector investment thus far in the Indian power sector, it is obvious that more needs to be done to attract investors. Foreign investors continue to perceive Indian power projects as risky investments because of the failure of the IPP policy, the continued losses of the State Electricity Boards, high transmission and distribution losses and other factors. Hence, these investors often demand credible payment security mechanisms, and credit enhancements often are provided to "comfort" the lenders (CEA, 2007b). Although there is no shortage of available funds in the international markets, the short-term nature of these loans (typically 5 years) is a problem. Plus, there are additional auditing and overhead costs that come with loans from multilateral banks such as the World Bank and the Asian Development Bank (CEA, 2007b).

As a result of all of these factors, there are significant financial constraints for introducing new technologies in the power sector in India. The great emphasis on reducing costs and risks tends to push the coal-power sector towards choosing robust, well-tested, although older and less-efficient, technologies.

Limited Analysis and Long-Term Planning

Policy-related analytical capacity available in domestic Indian institutions is limited. Even in cases where there may be relevant expertise in the government, the enormous and varied workload of the relevant public-sector agencies precludes the possibility of devoting sustained attention to long-term issues.[36]

A significant portion of the domestic capabilities for carrying out such analysis in the government lies in the Planning Commission. Its efforts, however, are limited by the small size of the energy-planning group, which has to deal with a myriad of issues (economics, regulation, technology, etc.) relating to various energy sub-sectors. Government institutions, such as the Planning Commission and the Power Ministry, rarely prepare White Papers that discuss significant policy issues and options for public comment. One singular exception is the recently released Integrated Energy Policy report by the Planning Commission, which was placed in draft form on its website for comments.[37] There is some precedent for key NGOs, think tanks and academics taking on advisory roles for the government; however, many of these interactions are on a one-off basis. Furthermore, those non-government actors that do engage in energy policy research have paid only limited attention to power-sector technology policies and their implications in terms of GHG mitigation. In addition, many of them may not have the technical capacity to do the required analysis.

Several external organizations have played a significant role in shaping the power sector and climate policies and priorities in India.[38] For example, aid agencies such as United States Agency for International Development (USAID) and the Department for International Development-UK (DFID) helped initiate the restructuring of the Indian power sector through funding that catalyzed major World Bank projects (Dubash and Rajan, 2001). The policy approaches advocated by international consultants, however, were accepted without an effective public discussion, and there was little space for injecting domestic policy analyses and perspectives into the debate. Such internationally-driven approaches have been criticized for not fully considering how they might play out in the Indian context.[39] These past experiences related to power-sector restructuring have now heightened sensitivities among the public and many policymakers, with many of them wary of new ideas and policies, particularly those pushed by international agencies.

Finally, the power sector remains in an endemic "panic mode" of operations based on the historical shortage of power. At the heart of the problem is increasing demand because of population and economic growth, alongside a lack of sufficient capacity additions. Adding to the challenge, the growth plans of the Planning Commission and the Ministry of Power often have overestimated the institutional potential for short-term additions, resulting in missed installation targets—further reinforcing the perception that the government cannot effectively respond to the country's power needs. There also has been a disproportionate emphasis by the planners on the generation side of the power sector. This "panic" or "catch-up" mode of operations effectively impedes the development of a suitable long-term strategy in the sector. The resulting short-term perspective has contributed to the country's risk-averse attitude towards new technologies, leading to technology replication rather than innovation in the coal-power sector. More effort in long-term power-sector planning would provide important opportunities to integrate GHG mitigation options as part of the overall planning for the sector.[40]

Towards GHG Mitigation in the Coal-Power Sector

India's efforts to significantly reduce GHG emissions will depend on international progress on climate negotiations, domestic political will, and the availability of suitable technical and financial resources. Nonetheless, the government should begin now to develop a set of policies that lay the groundwork for reducing GHG emissions from the coal-power sector, even while enhancing the availability and quality of power available in the country. This section presents a range of policy options in five areas:

- Improving efficiency in all elements of the existing power system;
- Near-term deployment of higher-efficiency combustion technologies;
- Long-term approaches for emerging technologies;
- Positioning power plants to keep open economic carbon capture options; and
- Investing in a focused effort to map geological storage locations.

New policies must take into account the current (and evolving) menu of technological options for coal-power generation as well as the current realities of the power sector in India. The technology assessment conducted by Chikkatur (2008) indicates that both combustion- and gasification-based technologies will likely be more efficient, with better pollution controls, and will cost less as these technologies are deployed in larger numbers with tighter environmental regulations in both the industrialized and developing countries. There are significant pros and cons associated with each technology within the Indian context, and this makes it difficult to project whether combustion or gasification technologies will dominate the global power sector in the future (even under carbon constraints), and which one of these might be more suited for Indian coals and conditions. Given this technology background and the need for financial prudence, it is essential for India not to commit at this time to a particular long-term technological trajectory for its coal-power sector, but rather to keep open its technology options. However, several activities discussed below can lay the foundation and prepare the sector for eventual deployment of technologies that allow for deeper GHG reductions.

The activities discussed here are not sequential; in fact, they all can be implemented simultaneously and as soon as possible. These immediate policy steps will allow the power sector to meet India's development challenges and provide GHG emission reductions as a co-benefit while preparing a foundation for future mitigation.[41] In the following section, we list some of the "enabling" activities that will allow for better implementation of these policy steps.

IMPROVING EFFICIENCY IN ALL ELEMENTS OF THE EXISTING POWER SYSTEM

There are three broad areas in which efficiency improvements within the country's existing power system can take place: generation, transmission and distribution (T&D), and end-use. Improving efficiency is a "no-regrets" step for the Indian power sector in that it allows for increased generation and better quality of electricity delivery using the existing generation stock and T&D system. An important side benefit of efficiency improvement is the reduction of GHG and local pollutants from the power sector. An equally important consequence is that increasing the efficiency of the overall power system (generation, transmission and distribution, and end-use) is akin to adding generation capacity without actually doing so. Thus, an efficiency-enhancing program delays the addition of generation capacity and therefore buys time to resolve the technical and market uncertainties associated with emerging or new technology options.

Generation

The efficiency of existing subcritical pulverized coal (PC) power plants has great potential for improvement. The average net efficiency of the overall sector is 29 percent, with best units (500 MW) being 33 percent (Chikkatur, 2005).[42] Nearly all existing power plants can improve their efficiency by one to two percentage points.[43] Efficiency improvement by one percentage point would reduce CO_2 emissions by about 3 percent (Deo Sharma, 2004). Furthermore, it is important to consider refurbishing (or repowering) older units with more efficient, higher-capacity units that use cleaner pollution control technologies.

Low efficiency is usually blamed on a variety of technical and institutional factors. The key technical factor is the use of poor quality coal, which is particularly problematic as it increases auxiliary consumption, operation and maintenance costs, and reduces overall efficiency. The use of better quality coals, including washed coals, would improve efficiency. Although there are already some existing mandates for use of washed coals, more incentives are needed both on the coal production and coal use sides. One approach could be to restructure existing coal grading and pricing schemes.[44] Changes in management practices and institutional structures might also improve efficiency (Khanna and Zilberman, 1999). The CEA (2005b) has noted that lack of emphasis on efficiency during operations and maintenance of power plants is one of the main reasons for poor performance. Hence, it is important for all power plants to measure efficiencies routinely and carry out energy audits to assess their efficiency levels.

Some energy efficiency activities have already been initiated by USAID and NTPC, with the creation of the Centre for Power Efficiency and Environmental Protection (CenPEEP). A NTPC-USAID collaboration, CenPEEP acts as a resource center for acquiring, demonstrating, and disseminating technologies and practices for reducing greenhouse gas emissions from power plants. Efforts such as CenPEEP must be strengthened and expanded nationally. NTPC could play a particularly key role in accomplishing this, given its experience and capabilities in power plant efficiency improvement. Current government efforts have been focused more on increasing generation and extending the life of older units (through renovation, modernization and life-extension programs) rather than on specifically improving efficiency. Hence, a focused program must be initiated for improving efficiency of existing plants both at the State and Central levels, with funding from the Central Government (Chikkatur, 2005). International energy agencies and laboratories (such as the U.S. National Energy Technology Laboratory, Japan Coal Energy Center, and IEA Clean Coal Centre) could play an important part in strengthening India's research and technical capacity, as well as furthering its efficiency improvement programs.

Electricity regulators also can provide tariff-based incentives for efficiency improvement of power plants. Although competitive bidding for tariffs might become available in the future, current electricity regulations in India continue to be based on cost-plus mechanisms.[45] Current tariffs based on normative benchmarks for performance are hobbled by information asymmetry, where regulators do not have access to detailed performance data. Looking ahead, regulators should promote incentive schemes based on benchmarks determined by actual performance rather than the prevailing normative approach, while providing additional performance-based incentives for improving efficiency (Chikkatur et al., 2007).

Policy Options:

- Require all power plants to measure efficiencies routinely and carry out energy audits to assess their efficiency levels.

- Ensure that the regulatory benchmarks on power plant efficiency are stringent, and provide sufficient incentives for efficiency improvements (see Chikkatur et al. (2007), for example).

- Provide better incentives for the production and use of better-quality coals, in addition to existing mandates—for example, by restructuring the coal grading and pricing scheme. (see Chikkatur, 2008).

- Strengthen international and bilateral efforts to deepen technical capabilities in India, and to acquire, demonstrate, and disseminate technologies and practices for reducing greenhouse gas emissions from existing power plants (for example, by expanding programs such as CenPEEP).

- Create a program to refurbish (or repower) older units, specifically focusing on installing more efficient, higher-capacity units that use cleaner pollution-control technologies.

Transmission and Distribution (T&D)

India has made major strides in the expansion and enhancement of its T&D network. The bulk transmission network (i.e., 132 kV or greater) has increased from 3708 circuit km (ckm) in 1950 to over 265,000 ckm today.[46] At the same time, there also has been a move towards higher-voltage lines and integration of the regional grids into a national grid. Yet the performance of this T&D network still leaves much to be desired. High losses result from the following factors:

- Long T&D lines and a high ratio of low-voltage to high-voltage lines;

- Haphazard growth to meet the short-term objective of extension of power supply to new areas, which has led to inadequate sub-transmission and distribution systems.

- Inappropriate size of conductors; and

- Improper load management, resulting in overloading of systems (Planning Commission, 2002).

Estimates of T&D losses for India routinely suggest that these are higher than those in most other countries. Reducing India's losses to a more manageable (though still high) 10 percent will release power equivalent to about 10,000-12,000 MW of capacity (CEA, 2007b). The aggregate technical and commercial (ATC) losses, which are higher than the technical T&D losses,[47] is estimated to vary from 18 to 62 percent, with the average for the country somewhere in the range of 34 to 40 percent (Planning Commission, 2002; CEA, 2007b). In contrast, T&D losses average around 4 to 8 percent in industrialized countries.[48] Although reducing commercial losses will not reduce demand much (since this power is being used by consumers, even though they are not paying for it), it will increase revenues for the utilities and improve their precarious financial condition, and therefore greatly help increase the availability of financial resources for the power sector.

Yet, despite the recognition of the importance of improving T&D performance, there is still a tendency in India to focus on capacity additions. In the 10th Plan, outlays for T&D were half those for generation (i.e., $19 billion for the former vs. $40 billion for the latter (CEA, 2007b). This is true despite the fact that many experts have called for investments in T&D to be comparable to those in generation (see, for example, Roy, (1999)). Efforts to upgrade the T&D system by modernizing the existing infrastructure and introducing new technologies must be accelerated through steps such as expanding high-voltage lines, improving integration among regional grids, and improving monitoring and metering of distribution networks.

The Government of India has begun to pay more attention to distribution reforms. In 2003, it launched the Accelerated Power Development and Reforms Programme (APDRP) to reduce ATC losses and increase reliability and quality of power supply.[49] Through the APDRP program, ATC losses have declined from 36.8 percent in 2001-02 to 33.8 percent in 2004-05, and the overall commercial loss (without subsidy) of State utilities has been reduced by 25 percent in the same time period (CEA, 2007b).

Policy Options:

- Increase government investments in T&D for modernizing the existing infrastructure and introducing new technologies, expand high-voltage lines, improve integration among regional grids, and improve monitoring and metering of distribution networks.

- Increase electricity metering and collection efficiency, especially in urban and peri-urban areas.[50]

- Reduce commercial theft by, for example, continuously auditing electricity use, promoting incentives for greater transparency, and strengthening the penalties for illegal connections.

Demand Management and End-Use Efficiency

The introduction of the Energy Conservation Act of 2001 and the establishment of the Bureau of Energy Efficiency (BEE) are signs of an increasing recognition of the importance of end-use energy efficiency in India. End-use efficiency must be a priority for India because the country's expected rapid economic growth will lead to an acceleration of demand for power and growth in electricity-based appliance stock, often with fairly long lifetimes (especially for some household goods and industrial equipment). Each kW saved at the end-use side is equivalent to almost 1.8 kW at the generation side (once auxiliary consumption at the power plant and T&D losses are taken into account). Furthermore, there is also great potential for end-use energy-efficiency gains in the country. For example, it is estimated that the deployment of energy-efficient lighting, more efficient refrigerators in households, and more efficient motors in industry could save as much as 10 percent of total national power generation (Shrestha et al., 1998).

The industrial and domestic sectors are the two largest consumers of utility-generated power in the country (see Table 2). Consumption in the domestic sector has been growing rapidly, mainly as a result of increasing penetration of energy-consuming appliances such as refrigerators and air conditioners. As a result, the BEE has been focusing its early efforts on improving end-use efficiency through standards and labels for domestic and commercial appliances, development of codes for energy-efficient buildings, and a focus on industrial end uses. At the same time, demand-side management measures by utilities need to be undertaken. While such measures have significant potential, a number of barriers must be overcome in order for India to achieve any significant success in improving end-use efficiency: for example, lack of information to consumers, lack of reliability and performance guarantees for equipment, and a high initial price for energy-saving appliances, equipment and materials. (Parikh et al., 1996).

While the 10th Plan emphasized the need for energy conservation, it did not allocate a specific budget towards these measures. The Working Group for the 11th Plan has suggested an outlay of about $1.4 billion for energy conservation measures, but this is very modest in relation to the budget for other elements of the power sector and must be enhanced.

Table 2: Consumption and annual average growth of electricity in various sectors

	Domestic	Commercial	Industry	Railways	Agriculture	Others
2005-06 consumption of utility generated-power (%)	24.9	8.4	35.9	2.5	23	5.3
Annual growth (%) (95-96 – 05-06)	8.13	8.49	4.53	5.95	2.02	7.55

Source: Economic Survey, 2006-07.

Policy Options:

- Reduce household demand through promotion of technologies such as solar water heaters.
- Promote the deployment of energy-saving devices such as energy-efficient lighting and more efficient household appliances (particularly air conditioners and refrigerators) through programs such as technology standards, labeling, etc.
- Promote greater efficiency in the industrial and commercial sectors through programs such as efficiency standards and incentive schemes and by encouraging energy service companies to implement these programs.
- Provide incentives for energy-efficient technologies through fiscal measures, such as differential taxes, discounts, and rebates.
- Actively support academics and other organizations (perhaps through BEE) to build capacity for energy-efficiency assessment, R&D, and improvement.

NEAR-TERM DEPLOYMENT OF HIGHER-EFFICIENCY COMBUSTION TECHNOLOGIES

Due to India's rapid growth of new generation capacity and its financial constraints, the near-term focus should be on the aggressive deployment of commercially-available, high-efficiency combustion technologies. Supercritical pulverized coal (SCPC) technologies are well suited for the Indian coal power sector in the near term, as they are commercial with plenty of experience worldwide in installing and operating them.[51] SCPC technologies, including flue gas desulfurizers (FGDs), would be at least 5 percent more efficient (35.1%) than current 500 MW subcritical units without FGD (33.3%). The use of washed coal would increase efficiency by another 1 percent (Nexant, 2003). In terms of capital cost, SCPC is only about 7 percent more expensive than subcritical PC, although the addition of FGD would increase the total plant cost significantly (Nexant, 2003).[52] Furthermore, there are many SCPC manufacturers worldwide, which should make it relatively easy to adapt to Indian conditions (particularly to the high ash content of Indian coal). Prospects for ultra-supercritical PC technologies, however, might be limited by the high ash content of Indian coals.

In 2003, the Central Electricity Authority deemed that supercritical technologies were suitable for India and recommended a rapid deployment of 8 to 10 new SCPC units. However, SCPC is being installed in only two NTPC projects (currently under construction), and only about 20 percent of the units included in the 11th Plan (accounting for about 30 percent of capacity addition) are expected to be based on SCPC technology. Nearly 70 percent of the SCPC units are planned under Central ownership; there is minimal interest in these technologies in the State and Private sectors. While it is understandable that the Central agencies, particularly NTPC, would take the lead in deploying SCPC, the State and Private generating companies must be involved as observers in the Central projects to ensure that they are encouraged to take up SCPC on their own. The CEA and the Power Ministry also must encourage the uptake of SCPC in the State and Private sectors through various incentives. The Power Ministry already has begun some efforts in this regard through its "Ultra-Mega Power Plant Policy," which intends to support several 4 GW projects using SCPC technology. At the same time, innovative efficiency-enhancing incentives could be incorporated into the regulatory framework to promote more efficient plants. It is only through increased experience with this new technology that concerns regarding its reliability, performance and operating costs will be resolved. In essence, SCPC must be viewed as the default technology and subcritical PC considered a technology of last resort.

Finally, it is essential for India to develop its own indigenous manufacturing and design capacity for SCPC technology. The reliance on domestically-manufactured coal power technology to date suggests that the industry is unlikely to shift quickly to imported technology, despite the increased use of global tenders. In addition, local manufacture of SCPC technology could result in significant cost savings, as is usually the case for many other technologies. So far, BHEL has been on the sidelines for the two NTPC projects at Sipat and Barh. BHEL already has licensing and technology-transfer agreements with Alstom for SCPC, and it must now be supported (at least in the initial phases) to begin the adaptation, manufacturing, and installing of indigenous SCPC units in India. One option would be to encourage a joint NPTC-BHEL SCPC project, similar to the 100 MW IGCC demonstration project that is currently being undertaken by these two entities.

Policy Options:

- Encourage State and Private sector generation companies to learn from NTPC's experience with the ongoing construction and future operation of the new SCPC-based power plants.
- Provide incentives to encourage the uptake of SCPC in the country, including a sustained provision of washed coal for these projects.
- Increase government-promoted, commercial-scale demonstration projects using SCPC technology in the State sector, including a focus on building up manufacturing capacity within BHEL and other Indian coal technology manufacturers.

LONG-TERM APPROACH FOR EMERGING TECHNOLOGIES

While advanced combustion technologies that currently are commercially available will be deployed in the short term, it is essential to assess and plan for emerging technologies that may become important for the medium- to long-term future of the coal power sector. Even the menu of technological options will continue to evolve as industrialized countries invest in programs of research, development, demonstration and deployment. Therefore, it is important for India to study and learn from these activities, and to leverage global innovation to its benefit. Technological advances and greater operational experience through industrialized-country programs will lead to a better understanding of the technical and cost trajectories, as well as the feasibility for large-scale deployment of new technologies. Hence, India should: a) monitor and perform feasibility assessments for existing advanced commercial and emerging pre-commercial technologies; and b) develop an innovation strategy for specific elements of particular technologies, including demonstration efforts. Such efforts will be critical for developing appropriate energy technology policies.

Technology monitoring and feasibility assessment

Current technology analyses conducted in India for the coal sector are mainly focused on technical issues, and are primarily driven by organizations such as CEA, NTPC and BHEL. The overall national vision and objectives, though, for technology assessments must be determined through a deliberative process involving a broad cross-section of stakeholders, and the assessments must address the various challenges and constraints faced by the sector. This will help to build consensus on the suitability of technology options for the country, while laying the groundwork for an effective technology policy and shaping future innovation efforts. Hence, a monitoring and feasibility assessment program needs to be established to continuously evaluate the status of emerging and near-commercial technologies, and to perform detailed techno-economic analysis and assessment.

For example, although integrated gasification combined cycle (IGCC) technologies are not yet commercially deployed, the technology is expected to become more robust as it begins to be deployed commercially in industrialized countries. As IGCC gains a significant market share in these electricity markets, the performance risks and power-plant costs will certainly be reduced, both through further technological advances and learning-by-doing. However, as discussed in Chikkatur (2008), the current "standard" entrained-flow gasifiers in IGCC are effectively ruled out for Indian coal, although they may be considered for power plants that rely exclusively on better-quality imported coal. Currently, India has only done feasibility studies for IGCC plants based on air-blown fluidized bed gasification, and the costs are nearly double those of subcritical pulverized coal (PC) technology, albeit with 20% more efficiency (Nexant, 2003).[53]

Other emerging technologies such as oxy-fuel combustion, which increases the potential of combustion-based plants being able to capture carbon efficiently and cheaply, are still in the early stages of innovation. Their technology trajectory will evolve as industrialized countries invest in research and development, demonstration and early deployment (RD^3) of these technologies. Technologies such as ultra-supercritical pulverized coal, integrated gasification combined cycle, and pressurized fluidized bed combustion are already demonstrated and deployed to varying degrees in several countries. Given this evolving technology landscape, it is very important to keep track of technological developments as well as the economics of these plants. Site-specific factors, such as coal properties, ambient conditions, and the temperature and availability of the cooling water, can strongly affect efficiency,[54] and electricity cost estimates in different studies vary significantly because they make different assumptions about the technology and economic/financial factors.[55] A proper comparison of relevant technologies in India requires engineering-based analyses using technical and economic factors and assumptions that are valid in the Indian context.

Furthermore, different scenarios for technology deployment should be explored, since these will have different implications for technology choices and deployment strategies. Hence, technology assessments should be broad and not be limited to only those that can efficiently use domestic coal. For example, India might want to consider a two-track technology strategy: one aimed at domestic coal, and another aimed at imported coal—especially as coal imports might increase in the future (Chikkatur and Sagar, 2009). The use of higher-quality coal from abroad would allow easier adaptation of new technologies in India. Introduction of these new technologies based on imported coal could help build additional technological capacity in the country. In addition, an expanded use of “standard” technologies, such as entrained-flow gasifiers, would allow for opportunities to demonstrate the capture and storage of carbon dioxide.

Innovation strategy

While many advanced technologies may not be deployable immediately in India, some research, development, and demonstration activities should be initiated on selected coal-power generation technologies that potentially might be of relevance to India in the coming years. For example, material research and development of control systems for advanced combustion technologies could be considered. Also, research on modeling (such as computational fluid dynamics) of combustion and gasification processes would be useful for engineering design of new power plants. India also should investigate possibilities for developing and testing carbon capture technologies in existing Indian power plants—this could provide more information about retrofitting options. New indigenous capture technologies that are better suited for plants using Indian coals could also be explored.[56] These activities will leverage existing capabilities and add value to the country’s industrial base.

Technology demonstration and early deployment should be strategically planned so that lessons from these activities are integrated into a well-defined action plan.[57] New ideas and options must be considered. For example, given that India is likely to import coal on a sustained basis, the country would benefit from the demonstration of an IGCC plant using imported coal, rather than Indian coals. This would allow the use of standard gasification technologies, and could help utilities learn how to operate a new technological system reliably, without having to solve simultaneously the hard problem of gasifying Indian coals. Such a demonstration also will test the IGCC's often-touted environmental performance in Indian conditions. Operational and cost data from such an IGCC demonstration will be highly relevant for designing future IGCC plants, even those designed for Indian coals. Similarly, carbon capture and storage (CCS) technologies could also be tested in Indian power plants (in either combustion or gasification plants) using imported coals and other feedstocks such as petcoke.

Such planning is probably best led by a government agency (possibly the Planning Commission), but will require the involvement of multiple stakeholders in India, including, once again, key enterprises such as NTPC and BHEL as well as private industries and utilities. Strategic partnerships and collaborations with international research initiatives could strengthen this planning process. In addition to government funding for technology innovation, international funding could be sought for leveraging government support for demonstration projects. At the same time, the major public sector energy companies must further increase their R&D budgets.

Finally, India should pursue international linkages with RD^3 programs and institutions worldwide, as appropriate and necessary. For example, strategic interactions with U.S., European and Japanese energy agencies and laboratories, the U.S. Electric Power Research Institute, the Japanese Central Research Institute of Electric Power Industry (CRIEPI), the U.S. National Research Council, coal industry representatives from various countries (U.S., Australia and South Africa), and U.S. and Australian geological agencies could prove useful for coal-power technology assessments in India.

Policy Options:

- Create a monitoring and feasibility assessment program for tracking emerging pre-commercial technologies and assessing the techno-economic feasibility of existing advanced commercial and near-commercial technologies.

- Involve a wide cross-section of stakeholders in developing a vision for technology assessments and for building consensus around technological decisions.

- Develop a long-term coal-power technology roadmap for India, including an innovation strategy for specific elements of particular technologies.

- Initiate and substantially support India-specific RD^3 activities on selected technologies, including control systems for advanced combustion technologies, combustion and gasification processes for new power plants, carbon capture technologies in existing Indian power plants, and indigenous capture technologies that are better suited for plants using Indian coals.[58]

- Increase India's involvement in strategic partnerships and collaborations with international research initiatives on advanced coal technologies and CCS.

- Increase the total government R&D budget related to advanced coal technologies and CCS.

POSITION POWER PLANTS TO KEEP OPEN ECONOMIC CARBON CAPTURE OPTIONS

The economical capture of CO_2 requires the removal of key criteria pollutants to very low levels, which implies that it is essential to set and enforce emission standards for these pollutants—particulates, SO_x and NO_x. A clean flue gas is a prerequisite for the economic use of post-combustion carbon capture technologies, such as amine scrubbing, and also for pre-combustion capture, such as in IGCC.[59] Post-combustion capture in new PC plants can lead to increases of 24 to 40 percent in auxiliary energy consumption, with a 14- to 25-percent increase in pre-combustion in new IGCC plants (IPCC, 2005). Retrofitting carbon capture to existing plants is quite expensive, with high power consumption and loss in efficiency. An estimated 65 MW can be lost as auxiliary consumption, with an associated efficiency loss of 30 percent, in a 210 MW unit if equipped with monoethanolamine (MEA) post-combustion capture technology (Sonde, 2005). Carbon capture in such a plant will also almost double the cost of power (Sonde, 2005). Such high costs might necessitate financial support from industrialized countries. In general, the possibilities for capture will be enhanced if the captured CO_2 has economic value. Furthermore, there is significant uncertainty at present regarding what actions a greenfield power plant can undertake to be "capture-ready" (MIT, 2007).

The high cost and loss in efficiency suggest that it is premature now for India to engage in capturing carbon. Nonetheless, it is critical that Indian power plants undertake "no-regret" steps that also increase the potential for capturing carbon economically in the future. The first step would be to increase generation efficiency (as outlined before). Next on the priority list: cleaning flue gases as much as possible through better regulations. The addition of end-of-pipe pollution control technologies (such as flue gas desulfurizers and selective catalytic reducers) is an important pre-requisite to post-combustion CO_2 capture, despite the fact that the addition of such equipment will require greater auxiliary power consumption, which can increase GHG emissions per kWh. Thus, there are significant synergies and tradeoffs between reducing local environmental pollution and increasing the potential for carbon capture in the future.

Local environmental protection is already an important goal for the Indian government, based on the fact that the impact of coal-based power plants on the environment has been significant. Current environmental regulations are primarily focused on controlling particulate emissions; electrostatic precipitators (ESPs) are used in all plants. However, the high resistivity of ash in Indian coals reduces ESP collection efficiency, making it important to modify ESPs to improve performance. Concentrations of sulfur oxide and nitrogen oxide in flue gases are not regulated, and the only regulations are on ambient air concentrations for these pollutants and the height of the flue gas stacks. Also, in many cases, even these regulations are not effectively enforced, and nearly one-third of plants continue to violate these norms.

Hence, it is essential that India's emission regulations are tightened and better enforced. The Ministry of Environment and Forests has been working with the power industry on developing better emission standards. The Corporate Responsibility for Environmental Protection charter aims to get non-compliant plants to install pollution control equipment and establish tighter pollution standards. Among the charter's other goals: getting power plants to use washed coal and to fully utilize fly-ash, and promoting the use of new cleaner coal technologies.[60] In addition to industry, it is important to engage with local communities and other stakeholders and also to consider pollutant levels necessary for carbon capture in determining future regulations.

Policy Options:

- Create a power plant emission standard for SO_x and NO_x, in addition to tightening particulate emission limits.
- Provide incentives and financial support for installing end-of-pipe pollution control technologies to control SO_x and NO_x emissions from all power plants.
- Build capacity to monitor emissions from power plants, with data being directly transferred to regulatory bodies. Incorporate lessons from international experiences.
- Consider innovative incentive schemes for better enforcement of environmental regulations.
- Consider impacts of pricing carbon emissions on techno-economics of Indian power plants.

INVEST IN A FOCUSED EFFORT TO MAP GEOLOGICAL STORAGE LOCATIONS IN INDIA

A good understanding of geological storage sites in India is essential, as the storage of captured CO_2 from power plants requires the availability of well-characterized storage sites. Geological underground storage in saline aquifers is currently the most promising option for storing large quantities of CO_2. However, storage in geological media requires detailed assessments of specific storage locations and capacity within these locations. Currently, only broad first-of-a-kind estimates of storage capacity are available in the country, and there is a strong need for detailed site-specific assessment of storage mechanisms and capacity in potential on-shore and off-shore locations.

It is important to embark on such detailed assessments, as well as relevant demonstration projects, as early as possible in order to inform any decisions about the deployment of power generation technologies with carbon capture. The assessments will also influence current siting decisions for coal power plants. This effort is complementary to the technology monitoring and feasibility program, and may be led by the Directorate General of Hydrocarbons (DGH), Geological Survey of India, and oil and natural gas exploration industries. Existing programs, such as the Carbon Sequestration Leadership Forum, should be leveraged to increase capacity within the country for storage assessments. Additional government funding will be necessary for such geological exploration. Given that Indian sedimentary basins are not yet well explored, exploration and assessments for CO_2 storage will also help buttress the geological effort for identifying new hydrocarbon and coal resources in the country.[61] Although it is prudent not to release all detailed geological information from such exploration, consolidated data and information should be made public. An independent board or commission could be set up to verify the reliability of the data.

Policy Options:

- Initiate a well-planned, detailed effort to map on-shore and off-shore CO_2 storage locations in India, perhaps led by the DGH.
- Establish and sustain sufficient government support for mapping and early demonstration projects.
- Coordinate mapping and demonstration efforts across public and private sector participants with the goal of protecting the interests of all parties.
- Leverage international and bilateral geological assessment activities to build capacity in India.
- Develop potential CO_2 storage maps in order to influence siting decisions for future power plants, as well as for techno-economic assessments of capturing and transporting CO_2 from current power plant sites.

Enabling Conditions for Effective GHG Policy Implementation

While the policy options discussed above can help put the Indian power sector on a path towards GHG mitigation and prepare it for the future, several broader enabling conditions are necessary to ensure the successful policy implementation. These enabling conditions include: a better understanding and use of coal resources; improved systems of technology and policy innovation; institutional coordination; and international action and cooperation on climate change mitigation.

BETTER UNDERSTANDING AND USE OF COAL RESOURCES

Sustained and sustainable growth of the Indian coal-power sector requires some changes and better policies in the coal sector. To begin with, better energy planning in the coal-power sector requires a much better understanding of domestic coal reserves, especially given the significant uncertainty about the extractability of India's coal resources.

There are considerable problems with the methodologies used for assessing Indian coal resources today.[62] The current definition for categorizing coal resources in India is different from the definitions under the United Nations Framework Convention on Climate Change (UNFCCC). Based on recent estimates (Chand, 2005; Chikkatur, 2005; Ministry of Coal, 2006), Indian coal reserves are thought to be about 44 billion tons (BT), out of a total resource inventory of 248 BT. These current reserves might be expected to last between 30 and 60 years, depending on the rate of domestic coal production (Chikkatur, 2005). This relatively short lifetime is in sharp contrast to the general assumption that Indian coal will last more than 200 years[63]—an assumption predicated on extracting all of the country's resources without accounting for technology or economics (CEA, 2004b, 2005a). Certainly, the amount of reserves can be increased through more investment in coal reserve assessment and technological advances in the coal sector, but these developments cannot be taken as a given. Reducing uncertainties and investing more in the coal sector will lay the groundwork for better energy planning, as well as for sustained growth in the coal-power sector.

Furthermore, coal imports are likely to increase significantly over the next 20 to 25 years. Imported coal is likely to comprise between 11 and 45 percent of total coal demand (equivalent to 70 to 450 Mtoe), compared to only 6 percent of total coal demand today (Planning Commission, 2006). This increased level of coal imports will have many implications for the Indian power sector. As discussed earlier, increased use of better-quality imported coal would allow easier adaptation of new technologies in India, and thereby increase the technological capacity in the country. An increased reliance on imported coal also would create a growing potential for a two-track technology strategy—one aimed at domestic coal, and another aimed at imported coal.

The poor quality of Indian coals has directly influenced the development of India's coal-power sector. Ash content in Indian coals has been increasing over the past three decades, primarily because of increased opencast mining and production from inherently inferior grades of coal (Ministry of Coal, 2006). Current mining practices have limited extraction to within 300 meters, and the focus is primarily on opencast mining for the next 20 to 30 years. However, it is essential that underground coal mining be promoted in order to access deeper coal reserves, and to increase coal quality. Also, coal beneficiation is an important element of improving India's coal quality. Beneficiation of coking coal is already well-established in India, and there are now washeries for non-coking coal as well, but there needs to be much more focused effort to increase economic washing. Furthermore, the current grading system of coals in India does not provide a proper pricing signal for coal producers to improve coal quality; this system has to be changed in order bring market forces into the sector.[64] Finally, new technologies, such as coal-bed methane and underground coal gasification, should also be promoted to make the best use of India's coal resources.

INSTITUTIONAL AND FINANCIAL HEALTH OF THE POWER SECTOR

India's success with the liberalization and restructuring of the power sector has to be seen as mixed at best, this outcome resulting from the interlinked factors of poor design of the "reformed" power sector (i.e., not fully suitable for the Indian context), inept management of the reform process, and deficient governance in practice (Dubash and Singh, 2005; Sharma et al., 2005; Singh, 2006; Dubash and Rao, 2007).

In the decade after these changes were made, the technical performance of the power sector has not improved much—for example, T&D losses as well as peak and energy shortages stayed almost the same, although the plant load factor did improve somewhat (Sharma et al., 2005). The economic performance of the sector has remained woeful—despite tariff revisions, losses at the SEBs continued to mount, their cost recovery through tariffs continued to decrease, and the rate of return dropped precipitously to less than 40 percent by 2002 (Sharma et al., 2005). Such a precarious financial situation impedes significantly the ability of the SEBs to raise funds for new power plants or to sign power purchase agreements with power generators (Singh, 2006). Making matters worse, the regulatory institutions have been less than fully effective because of a lack of political support, weak capacity, ambiguity in operating procedures and norms, and aversion to conflict with entrenched interests (Dubash and Rao, 2007).

Although improvements in the institutional and financial health of the sector will not come easily, there are signs of hope. These include: greater scrutiny of the performance of the reforms; better understanding that successful reforms necessarily will require a tailoring to the Indian context; and institutional learning and capacity-building. Hybrid approaches to power-sector reform will have to be considered, along with better planning for the transition period (Dubash and Singh, 2005). Regulatory institutions will have to be strengthened by giving them greater credibility and enabling the development of their capacity. In addition, regulators themselves must work in a cooperative manner to improve and strengthen regulatory practices and improve stakeholder participation (Dubash and Rao, 2007). There is also some expectation that open access, by giving industrial customers the choice to exit the system, will force a "facing-up" to subsidy issues (Dubash and Singh, 2005; Singh, 2006), which have been the bane of the SEBs.

While private investors have entered other sectors in India, they have been more hesitant to enter the energy market because of the preferential treatment given to public-sector energy companies (IEA, 2007b). It is, therefore, important that a transparent, predictable and consistent investment framework be put in place. Another priority should be to reduce start-up hurdles, such as delays in acquiring land, environmental clearances, and construction permits (IEA, 2007b). The recent Ministry of Power's "Ultra-Mega Power Project" scheme is intended to reduce the initial hurdles by creating shell companies that obtain all the required clearances before awarding the project to a bidder (CEA, 2007a).

Ultimately, the institutional and financial health of the sector cannot be delinked from the politics of the power sector. The institutional transformation of the power sector has to contend with entrenched interests and politics, which will only be overcome through greater and more open public debate on these issues. In fact, any plans to deploy advanced technologies at large scale may fall short if the issue of broader reforms is not adequately addressed.

NEED FOR DOMESTICALLY-DRIVEN COHERENT ENERGY POLICY ANALYSES

As discussed in an earlier section, development of meaningful energy policies in India has been limited by a lack of domestic policy research and analysis, and by the "panic-mode" that compels the power sector to emphasize short-term solutions rather than longer-term planning. The Planning Commission needs to strengthen its policy analysis capacity, as a significant portion of the domestic capabilities in the government lies in this body. In addition, it is important for NGOs, academics, and think tanks to strengthen their policy analysis capacity and engage with the Planning Commission. Such engagement should also promote the involvement of a wide swath of stakeholders through open, multi-institutional discussions.

Build-up of domestic policy analysis capability can contribute to better understanding of the implications of policy approaches advocated by external agencies in the Indian context. Better policy research capacity also will help in integration of power-sector policy with cross-sectoral issues such as national security, environment and labor. This is particularly important as the power sector is in a period of transition and is faced with major issues, such as labor relations resulting from restructuring. At the same time, there are key emerging issues such as energy security and climate change that have significant implications for the sector.

A strong domestic policy analysis capacity in India will help the power sector shift from an incessant focus on short-term solutions towards more holistic and long-term approaches. It is critical for the government to step back and determine long-term strategic policies and planning in the sector. Such long-term planning would allow for integrating GHG mitigation into the broader energy policies of the country.

INTER-MINISTERIAL AND REGULATORY COORDINATION

Policymaking and planning in the Indian power sector occur in a complex environment with multiple institutions and actors that have different interests. As a consequence, there is a great need for improved interministerial and regulatory coordination.

Given the many ministries, public-sector enterprises and organizations involved in the coal-power sector (see section on Policy and Institutional Landscape), the actions and policies of any single actor can affect the trajectory of the entire sector. Hence, it is crucial that different ministries and the Planning Commission coordinate the development of policies and planning (as well as their effective implementation) in the power sector. There already are some efforts under way aimed at increasing coordination and devising coherent policies for the country's overall energy sector. The Planning Commission, for example, recently produced the above-mentioned Integrated Energy Policy report (Planning Commission, 2006). In addition, the planning process for the national Five Year Plans involves getting input from different ministries within the different working groups for the Plans' formulation. However, there is little critical analysis of the provided data in this forum. Furthermore, in 2005 an Energy Coordination Committee was set up in the Prime Minister's Office for better inter-ministerial coordination and integrative decision making in the area of energy planning and security.[65]

In addition to the coordination of the different ministries, the influence of independent regulatory agencies is particularly important. Independent regulation, unbundling and privatization of vertically integrated utilities owned by State governments, and introduction of competitive distribution were first introduced in the power sector by the World Bank,[66] and then later institutionalized by the Electricity Act 2003. In this changing institutional environment, the regulators have been trying to introduce competition and reduce the cost of electricity for consumers, while maintaining a good investment climate for the utilities to add capacity to ameliorate existing power shortages and meet expected demand growth. More importantly, the regulators have provided an important space for incorporating the concerns of various stakeholders, including public-interest issues (Prayas, 2003).[67] Under the current approach, regulators have been passing through the costs of complying with environmental regulations to consumers. For example, regulators allow for additional capital expenditures needed to meet environmental standards and consider these assets for depreciation if environmental standards are complied with in the previous period.

It is not clear how regulators would deal with installing climate mitigation technologies, as it will likely increase the cost of the power dramatically, especially if this will require retrofitting of existing power plants. Regulators also will need to work with MoEF, the Ministry of Power, BHEL, and the utilities to introduce suitable mechanisms that will promote the introduction of suitable power generation technologies as climate policies are better developed. Hence, electricity regulators also are likely to play a crucial role in determining when and how carbon controls will be deployed in India.

BUILDING TECHNOLOGICAL INNOVATION CAPACITY

The technology innovation system for the coal power sector in India requires an infusion of significant domestic financial resources, as well as institutional changes. Improvement in the Indian technology innovation system is important not only for the coal-power sector, but also more broadly, as India aims to successfully develop and deploy new technologies, and as Indian firms strive to compete with other international firms.

India's innovation system is relatively small, largely fragmented, and performs well only in a few sectors, such as nuclear power, information technology and biotechnology. Despite significant investments in scientific and technological capabilities, the progress on indigenous technology development has been spotty. For example, in the coal-power sector, although most power plants are indigenously manufactured, much of the technology continues to be licensed from foreign technology providers. The development, adaptation, and deployment of advanced technologies, including carbon capture technologies, are likely to be impeded by the existing technological capacity.

In India, as in other countries, technological capacity is not generated simply by producing more engineers and scientists, nor is it gained automatically through deployment. Rather, it derives mainly from deliberate R&D and learning-by-doing, which are based on a range of factors, including production experience, import of knowledge and technologies from foreign sources, and a systematic process of investment in indigenous creation of knowledge and skills (Lall, 1987).[68] Hence, improving the coal-power sector's technology development system should include not only more funding for research and development, demonstration and early deployment activities (RD^3), but also better-designed RD^3 programs.

Government institutions are the main performers of R&D in India, which contrasts with the approach of most industrialized countries, where the private sector takes the lead—in the United States, for example, private industry performs about 70 percent of the total R&D (NSF, 2008). There is little concerted effort to coordinate the development of new technologies in India, and R&D efforts often are not synergistic. Innovation of new technologies requires strategic, sustained interactions between academic researchers, R&D labs, and industries (manufacturers and utilities)—currently, such interactions take place on an ad-hoc basis. However, given that major public-sector units are deeply involved in the coal-power sector, particularly BHEL and NTPC, it would be logical to leverage and deepen their RD^3 capabilities[69]—in addition to private sector and academic R&D investments.

Currently, many of the technical activities in the coal-power sector continue to rely on foreign sources of funding. For example, the BHEL R&D facilities were supported technically and financially by U.S. AID funds. U.S. AID is also supporting CenPEEP to improve the efficiency of Indian power plants and to assess the feasibility of technologies for IGCC in India. Such studies typically use foreign consultants, eliminating opportunities for Indian consultants and researchers to engage in such analyses and, in turn, to increase their capabilities. For example, Nexant was the key consultant for the recent IGCC assessment for India.

Focused and competitive RD^3 efforts and building up broad technological capacity in India will help ensure that deficient technology innovation systems do not become a serious constraint for indigenous technology development in India. Meeting the carbon capture and storage challenge (as well as other challenges) adds to the complexity of the overall task and will necessitate adding these (non-traditional) components to the power technology innovation system.

INTERNATIONAL ACTION AND COOPERATION ON CLIMATE CHANGE MITIGATION

International action and cooperation will play a very important role in accelerating the development and deployment of lower-GHG coal-power technologies in India, since India does not have the financial or technical resources to do this on its own in any significant manner. The practicalities of undertaking any large GHG-mitigation efforts are complicated by limited political or public will to engage in such actions. Developed countries themselves have done little in reducing emissions from their coal-power sectors, despite their enormous technical and economic capabilities.

GHG mitigation in the Indian power sector will be influenced by the outcome of international climate treaty negotiations; leadership from developed countries, particularly the United States, is essential for India and other developing countries to consider strong GHG-mitigation activities. In fact, there are three key ways in which the international community can help promote the transition to lower-GHG coal-power technologies in India:

a) Industrialized countries (particularly the United States) must lead by example and implement concrete policies and actions to reduce their GHG emissions. This will advance the likelihood of India developing and implementing specific climate-mitigation policies that go beyond "no-regret" policies such as enhancing energy efficiency;

b) Climate change mitigation activities in industrialized countries will result in the development and deployment of lower-GHG coal-power technologies that will increase the range of technological options available to India and lower their costs; and

c) Industrialized countries can assist India in performing technology analysis as well as in deepening its technology capabilities to facilitate the selection of technologies best-suited to the Indian context and their adaptation to local conditions. There is a significant onus on Indian institutions to ensure that international collaboration is effective not only for climate mitigation but also for the broader development goals.

Thus, the need for, and the roles of, foreign partners and collaborators at each stage of the technology innovation process must be assessed, so that they can help overcome lacunae in domestic capabilities. Linkages with appropriate international research organizations (such as the national laboratories in industrialized countries) and engineering firms might add significant value and speed up basic and applied research for specific technologies. It might also be necessary to utilize the expertise of foreign analysts and consultants for policy analysis and technology assessments, although domestic experts must remain involved to ensure a suitable incorporation of local perspectives and build-up indigenous analysis capacity. Finally, international collaboration makes commercial tie-ups and joint venture projects more feasible for the technology deployment and commercialization phase. In such cases, it is very important to assess whether the foreign collaborations are need-based and how foreign linkages and tie-ups can best further India's long-term technology strategy.

For carbon capture technologies in particular, deployment in industrialized countries will help to reduce technology risks and cost, which is necessary if these technologies are to be given serious consideration by India and other developing countries. This, of course, implies the need for serious GHG policies in industrialized countries that actively promote the deployment of advanced technologies such as IGCC and CCS. Initial demonstration of advanced carbon-control technologies in developing countries such as India would also likely need international financial support. Furthermore, financial support for carbon mitigation in developing countries through the Clean Development Mechanism and other policies would increase the possibility for the deployment of low-carbon technologies in India. In addition, internationally supported capacity-building activities would help strengthen the technological capacity in the sector and help lower GHG emissions in the long run.

On the other hand, it is important to note that an excessive and premature push on power-sector GHG mitigation in India, particularly by international agencies, might be counter-productive, especially if it is not clear what technological options make sense from the long-term perspective and if their technological and economic feasibility is not well-demonstrated.

Conclusions

GHG control and reduction of emissions from the coal-power sector necessarily will be a critical element in the India's carbon-mitigation strategy. However, there also are other, more immediate challenges for the power sector, of which the most pressing is the need to enhance the availability of electric power to the country's citizenry and industry. The implementation of any significant GHG-mitigation strategy in India will depend on progress on an international climate regime that promotes participation by India and other developing countries. In addition, commitment and action by industrialized countries will be critical in creating robust markets for carbon, catalyzing research advances and price reduction by creating markets and incentives for new technologies, and enhancing the possibility of developing countries taking on commitments for reducing their GHG emissions growth.

In the meanwhile, though, India can (and should) take a number of immediate steps that start reducing the GHG-emissions growth of the power sector while advancing the country's development agenda and also laying the groundwork for future deeper emissions reductions. In parallel, it is equally critical to focus on the improvement of knowledge, institutions and processes that will strengthen the power sector, and ultimately assist in the development of effective GHG-mitigation policies and actions. This dual-track approach will ensure that the country is adequately prepared to implement long-term GHG-mitigation policies and technologies that are suitable and appropriate for India's coal-power sector.

These domestic and international steps will allow the development and implementation of a GHG-mitigation strategy in the Indian coal-power sector while allowing it to contribute suitably to the country's energy needs. Such a deliberate and careful approach pursued with short- and long-term perspectives in mind is likely to be effective in crafting an integrative energy and climate policy that will allow the country to contribute to meaningful GHG mitigation while helping meet its pressing energy needs.

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Endnotes

1 In fact, there is a broad correlation between per-capita energy consumption and the Human Development Index (HDI), as well as between per-capita GDP and per-capita energy consumption. However, there is no fixed relationship between GDP and energy consumption. For example, among industrialized countries, Japan and many European countries are less energy intensive than the United States and Canada.

2 The total primary energy supply (TPES) in the country was estimated to be only 0.49 tons of oil equivalent (toe) in 2005, which is just over one-tenth of the OECD average, just over a quarter the global average, and just over a third that of China (IEA, 2007a).

3 Even when electricity use is normalized with respect to GDP, Indians have a much lower availability of electric power compared to other countries.

4 For example, see: (UNDP, 2004).

5 Article 3.1 of the UNFCCC states that parties should protect the climate system "on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof. Article 4.7 states that the extent to which developing country Parties fulfill their commitments will depend on the level of financial and technological assistance from developed countries and "will take fully into account that economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties."

6 See. National Action Plan on Climate Change, Government of India, http://pmindia.nic.in/Pg01-52.pdf

7 See: Chikkatur, A.P., A Resource and Technology Assessment of Coal Utilization in India. Prepared for the Pew Center on Global Climate Change. 200.

8 http://www.cmdl.noaa.gov/ccgg/trends/

9 As the IPCC (2001) states, "the impacts of climate change will fall disproportionately upon developing countries and the poor persons within all countries."

10 http://unfccc.int/resource/docs/convkp/conveng.pdf. See: http://unfccc.int/essential_background/feeling_the_heat/items/2914.php for more information about the Convention.

11 As of April 2006, India had 206 registered projects (out of 595 registered projects worldwide). See: http://cdm.unfccc.int/Statistics/index.html.

12 The APP intends to accelerate the development and deployment of clean energy technologies, although there is some skepticism about the motivation and potential of this approach [see, for example, C. Dennis, "Promises to clean up industry fail to convince" *Nature* 439: 253 (2006)]. Some critics even suggest that this move may undercut the multilateral process to tackle climate change under the UNFCCC through binding GHG-mitigation agreements and therefore, in the end, may be counterproductive (Narain, 2005).

13 The cumulative contribution to the rise in atmospheric concentrations and rise in global temperatures is a complex issue, especially given the long lifetimes of many GHGs.

14 Therefore, it is important not to juxtapose India and China together when one is discussing responsibility for climate change.

15 WRI, CAIT. Only includes CO2 emissions from energy.

16 World Development Indicators, accessed January 11, 2009.

17 Community development blocks are administrative units, consisting of about 100 villages, for development activities in India.

18 The role of coal in future electricity-sector growth in India is discussed further in Chikkatur, 2008.

19 See Ministry of Petroleum and Natural Gas website. http://petroleum.nic.in/petstat.pdf

20 "State governments" here also includes Union Territories of India.

21 With the onset of liberalization in the early 1990s, the government began to provide incentives for increasing private-sector involvement in the power sector. Initially, the government focused on increasing foreign direct investment for the Independent Power Producers (IPPs), and later electricity boards were unbundled and independent regulators were set up in each state. See Chikkatur and Sagar (2007) and Chikkatur, 2008 for more information.

22 Discussed further in Chikkatur, 2008.

23 See: http://dhi.nic.in/role01.htm.

24 See, for example, Khator (1991); see also Sunita Dubey (2006), "An Undemocratic Environment" http://indiatogether.org/2006/oct/env-democenv.htm.

25 The objective of the Planning Commission is to promote a rapid rise in the standard of living of the people by efficient exploitation of the resources of the country, increasing production and offering opportunities to all for employment in the service of the community. See: http://planningcommission.nic.in/aboutus/history/about.htm

26 Popularization of the "Green Revolution" led to greater water, fertilizer and pesticide inputs into agriculture; irrigation pump sets allowed for delivery of large amounts of water needed for such input-intensive agriculture.

27 This situation was entirely different from the early 1970s. In 1971-72, the average revenue from domestic and commercial (Rs. 0.31/kWh) consumers was nearly three times more than from industrial consumers (Rs. 0.11/kWh), and almost two times more than agricultural consumers (Rs. 0.16/kWh) (Henderson, 1975).

28 Theft and pilferage of electricity is estimated at about $5 billion annually. In addition, the efficiency of billing is about 55 percent and collection efficiency is 41 percent in almost all States.

29 As their finances worsened, the SEBs resorted to state government subventions, cross-subsidies and other accounting manipulations to meet their financial obligations (Tongia, 2003).

30 This includes the controversial and currently shut-down 740 MW Dabhol/Enron gas-based power plant in Maharashtra.

31 The reforms package included (World Bank, 1993):

- Independent regulatory bodies that set tariffs for both private and public utilities through a transparent process, and balance public interest with "the need for enterprise autonomy";
- "Relaxation of restrictions on entry and exit" into the power sector to increase competition;
- Commercialization and corporatization of utilities in various States to attract private investment;
- Separation of "generation from transmission and distribution, and encouraging cogeneration and independent power production through private investment in plants that sell to the grid"; and
- Greater private-sector participation in all aspects of the power sector: generation, transmission and distribution.

32 It must be noted that the government has not completely abdicated its responsibility of providing power to the poor, as illustrated by its rural electrification activities.

33 Expenditure in the power sector has dropped to between 65 and 80 percent since the 1980s—indicating that the power sector has been unable to meet the national Plan's goal of installing new capacity.

34 According to CEA (2007), PFC and REC are expected to disburse about $30 billion in the 11th Plan, whereas the estimated funds required for the 11th Plan are about $230 billion.

35 Key incentives for the IPPs included a guaranteed minimum of 16-percent rate of return (after-tax) on equity, full repatriation of profits in dollars, five-year tax holiday, guaranteed off-take and payment, high cost-plus tariffs, and selective counter-guarantees from the Central government in case of payment default by the SEBs (World Bank, 1999).

36 This is based on the authors' interviews and interactions with numerous individuals and experts in the Indian government.

37 Given that significant parts of the final report were different from the draft, one can conclude that public comments may have had some influence. However, the Planning Commission has not released any statements about what comments it received, nor has it stated how these comments were incorporated in its final report.

38 See, for example, Kandlikar and Sagar 1999, and Dubash and Rajan 2001.

39 This is best illustrated by the debacle of the Enron Power Project; see, for example (Mehta, 2000).

40 It is sometimes perceived that India is one of the few developing countries that has a "good" planning process and the problem lies more in implementation rather than the planning itself. However, planning and its implementation cannot be separated out cleanly: if the plans cannot be implemented to the fullest extent on a regular basis, the planning process must be considered unrealistic.

41 Note that these policies are specifically aimed at the coal-power sector, as opposed to the broader power sector. Therefore, we have not included policies, for example, that promote renewables-based power generation.

42 In comparison, the average efficiency for the top-50 most-efficient U.S. coal-based power plants is 36 percent, with the fleet average being 32 percent. (Power Magazine, July/August 2004)

43 See Chikkatur, 2008.

44 Reference section in Chikkatur, 2008.

45 Under the current approach of cost-plus tariffs, regulators approve the fixed and variable costs of utilities based on a range of benchmarks determined by the regulators, and the profits of the utility (i.e., rate of return on investment and other incentives) are included in the tariff calculation—hence the term "cost-plus."

46 http://powermin.nic.in/transmission/transmission_overview.htm, accessed April 8, 2007.

47 T&D losses are computed as the difference between the energy input to a T&D system and the energy consumed, as a percentage of the energy input. ATC losses are calculated as the difference between the energy input to a T&D system and the energy realized (i.e., for which payment has been collected), as a percentage of the energy input. Hence, ATC losses include commercial loss (which is generally a euphemism for outright theft of electricity), and are more representative of the performance of the distribution system.

48 http://www.thehindubusinessline.com/2005/12/03/stories/2005120303300900.htm.

49 Funds are being granted to State utilities for upgrading sub-transmission and distribution networks. Furthermore, incentives are provided for reducing cash-loss by State utilities.

50 Metering and collection efficiency would increase if the utilities are able to guarantee consistent, high-quality electricity supply.

51 See Chikkatur, 2008.

52 The cost of the standard subcritical pulverized coal (PC) plants range around $700-900/kW, without any sulfur control technologies (Nexant, 2003; Chikkatur and Sagar, 2007).

53 Note that efficiency improvement is given in terms of percentages, and not percentage-points, i.e., a 20-percent increase in efficiency for IGCC, compared to subcritical PC, would imply that efficiency of IGCC is about 40 percent and subcritical PC about 33 percent.

54 For example, power plants based on cooling water temperatures of 14-15 oC can achieve an extra three percentage points in efficiency, when compared to plants with cooling water temperatures of 27-28 oC (PowerClean, 2004).

55 Even electricity cost estimates using different technologies vary widely in published studies, and the uncertainty in these cost estimates is often higher than the difference in cost estimates among the different technologies.

56 For example, new capture technologies might be devised that do not require high-purity flue gases.

57 For example, demonstration projects (including those carried out in collaboration with international organizations) should only be considered if they are in line with the a larger strategic RD3 program.

58 Note that the new energy R&D laboratories at NTPC are aimed to addressing some of these R&D issues.

59 See Chikkatur, 2008.

60 See Chikkatur, 2008.

61 In some cases, geological areas suitable for CO2 storage may not be hydrocarbon-rich.

62 See Chikkatur, 2008.

63 See, for example: (BP, 2006), (Shahi, 2003), (Sagar, 2002) and http://www.cslforum.org/india.htm.

64 See Chikkatur, 2008.

65 See: http://pmindia.nic.in/eccbody.htm

66 In 1998, a quasi-judicial Central Electricity Regulatory Commission (CERC) was established, with jurisdiction over setting tariffs for electricity purchased from Central utilities and inter-state transmission, to formulate guidelines and advisory powers for the Central government on new policies (CERC, 2000).

67 It should be noted that not all state regulatory commissions operate transparently, nor have they provided sufficient space for including public-interest issues (Prayas, 2003).

68 Technological capacity can be broadly defined as the technical, managerial and organizational skills that are necessary for industrial enterprises to set up industries based on given technologies (regardless of their source), utilize them efficiently, improve and expand them, and develop new products and processes over time (Najmabadi and Lall, 1995).

69 While BHEL dominates the R&D effort on energy technologies in India and has a robust R&D program (by Indian standards), it falls far behind in comparison to international firms. For example, in 2004-05, BHEL spent $28 million on R&D, whereas the power division of Siemens spent $525 million in 2004 on R&D, and Alstom had an overall R&D expenditure of $417 million (Alstom, 2005; Siemens, 2005). In 2004, Siemens power R&D expenditure was 3.8 percent of sales, and the corresponding number for BHEL (i.e., overall R&D as a percentage of total sales) was only 1.2 percent.

This paper describes policy options that could help India reduce greenhouse gas emissions from coal-fired electricity while meeting the country's growing energy needs. It is part of a Pew Center on Global Climate Change Coal Initiative, a series of reports examining and identifying policy options for reducing coal-related GHG emissions. The Pew Center brings a cooperative approach and critical scientific, economic, technological, business and policy expertise to the global climate change debate at the state, federal and international levels.

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