

Electricity Sector Reform in India: Environmental and Technical Challenges

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(Received : 30 November 2004 – Accepted : 30 March 2005)

Abstract: Electricity-supply Industries (ESIs) in both developing and developed countries are experiencing a wave of reform heading toward a competitive market, though the characteristics of reform are unique for individual countries. With the initial introduction of competition in its generation sector, India has initiated a power sector reform process via institutional reforms such as commercialization and restructuring. However, most of the state utilities are still characterized by regulated monopolies, under pricing, excessive cross-subsidies, huge power system deficits and losses, and excessive political interference in the power system management. Moreover, as the reform process from 1991 continues, environmental concerns are either overlooked or not

a substantial consideration. As a result, greenhouse gas emissions in the electricity sector have become exacerbating. In terms of technical, financial and institutional problems associated with ESIs, the power sector reform process in India faces challenges above and beyond most other countries that are currently working toward reform. This paper analyzes some of the issues that ESIs in India are facing, and recommends policy options to meet those challenges.

Keywords: Electricity-supply industries, India, reform, greenhouse gas.

Introduction

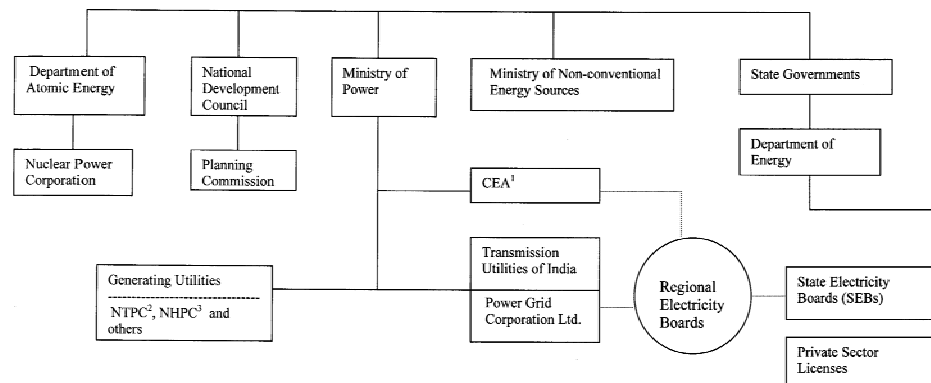
Electricity-supply Industries (ESIs) in both developing and developed countries are experiencing a wave of reform; however there are substantial variations among countries in the timing, approach and scope of that reform [9]. Electricity price reduction through the improvement of economic and technical efficiency is the major goal of electricity sector reform efforts in developed countries, whereas breaking of the vicious cycle of poor performance, low prices, high losses and inadequate electricity supply (as a result of state ownership and political interference) are the primary targets of electricity reform in developing countries. Nonetheless, in both developing and developed countries, the common goal of electricity reform is

to improve performance, reduce the financial burden on government and create a sustainable and resilient path of electricity sector operation. World-wide reform initiatives have resulted in Independent Power Production (IPP) and competition in generation, unbundling of conventional vertically integrated utilities into generation, transmission and distribution, and operation of an independent transmission/system for the transaction of wholesale/retail electricity. With the evolution of world-wide power sector reform, India has also started its reform process, beginning in 1991 with the introduction of Independent Power Producers (IPPs). Restructuring and commercialization of ESIs have been the major institutional reforms at the state level in India.

Characteristics of the Indian Electricity Sector

India ranks eighth in the world in terms of annual electricity generation. India's electricity sector has expanded substantially during the last decade from 71,750 MW in 1990 to 111,700 MW in 2000, yielding a compound annual growth rate of 8.2 percent [1]. However, its per capita electricity generation is one of the lowest in the world (460 kWh/yr average for India vs 1,252 kWh/yr average for the entire world) [2]. Due to the country's high electricity demand, the supply-demand gap is widening as a result of the state and central governments' financial inability to construct new power plants. India's electricity sector is primarily owned and operated by the public

sector. About 30 percent of the country's total generating capacity is produced at the central level, mainly from the National Thermal Power Corporation (NTPC) and the National Hydro electric Power Corporation (NHPC); this power is ultimately sold to State Electricity Boards (SEBs). There are 19 SEBs, which are divided into five Regional Electricity Boards, each having their own regional grid. SEBs contribute about 60 percent of the electricity generation, the rest (under 10 percent) is provided by IPPs. The central and state governments are both responsible for generation and transmission, as well as major policy implementations. Electricity distribution and price setting are completely under the purview of state governments (Figure 1). About 75 percent of the country's electricity generation is comprised of thermal power plants, followed by hydro (15 percent), and gas (5.5 percent). The level of thermal electricity generation is expected to rise to 81 percent in 2010, with coal-fired power plants leading the share of electricity produced [3].



¹ Central Electricity Authority, ² National Thermal Power Corporation,

³ National Hydropower Corporation

Figure 1. Institutional structure of the power sector in India.

The contribution of renewable power sources in India is insignificant, representing less than 1 percent of the total electricity production and less than 5 percent of the renewable energy potential [4]. Due to the increase in thermal generation, emissions from the electricity sector have become a significant problem (Figure 2), and the lessening of energy diversity and security are also concerns.

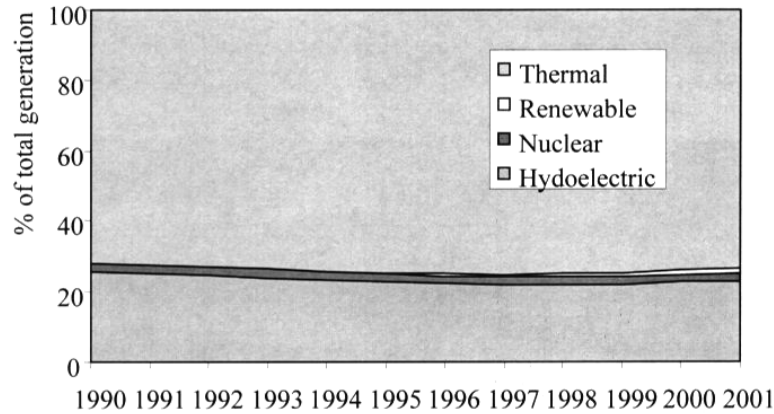


Figure 2. Trends of thermal generation in Indian electricity sector [1].

Challenges Faced by the Indian Electricity Sector

India lies in the South Asia region and accounts for more than 85 percent of regional electricity demand, followed by Pakistan (10 percent), Bangladesh (2 percent), Sri Lanka (1 percent), Nepal, Bhutan, and the Maldives (1 percent of total) [2]. India's Electricity supply-demand is the widest amongst the South Asian countries. Although about 80 percent of India's population has access to electricity, 73 percent of the poor

people in the electrified areas have no access to electricity; power outages and brownouts are very common, creating shortfalls greater than 15 percent of the demand [2]. India needs an addition of 100,000 MW capacity, which would require more than \$150 billion, including investment in transmission and distribution (T & D) [5]. To meet the excessive power deficit in the country, India could use higher capacity power plants. These plants however, have a high gestation period and require sufficient financial resources. Additionally, the supply-demand gap is worsened by a lack of adequate maintenance for old and conventional power plants, resulting in a progressive decline in plant efficiency and excessive operation and maintenance costs [6]. System losses are running in the double-digit order, and T & D losses are 20-25 percent (although the unofficial figure is believed to be around 40 percent) [5,6,7]. The average plant load factor (PLF) of thermal plants is 64 percent compared to the 70-75 percent international standard. India's five regional grids are operated independently, creating transmission bottlenecks. Inadequate T & D is also considered a primary cause for the peak power deficit in India.

The state electricity boards have not yet operated under a commercial directive [6]. Agricultural and residential electricity prices are heavily subsidized. As a result, the state utilities are operating with heavy financial deficits (in the order of \$5.8 billion a year). In addition to state subsidies, the central government is subsidizing the price of coal. Due to these subsidies, the rate of return on capital investment is increasingly

negative (reaching to -19.8 percent) and financial resources needed to meet projected demand are unlikely to be realized through internal resources [8]. Donor organizations such as the International Monetary Fund (IMF) and the World Bank (WB) have been pushing governments to reduce subsidies. Bureaucratic obstacles and underdeveloped regulatory policies created by central and state level governments have led to reduced private participation (mostly foreign investment). As a result most large IPP projects in the region have been delayed or cancelled over the past two years due to the poor financial status of most state utilities. Private participation in the distribution sector has been very difficult, although some of the states (i.e., Orissa, Haryana and Andhra Pradesh) have initiated their reform processes with the principles of corporatization and unbundling of the vertically integrated structure with an independent regulatory authority. Monetary assistance to the power sector through the WB and Asian Development Bank (ADB) is under the condition of regulatory reforms [9].

Evolution of Electricity Reform in India

Looking into the evolution of electricity sector reform throughout the world, each reform process is characterized by at least one or a combination of the following characteristics: independent power production, competition in generation and/or distribution, decentralization, privatization, and unbundling of generation, transmission and distribution [10].

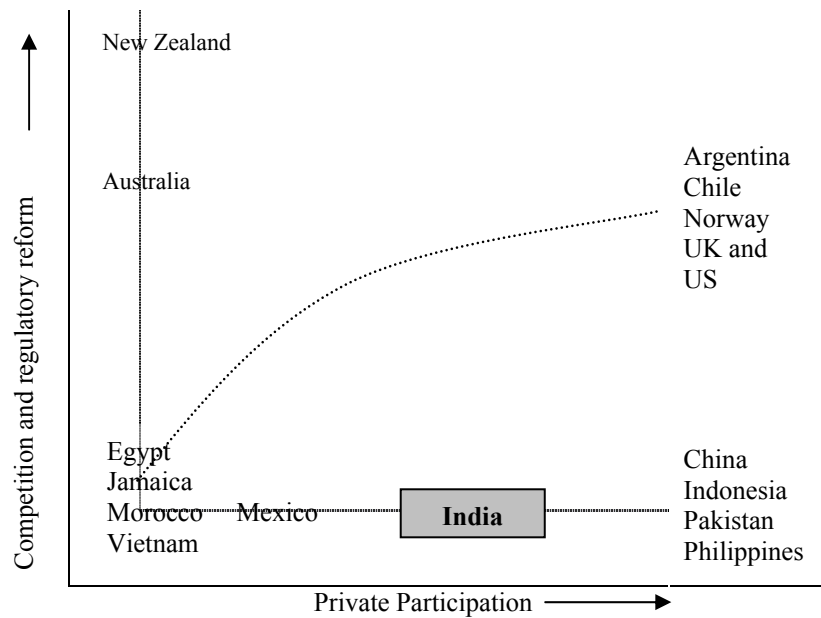


Figure 3. Evolutionary path of reform in different countries [11].

However, The success of the reform greatly depends upon the existence of institutional, regulatory and structural context in which it is taking place [12]. The Indian model (South Asian model) is characterized by a high level of private participation and a low level of competition, as well as regulatory reform. The Indian reform model, as depicted in Figure 3, is characterized by a horizontal path that lacks significant regulatory reforms. Regulatory reforms are minimally integrated into the reform processes and are introduced as per the criteria set by international investors (i.e., the WB and ADB). The entry of IPPs in the generation sector was essential in the transition of the electricity sector, which was dominated by a vertically integrated monopoly, to one characterized by competition. The entry of IPPs in these instances paves the way for further

reforms and increases the competitiveness of the electricity sector. In India as a whole, competition in generation with a single buyer model is very common, except for a few states (Orissa and Andhra Pradesh) which are moving toward competition in the distribution sector as well. However, the reform process in the Indian electricity sector aims to proceed through the following stages: partial competition, wholesale competition, and retail competition [13].

The Indian power sector, characterized by a regulated monopoly, under-pricing, excessive cross-subsidies, widespread staffing, large technical and commercial losses, and heavy political interference on the management, began its reform process in 1991 with partial competition in the generation sector, an initial stage in the competitive reform mode [6]. The different state electricity boards (i.e., Haryana, Orissa and Andhra Pradesh) during the last few years have been progressing toward partial corporatization and IPP development in generation with the establishment of independent State Electricity Regulatory Commissions (SERCs). Some of the states, such as Orissa, have exercised private participation in the distribution sector as well. Privatization in the distribution sector is essential to reduce the distribution losses (both technical and non technical), which would be impossible under the public monopoly. The World Bank, a major funding institute for Orissa State Electricity Board (OSEB), claims that the distribution system's pre-reform high technical losses (i.e., 23 percent) could be reduced to 11 percent during the reform program [22].

However, private parties in the distribution sector are not fully confident to participate since it is not operated on a commercial basis. Additionally, it is very challenging for new entrants to break the vicious cycle of political interference on distribution system management and to remediate the worsening situation of the distribution infrastructure [6].

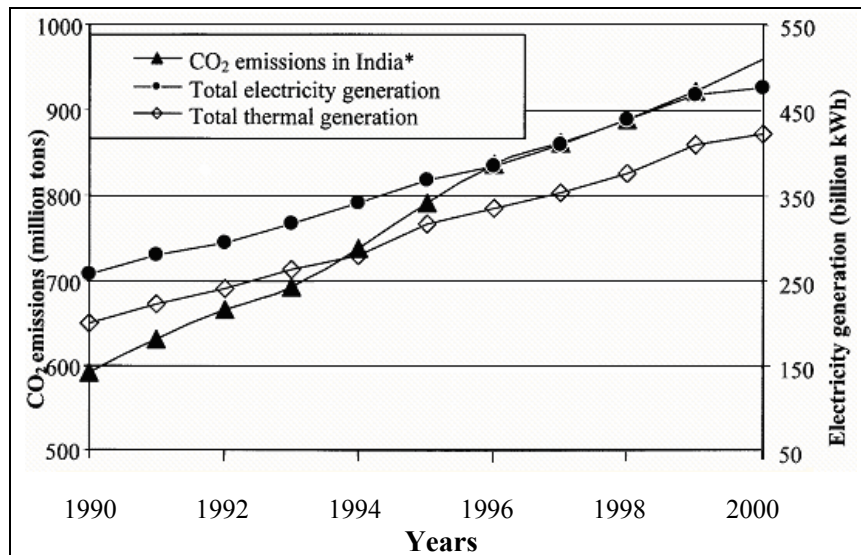
Electricity Sector Reform and its Environmental Concerns in India

In considering the drive toward electricity sector reform, it is imperative to understand how the reform will affect the environment. The reform greatly affects the different technology options (both supply and demand-side) of meeting electricity demand. The level of air emissions controlled from different technology options will determine the environmental performance of the sector. Proponents of electricity reform often argue that it will automatically result in environmental improvements through the more efficient use of fuel resources [10]. It is also believed that when reform involves significant private sector participation, the government will be more stringent in enforcing regulations with the private sector than with public utilities [9]. On the other hand, a contrary argument arises indicating that private participants are more concerned about their profitability and may opt for low cost dirty power sources (i.e., coal), which could deteriorate the environment in an emerging competitive market [9]. As the reform process in

developing countries evolves, environmental concerns could be either overlooked or not given significant attention [10, 14]. Experience demonstrates mixed results, which in each country depends upon how environmental regulations are integrated into its reform agenda [10].

The British reform experience showed promising results in environmental improvement, primarily due to the switching of electricity supply sources from coal to natural gas. This was possible as a result of significant reduction in domestic coal subsidy by the Thatcher government. As a result, natural gas based electricity increased from just a 1 percent share in 1990 to 13 percent in 1994 [15]. Additionally, various environmental regulations coincided with the privatization process in 1990, one of the notable environmental policies being a FGD program to control/reduce SO₂ from coal-fired power plants initiated by UK Department of Energy.

Contrary to the UK experience, contribution from conventional thermal electricity generation has been increasing in India; share of coal based electricity generation increased from 50 percent in 1985 to 73 percent in 1997 [25]. As a result, environmental emissions have also been steadily increasing over the last decade (see Figure 4). India is one of the leading countries in terms for worldwide CO₂ emissions. In 1999, the power sector alone contributed about 45 percent of the total anthropogenic carbon emissions, up from 37 percent in 1990 [3].



* includes the emissions from heat generation

Figure 4. Evolution of thermal electricity generation and CO₂ emissions in the electricity sector [1].

Figure 4 demonstrates the inter-relationship between thermal electricity generation and CO₂ emissions, indicating that an increase in thermal generation will cause corresponding CO₂ levels to rise disproportionately more rapidly.

Barriers to Addressing Environmental Concerns in the Indian Electricity Sector

The financial crisis of the Indian state and central governments has resulted in an increase in the electricity supply-demand gap. Energy supply has become an urgent issue, and to meet a rapidly growing demand the government has focused on cheap, low cost coal-fired power plants, which have a relatively

short gestation period. Although India possesses significant hydroelectric potential (84,000 MW), only about 30 percent of it is currently developed [17]. Hydropower plants in large rivers and major river basins in the northern region have consistently created controversies. This is largely due to environmental concerns such as inundation, community displacement, negative impact on river water quality and harm to riparian ecosystems from the building of dams. As a result, large-scale hydropower has continued to grow very slowly [4]. Nuclear power could also not be expanded due to public perception on safety issues associated with these plants.

India has National Ambient Air Quality Standards (NAAQS) as stringent as US NAAQS. India's high concentration of pollution is not due to a lack of effort in building sound environmental policies, but rather to a lack of regularity in enforcement of those policies at the local level [1]. India has reasonably tightened environmental rules and regulations, but compliance at the power plant level is poor due to the absence of pollution monitoring and control facilities. Moreover, there are lack of resources (both technical and financial) for the government regulatory agencies to implement the rules and regulations. Consequently, operation and maintenance practices are minimal at the existing thermal power plants. This can be illustrated from the fact that two of the five electrostatic precipitators (ESPs) in a 324 MW coal-fired power plant in New Delhi malfunctioned for several weeks in 1996 resulting in fly ash emissions of 1,500 tons daily

in the densely populated area of the city [22]. This suggests that there is an urgent need to form an independent regulatory authority committed to enforcing regulations. However, for effective monitoring and control of emissions, as well as enforcement of policy, requires significant financial and human resources.

Rapid environmental deterioration from the burning of coal in the power sector has been blamed on the poor quality of domestic coal as well. The estimated annual CO₂ emissions from these plants are approaching 400 million tons, but CO₂ has not been a major decision-making factor in India (except when funding is available for alternative energy conversion technologies). Indian coal suffers from a high percentage of ash, and low heating value [1]. More than 73 percent of the domestic coal has an ash content of 33 to 55 percent [2]. Due to the high ash content, particulate emissions are over 325,000 tons per year, contributing to Suspended Particulate Matter (SPM) levels exceeding safety limits in most of the metro areas. However, Indian coal has relatively low sulfur content (0.5 percent) and acid rain problems due to coal use in the electricity sector is not as critical as in East Asian Countries (i.e., China, Japan, Korea and Malaysia etc).

Economic Impact of Electricity Price Subsidy in India

In India, a significant proportion of GDP is distributed as subsidies. The government of India considers universal access to electricity a social and political objective [8]. As a result, subsidies on electricity have been heavily implemented in order to make it accessible to residential and agricultural consumers. However, the connection fee for electricity is so high that only about 30 percent of the rural population have been able to afford it. Greater access to electricity in India is constrained by three factors:

- a) Most of the state utilities are vertically integrated monopolies with a high level of government interference, resulting in high system losses. Revenue collection, theft reduction and cost rationalization have been almost impossible.
- b) Low prices, especially for farmers and households leave utilities without sufficient finances to rectify technical problems such as frequent electricity supply interruptions, low reliability, and low voltage profiles at the consumer level.
- c) The power sector alone accounts for about 20 percent of all public sector investment in India. This amount is still not sufficient, as evidenced by persistent brown-outs and black-outs. Because of subsidies to rural and

agricultural customers, opportunities for increasing revenue to meet generation needs cannot be realized.

Electricity subsidies lead to higher energy use and reduce incentives to conserve and use energy more efficiently. These subsidies have negative repercussions on India's economy as well.

Electricity Subsidy and its Environmental Impact

The electricity subsidy, which encourages the higher consumption and production of fossil fuels, are detrimental to the environment. Reduction or removal of such subsidy under the electricity sector reform program is beneficial for both the environment and the economy. Both economic and environmental advantages could be reaped by utilizing money spent as subsidies to income generating activities, health, environment, education or regional development programs.

Electricity in India is provided concurrently by both the state and central governments. The central and state governments' energy policies are focused on enhancing electricity for increased coverage to rural populations, which are economically subsistent on agriculture. Costs for agriculture and residential households are far below the actual supply costs, whereas the electricity price to commercial and industrial consumers is cross-subsidized by above-cost prices (see Figure 5).

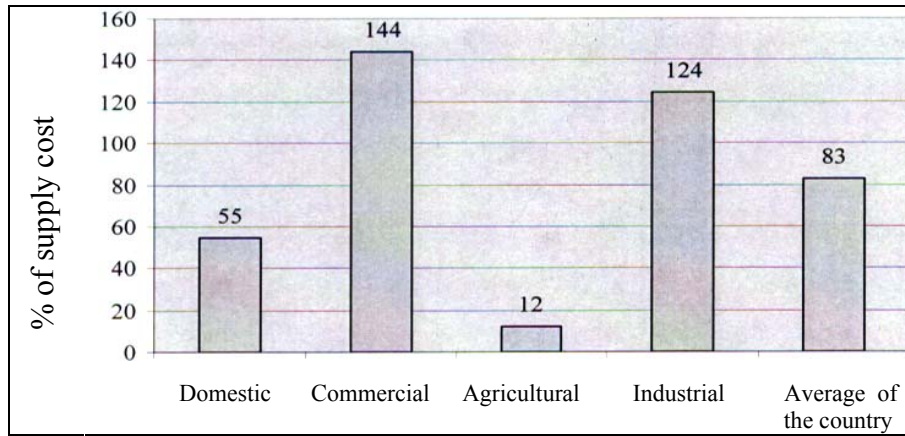


Figure 5. Recovery of cost of supply by category in India (percent of supply cost) [19].

An efficient price structure would charge the lowest cost to industrial consumers (which have the highest level of consumption and load factor and the lowest electricity supply cost). In the current pricing system, overall retail electricity prices cover only 83 percent of the total supply cost [19].

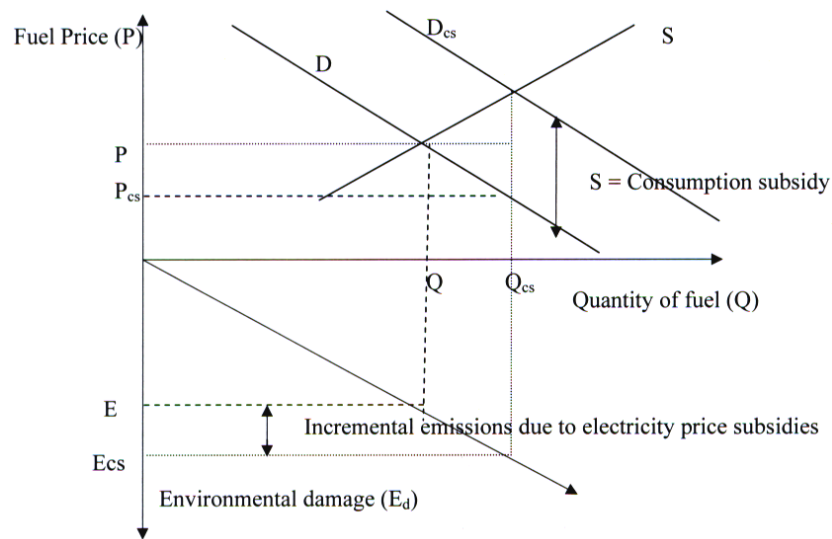


Figure 6. The environmental effect of electricity subsidies.

Figure 6 explains how a subsidy on electricity prices can affect environmental emissions from the electricity sector. In the Figure, P is the price of the electricity, and D is the electricity demand when there is no intervention by the government on the electricity price. As electricity price is kept low at P_{cs} by subsidies provided to selected consumers, the level of electricity consumption (D_{es}) becomes higher than the base case (which has no market interference). The higher demand requires more fuel (Q_{cs}) which results in the increase in environmental damage from E to E_{cs} . This concept can also be explained by the principle of price elasticity where an increase in electricity consumption occurs with respect to a decrease in electricity price. The short-run electricity price elasticity varies from -1.35 in agriculture to -0.65 in the residential sector [20]. Hence, due to subsidies, agricultural and residential customers consume a higher amount of electricity and emissions rise accordingly. With higher costs and an absence of reliable supply, most industrial consumers are equipped with their own back up supplies (typically diesel generators), which they prefer to use. The environmental emissions become more serious when numerous consumers use stand alone diesel generators. Removing subsidies in the agriculture sector alone could potentially offset the primary energy requirement by 86 percent and reduce emissions (see Table 1).

Table 1. Electricity Subsidies: Summary of Results [2].

Sector	Average price (Rs./kWh)*	Supply cost (Rs./kWh)	Rate of subsidy (%)	Potential primary energy savings from subsidy removal (%)
Households	1.50	3.56	57.9	48.0
Industry	3.50	3.42	Not applicable	0.0
Agriculture	0.25	3.56	93.0	86.0
Average	-	-	38.0	34.0

*1 US\$ = Rs. 45.0 at current exchange rate.

Since the majority of real poor people have no access to electricity, those economically better off are taking advantage of the subsidy program. About 73 percent of poor households are not connected to electricity in India [8]. In this situation, even direct monetary support (for connection and/or energy costs) to the poor people would reduce the monetary burden for the government by five times compared to the present cost of subsidies [2].

Role of Distributed Generation IPPs in Emissions Mitigation

Distributed generation sources are installed on the low voltage side of the electricity network and avoid investments in generation, transmission and distribution infrastructure. Reducing such investments lowers the utility's costs and

financial risks, as well as overall fuel consumption. As a result, DG reduces environmental emissions compared to the centralized generation sources. Analysts often argue that DG provides an opportunity to spur the transition into a “micropower future”, i.e., a sector based on small-scale generation units the same size as the electric loads being served [9]. Microturbines are very well suited to operate in DG as they are available in different modular sizes (i.e., from 75 kW-1 MW). The smaller size of the microturbines matches well to serve the small load characteristics of the rural areas. Microturbines operate by converting gaseous fuels into electricity using the expansion of hot combustion products. Microturbines are highly efficient compared to the diesel generators, which are presently used extensively as electrification means in the rural areas of India. The only disadvantage of microturbines is the higher capital costs compared to the diesel plants. However, with the ongoing research and development on microturbines (i.e., biomass gasification technologies), the cost is expected to go down within a few years. Power generation potential from biomass gasification is estimated to be 17,000 MW, with an additional potential of 3,500 MW being estimated using sugarcane residues (FAO, 2000).

Among the various DG options, wind, and small and micro-hydro technologies are highly cost-effective and have significant emission mitigation potential in India [3, 4]. A case study of the Northern Regional Electricity Board (NREB), a

vertically integrated utility in India, reveals that DG can eliminate significant capacity additions, yielding cost savings and reducing electricity prices [3]. Additionally, rural electrification in India suffers from an extremely poor distribution voltage profile. DG close to the rural load centers improves the quality of the supply by stabilizing voltage and increasing reliability [5].

In a competitive electricity market (i.e., where the generation, transmission and distribution services are divested into their own independent businesses), the cost benefits of DG become more pronounced. DG becomes highly competitive when electricity pricing is based on Locational Marginal Price (LMP) and the distance of rural electric load increases from the centralized source. Pricing - in terms of average cost (as opposed to the LMP) - may fail to give consumers an indication of opportunities for cost savings in specific localities. Remote areas can be supplied with DG which would otherwise have higher energy costs with a centralized T & D system. With the decreasing trend in reliability of large, centralized electrical power plants, DG can increase the reliability of the power system (by ensuring a larger number of local resources to deliver energy to a certain area) and reduce the active and reactive energy losses along T&D lines [21]. This will lower the local and network nodal spot prices.

During 1990, there has been a noticeable increase in renewable energy investment due to favorable tax incentives and

power-sector regulatory changes in India. During the period, IPP framework played a vital role in accelerating markets for environmentally friendly generation technologies (especially wind, mini-hydro and solar PV) [10]. After the reform started in 1991, about 7 GW of installed capacity (60 percent of which is based on LNG, followed by 22 percent wind) has been added as IPPs. Because these power plants are modular and environmentally friendly with a low gestation period, the emission intensity due to installed IPP projects has been reduced by 40 percent, compared to the utilities (see Table 2). Based on the trend toward planned capacity additions for 2002-2007 by IPPs, future investment is more likely to be environmentally friendly. Utility planning based on power purchase agreements with IPPs has significant potential to reduce capital and operation costs, as well as environmental emissions (such as CO₂, SO₂ and NO_x) [3]. Greater financial and environmental benefits of IPPs are realized if projects are handled in the framework of DG. Distributed generation can be used to decongest T & D lines by freeing up capacity and avoiding long power flow distances to local areas from centralized power plants.

Table 2. Capacity by fuel type for IPPs and utilities and specific emission factors[#] [12].

Category	Capacity, by fuel type (percent)							
	Specific emission (gm CO ₂ /kWh)	Coal	Gas	Fuel Oil	Nuclear	Hydro	Wind	Total (MW)
Utilities								
commissioned	675.53	62.47	7.35	0.6	2.78	26.74	0.06	97,724
Planned (2002- 7)	611.62	60.22	3.49	0.23	3.19	32.87	0.0	40,746
IPPs								
Commissioned	366.77	7.27	61.08	8.23	0.0	1.98	21.44	6,738
Planned (2002- 7)	433.64	24.00	39.6	5.93	0.0	13.35	17.12	8,763

[#] Emission factor refers to the amounts of emissions (gm.) due to one unit of electricity generation (kWh).

Although IPPs in India introduce less emission intensive power sources, (as demonstrated in Table 2), it would be misleading to claim that significant environmental benefits will be reaped due to IPPs in the near future. As illustrated, the contribution of IPPs toward total system capacity is fairly insignificant (7 GW accounts for about 7% of total installed capacity). The low level of IPP participation is unlikely to increase until effective policies are created to support their growth.

Policy Options for Environmental Improvement in the Electricity Sector

The responsibility to create policy options to manage environmental issues in the electricity sector lies with the

government. Some of the opportunities to remediate environmental problems in the Indian electricity sector through additions and/or changes to government policy are discussed herein.

1. Development of an Appropriate Framework for IPPs

The IPP framework has demonstrated a positive role in wind power development in India (50 MW in 1990 to more than 1267 MW in 2002) [10]. Institutional and fiscal policy incentives have played a very encouraging role in this process. Similar and/or additional financial and regulatory incentives can be provided to private developers and manufacturers to further increase wind generation and develop other renewable energy sources such as small-hydro and solar. These small-scale generation technologies are generally more efficient and environmentally friendly than the older larger technologies [10]. When they are added through DG, high T &D losses are avoided and emissions are kept to minimal. To encourage DG participants, regulation can be imposed on distribution companies through economic incentives that promote renewable energy technologies [10]. Non-fossil fuel obligation (NFFO), a policy measure introduced after the reform started in the British electricity sector, had a positive impact on the development of renewable energy sources in the early nineties. The Indian government can appropriately enact such regulations for IPPs to provide incentives for renewable energy generation.

2. System Efficiency Improvement

Thermal power plants in India have lower than average thermal efficiency compared to the best same technology based plants in Japan or OECD countries. Average thermal efficiency for oil and gas-fired power plants in India were 5 percent less efficient than the Japanese plants in 1997. The Indian average annual gross efficiency of coal fired plants, representing about 75 percent of the total installed capacity, is 30 percent. Whereas the average efficiency of coal-fired power plants in Japan is 44 percent. Improving gross efficiency through renovation and modernization can reduce greenhouse gas emissions by 17-22 percent [18]. Hence, India's thermal fired power plants need to improve thermal efficiency and optimization technologies to raise the electrical and environmental performance. Older coal plants, which still rely upon sub-critical pulverized-coal technology (and typically do not contain significant emission control equipment), contribute to rapid environmental degradation [16]. Similarly, the average annual Plant Load Factor (PLF) of an Indian plant is 65 percent. Improving PLF through renovation and modernization would offset greenhouse gas emissions by 2-5 percent. Similarly, there are opportunities with T&D and end-use efficiency improvements.

3. Introduction of Environmental Regulations for Coal Plants

The average age of coal-fired power plants in India is 13 years and these plants emit excessive emissions into the environment. National policy can be formulated to mandatorily retire the older, emission intensive plants, however, there are difficulties in implementing such policies, particularly when utilities face severe high supply-demand gap [10]. Corruption and political influence are blamed for the weak enforcement of environmental laws in India; however, there has been substantial improvement in environmental compliance. In 1991, less than 10 percent of the main industries prone to severe pollution were equipped with pollution control equipment. Whereas, the figure rose to 65 percent in 1994 [22]. Additionally, electrostatic precipitators fail frequently and conventional systems for flue gas clean-up, particulate removal and waste disposal, are not in place in many thermal power stations. Even stringent environmental emission standards and monitoring have not been able to handle environmental problems as the regulatory authorities lack inadequate capacity for inspection and remedial action. Formation of an independent regulatory authority, without the government's intervention, will be effective in terms of regulatory enforcement.

4. Price Rationalization

Residential and agriculture electricity prices in India are highly subsidized. As the reform process continues, it is likely

that the average electricity price will increase [7]. In this situation, agriculture farmers are willing to pay a price hike provided that the power quality is guaranteed. This price increase could potentially reduce the level of unwanted electricity consumption in the agriculture and residential sector, which would help to decrease the level of environmental emissions. For example, 99 million tons of CO₂ could be reduced as a result of electricity price subsidy removal in India. (An additional six million tons reduction could be achieved by removing direct coal price subsidies) [2]. In 1991, total fossil-fuel subsidies in the developing countries were estimated to be about \$210 billion, which is equivalent to 20-25 percent of the monetary value of world's fossil-fuel consumption. The removal of such subsidies is expected to reduce carbon emissions by 7 percent as a result of electricity price increase and reduction in electricity consumption. [22]. Price signals are effective to raise customers' incentives to opt for end-use energy efficiency improvement, which plays a very effective role on emissions reduction. For example, one study shows that 43.6 million tons of CO₂ could be avoided during 1997-2015 by replacing incandescent bulbs (40W) by compact fluorescent lamps (13 W) in the residential sector of India [23].

5. Switching from Coal to LNG

Liquid Natural Gas (LNG) is emerging as an important energy source III electricity generation in India; the share of LNG in electricity generation increased from less than 1

percent in 1980 to 6 percent in 1997 [25]. Switching from conventional coal generation to LNG based generation is another option utilities may choose to solve long-term environmental and power deficit problems. LNG based generation technology is highly favored in a competitive market due to its modularity and short gestation period. However, a rapid increase in LNG based power generation may create the potential problem of demand outstripping the supply resource within the country. Neighboring Bangladesh has sizeable LNG sources (beyond its generation capacity) so regional co-operation on LNG might be an option for meeting short-term energy demands.

6. Regional and National Cooperation

Pakistan and Nepal, other neighbors to India, currently possess considerable power surpluses. Interconnecting Nepal's hydro-based power system would result in considerable economic and environmental benefits as Nepalese hydro-based plants can produce peak load power at minimal additional cost. Transmission bottleneck is considered as a major barrier to evacuate Nepal's surplus hydropower to the bordering states of India. Similarly, the electricity sector in India, at present, is comprised of five separate regional electricity grids having no integrated operation. If the reform process can integrate these grids it could offset considerable capacity requirements, and significantly reduce emissions. Creating a national grid would reduce generation capacity increases by 1,784 MW (which

would cost an additional \$5,000 million including capacity addition and operation and maintenance) [7].

Conclusions

It is the authors' view that technical and regulatory changes associated with the reform process in India are greatly challenged by the size, demand and complexity of its electricity sector. However, opportunities to overcome these challenges exist. System losses (both technical and non-technical) are enormous, hence efficiency gains through the reform process can be realized. For this to occur, adequate information, awareness, confidence and familiarity with efficiency programs must be understood among concerned stakeholders. To meet India's power requirements both qualitatively and quantitatively, a high level of investment is required. Policy makers must attract both foreign and local investors. Opportunities for investment will increase if system losses are minimized and efficient cost structures are implemented. Distributed generation can help India achieve both of these objectives. Additionally, the development of IPPs in the context of DG allows for beneficial environmental and technical outcomes. Improved quality of power supported by DG in the rural areas can create a very supportive role in electricity price rationalization (which is currently a very challenging component of the reform process). To compensate for potential price increases due to price rationalization, policy makers and/or

planners must develop the required knowledge to manage the distribution network. This can be a formidable (but not impossible) task because appropriate models for generation expansion and rural electrification may not necessarily follow the reform experience gained in developed countries. Entirely new models or modifications to existing models will be necessary.

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