Towards a Cleaner Environment with IRP—An Indian Case Study

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Editor's Note: To call India an "emerging nation" is an insult. As a society, India has been civilized far longer than ours. Let's call it a "technically expanding" nation. In India's technical evolution, as with many other nations, the power sector is faced with the twin challenges of increasing generating capacity to combat growing power shortages, and at the same time reducing the environmental degradation caused by electricity generation. This article examines the alternatives to traditional fossil-fuel-fired or large hydropower stations.

The conclusion presents two scenarios, the first being the "business as usual" case where traditional coal-fired generation remains the mainstay of the Indian power sector; the other being an integrated resource planning (IRP) scenario. The installed capacity required and the consequent emissions of acid and greenhouse gases are compared between the two scenarios for different years.

INTRODUCTION

It has often been noted that one of the critical elements in raising the standard of living of a country's population is the provision of affordable and reliable energy services. The situation in India is no exception. Reliable electric power, available to the most remote community at prices that even the poorest can afford, has been a strategic objective of the Indian power sector for many years. To meet this goal, the power sector has had to compete for physical and financial resources with other sectors of the economy and with other social policy objectives of the central and state governments.

India's electric power sector can be characterized as one caught between environmental challenges and the country's difficult economic, social, and political realities. On the one hand, Indian electric utilities are being pressured to: (i) pursue generation technologies which are as environmentally benign as possible; (ii) ensure that customers are using electricity efficiently; and (iii) retrofit existing generation capacity with equipment to either remove or reduce harmful emissions. On the other hand, the Indian electricity sector's ability to accomplish the above objectives is constrained by their poor financial state and inability of their customers to pay for power consumed and the mix of central and state guidelines for the power sector.

The last decade has seen the increasing ascendance of concern over the environmental impacts of electric power development. Strategies to reduce greenhouse gas emissions (carbon dioxide and methane) and regional emissions of acid gases (sulfur dioxide and nitrogen oxides) have become a critical component of the power planning process. Consequently, developing a framework to examine electric power development and emission levels under alternative energy and economic assumptions for India is an important step in providing decision makers with the information they need to make decisions.

Population pressures, accelerating economic development, and resulting energy and electricity demand growth, are placing increasing pressures on the energy infrastructure in India. Economic and efficiency arguments for cost-based pricing of energy services and increased foreign investment in energy sector development and recovery, must be weighed against cultural traditions, social objectives, and equity considerations. Lurking behind all of this is the realization that "business as usual" (BAU) practices are environmentally unacceptable and unsustainable in the Indian context.

In order to mitigate some of the above concerns, a study was conducted jointly by the Tata Energy Research Institute (TERI), New

Delhi, India, and the Canadian Energy Research Institute (CERI), Calgary, Alberta, Canada to evaluate various options available to the Indian power sector, and suggest a suitable growth strategy incorporating both environmental and development considerations. This article presents the key findings of the study.

ALTERNATIVE OPTIONS FOR MEETING INDIA'S ELECTRICITY DEMAND

The important alternative planning options available to the Indian power sector to meet future electricity demand are:

1. Decentralized energy production systems
2. Demand side management
3. Industrial cogeneration
4. Increased efficiency in thermal power stations through clean coal technologies
5. Reduction in transmission and distribution losses

Decentralized Electricity Generation System

Decentralized electricity generation system offer several advantages in application where flexibility in system size and location are desired. Considerable improvements in reliability, costs, and efficiencies of these technologies, together with the rising costs of large-scale electricity generation and favorable public policy, have resulted in active consideration of dispersed electricity generation options.

The biogas program has traditionally been the single largest renewable energy program, accounting for over half of the funds allocated. All other individual programs have received less than 10 percent of the funds. In terms of numbers, however, the dissemination of improved cook stoves has been the largest program followed by the biogas program. Biogas plants and improved cook stoves have enjoyed a fair amount of success and acceptability among rural households. However, there is scope for considerable improvement in the implementation of these programs.

Among other technologies, wind farms have emerged as a viable option in the power sector. 823.62 MW of grid connected wind farms were operational in end of December, 1996 (1).

Estimates by the Ministry of Non-conventional Energy Sources (MNES) place the ultimate wind energy potential in India at 30,000 MW.

Small hydro-electric power has evolved as another promising option for electricity generation, especially in remote hilly areas where the cost of grid electricity is prohibitive. Total potential for small hydro in India is estimated at about 10,000 MW. The main obstacle in the promotion of this technology is the high capital cost.

Demand Side Management (DSM) Strategies

Electricity savings potential in various sectors should be estimated based on realistic participation rates as a result of favorable economics of the energy efficient technologies, discount rates assumed by the consumers, availability of energy efficient technologies, amongst others. Savings potential is likely to be sensitive to market penetration rates. For instance, savings would increase from 14 percent to 18 percent in 2011/12, if the number of pumpsets retrofitted every year is increased from one percent to two percent of the total pumpsets in use. In the commercial sector, an increase in the market penetration rate for the compact fluorescent lamp (CFL) lighting option from 5 percent to 7.5 percent in 2001/02 onwards, would result in an increase in savings from 10 percent to 11 percent in 2011/12.

It is estimated that the Indian power sector can save up to 8 percent of the total electricity requirements by the year 2011/12, through adoption of energy efficiency and DSM options (2). Maximum benefits are estimated to come from agriculture, residential, and commercial sectors. Table 1 lists the energy conservation potential in different sectors in India.

There is little doubt that India's electric power sector could gain from the implementation of energy efficiency and DSM programs. Technical potential and cost-effectiveness of various measures for improving end-use efficiency are well established. However, the actual efficiency gains remain far from being realized, due to a variety of technical, policy, institutional, and information related barriers. Some of the important barriers include high initial cost of energy-efficient equipment, limited availability of energy-efficient technologies, risk aversion by consumers, and lack of information and awareness among consumers.

On the policy front, perhaps the most important barrier is the

Table 1: Energy Conservation Potential in India

Sectors	Potential (%)
Economy wide potential	≈ 20
Agriculture	≈ 30
Industry	≈ 25
Transport	≈ 20
Domestic and Commercial	≈ 20
Industries	
• Textiles	20-25
• Paper and pulp	20-25
• Ferrous foundry	15-20
• Glass	15-20
• Fertilizers	10-15
• Cement	10-15
• Chlor-alkali	10-15
• Aluminum	8-15
• Iron and Steel	8-15

SOURCE: Energy Management Center, Ministry of Power, Government of India

present electricity pricing policy of the State Electricity Boards (SEB). Electricity prices are regulated and based on historical cost of the utility. For most of the utilities, average revenue realized per unit is actually less than the average cost of supply as can be seen from Table 2 (3). The extent of subsidies is particularly high for the agriculture sector at 80-100 percent, with subsidies for the domestic sector ranging between 40 and 60 percent. Such a pricing policy does not provide the consumers with the right signals and does not induce consumers to conserve electricity. Also, lack of utility commitment to DSM and to an integrated approach to power planning, is responsible for the slow progress in energy efficiency and DSM in India.

Industrial Cogeneration

The industrial sector presently accounts for almost 52 percent of the total electricity consumption in India (4). Several energy-intensive industry categories such as sugar, paper, textile, and fertilizer generate their steam requirements internally and also purchase elec-

Table 2: Average cost of supply and average tariff for electric utilities in India (1995-96)

State	Average cost of supply	Average tariff	Average cost of supply	Average tariff
	Phase/kWh		¢/kWh	
Andhra Pradesh	151.10	126.43	4.32	3.61
Assam	308.10	234.09	8.80	6.69
Bihar	201.10	146.92	5.75	4.20
Delhi	210.30	174.96	6.01	5.00
Gujarat	182.20	141.50	5.21	4.04
Haryana	166.20	111.05	4.75	3.17
Himachal Pradesh	107.10	114.58	3.06	3.27
Jammu & Kashmir	204.10	32.88	5.83	0.94
Karnataka	145.90	142.48	4.17	4.07
Kerala	116.70	98.46	3.33	2.81
Madhya Pradesh	168.70	136.47	4.82	3.90
Maharashtra	183.50	172.04	5.24	4.92
Meghalaya	165.10	109.30	4.72	3.12
Orissa	127.90	131.79	3.65	3.77
Punjab	177.00	109.03	5.06	3.12
Rajasthan	188.90	147.53	5.40	4.22
Tamil Nadu	178.00	146.33	5.09	4.18
Uttar Pradesh	177.60	130.64	5.07	3.73
West Bengal	187.90	154.88	5.37	4.43
All India	**170.11**	**140.72**	**4.86**	**4.02**

SOURCE: Annual Report on the Working of State Electricity Boards & Electricity Departments, Planning Commission, Government of India

tricity from the grid. Cogeneration of electricity and steam offers increased system and fuel efficiency to the industry. It reduces industry demand for utility power and the additional surplus, if any, could be sold to utilities. Cogeneration thus provides an alternative to utility power and reduces the overall emissions from the power sector.

While cogeneration systems are in use in some of the paper, pulp, and fertilizer industries in India, there are little efforts to optimize the steam and electricity requirements for various reasons.

These include company investment criteria, unavailability of equipment, concerns about incremental costs, and above all movement regulations.

Significant cogeneration potential has been identified in the Indian industrial sector. The National Productivity Council, New Delhi, carried out a macro study in 1979 on the feasibility of cogeneration in Indian industries and estimated a potential of 421 MW in 28 of the 150 industrial units surveyed. It also estimated that over 1500 MW of additional power could be generated with marginal investments in cogeneration systems.

A study carried out by the Inter-ministerial Working Group, Government of India, in 1983 estimated that the economic potential for cogeneration in the major industries in India is about 1500 MW. More recently, a study carried out the Tata Energy Research Institute, New Delhi, in 1993 based on a detailed survey of 300 industrial units, estimated a total cogeneration potential of 7574 MW (Table 3), of which the sugar industry alone was estimated to account for over 65 percent of the total identified potential. Substantial potential also exists in the textile and paper industry.

Table 3: Cogeneration Potential in India (MW)

			Year		
Region	**2001**	**2006**	**2011**	**2016**	**2021**
Northern Region	4026	5910	8472	12153	17443
Western Region	3275	4756	6766	9642	13759
Southern Region	5301	7755	11093	15883	22763
Eastern Region	1698	2501	3593	5164	7425
North-Eastern Region	50	75	109	159	230
Total	**14350**	**20997**	**30033**	**43000**	**61621**

SOURCE: Tata Energy Research Institute, New Delhi, 1993

Clean Coal Technologies

Clean coal technologies (CCT) offer the potential for significant reduction in environmental emissions when used for power generation. These technologies may be used in new, as well as existing plants and are therefore an effective way of reducing emissions in the world's aging inventory of coal-fired generating units. Several of these systems are not only very effective in reducing SO_2 and NO_X emissions but, because of their higher efficiencies, they also emit lower amounts of CO_2 per unit of power. CCTs can be used to reduce dependence on foreign oil and to make use of a wide variety of available coal types and quality (5).

In India, coal constitutes about two-thirds of total commercial energy consumption. The power sector and industries together account for 94 percent of total coal consumption. Indian coal is characterized by high ash content and low sulfur content. Over 60 percent of the Indian coal reserves are of inferior quality with gross calorific value (GCV) of 4000 kcal/kg or less. The efficiency of coal conversion in Indian thermal power stations is low; relative to the design gross efficiency of 36 percent, the average gross conversion efficiency is about 28 percent and the average net efficiency is only 25 percent. About 75 percent of the country's thermal capacity operates at efficiencies below 30 percent.

The environmental consequences of increased coal use are recognized today by India's energy and environmental planning agencies and there is a growing realization that coal-related environmental problems must be controlled in the future through use of CCTs in the various consuming sectors.

Transmission and Distribution (T&D) Loss Reduction

High T&D loss is an issue of major concern for the electric utilities in India. Losses increased from about 15 percent in 1966/67 to 21.74 percent in 1986/87, and have since increased to about 23 percent. Of the total 23 percent T&D losses, four percent corresponds to losses in the transmission (400 kV, 220 kV, 132 kV and 66 kV) system and the remaining 19 percent to losses in the distribution (33 kV, 11 kV and 400 V) system.

The impact of the excessive T&D losses in the Indian power system is two-fold. Firstly, they result in under-utilization of the total energy that is being generated, which is unpardonable considering the energy shortages that the country is currently facing. Secondly, the energy wasted due to T&D losses must be compensated by constructing new generating stations (in all probability fossil fuel based thermal), which means additional environmental degradation due to emission of greenhouse gases and other associated problems.

Perhaps the single most important factor responsible for high T&D losses is the lack of adequate investment by the electric utilities in the T&D systems. In the past, the investments in generation have gained priority over investments in T&D. Investments in T&D in the various Five Year Plans in the past have been only 40-50 percent of the total investments in generation. Technical factors responsible for the large T&D losses include:

i) lack of systematic distribution system planning which invariably results in overloading of the system;

ii) existence of many stages of transformation, viz. 132/33 kV, 66/33 kV, 33/11 kV, 11/0.4 kV;

iii) adoption of inappropriate distribution technology, viz. low voltage distribution system (LVDS) which is suitable for countries with high load densities and not for a large country like India with loads sparsely spread over wide areas;

iv) inadequate reactive compensation; and

v) poor quality of electricity meters and lack of adequate calibration facilities.

Another factor responsible for high distribution losses is non-technical losses occurring on account of defective metering, unmetered power supply, pilferage, etc. Reduction of T&D losses is today a priority area for the SEBs. It is expected that the losses should be reduced by one percent point every year and gradually brought down to 15 percent.

METHODOLOGY FOR EVALUATION OF OPTIONS

The alternative planning options outlined above were evaluated using the ELITE (Electric Inter-Regional Transfer and Emissions) model specially developed for the study by the Alberta Research Council, Canada and CERI. ELITE is a linear programming, optimizing, long term electric power planning model for India.

Important questions addressed in evaluating the alternative planning options for India include:

1. The implications of various financial and resource utilization constraints on power sector development.

2. The effect of new capacity additions required to meet forecast electricity demand in India on the growth in emission of particulate matter, CO_2, SO_2, and NO_X.

3. The extent of resources required to fully meet projected electricity demand.

4. The impact of DSM, CCTs, cogeneration and reduced T&D losses on bridging the gap between power demand and supply in India, and reducing environmental emissions.

5. Cost implications of electricity supply under various scenarios.

COMPARISON OF SCENARIOS

Each alternative option for meeting India's electricity demand gave rise to a planning scenario. In addition, an integrated resource planning (IRP) scenario was generated which utilized all the alternative planning options. It was observed that there is a significant reduction in the environmental emissions, as compared to the business-as-usual (BAU) scenario, if any of the alternative options are followed.

As expected, the most significant reductions in the emissions and installed capacity required occur in the case of the IRP scenario. Tables 4, 5, and 6 list the expected emissions and the installed capacity required for various scenarios for the years 2001, 2006, and 2011 respectively.

Table 4: Comparison of Various Scenarios During 2001

	Business as Usual	DSM	CCT	Cogen-eration	T&D loss reduction	IRP
Total Capacity Reqd. (MW)	142,782	126,630	137,584	139,363	130,971	119,587
Emissions						
Particulates ('000 tonnes)	4,671,239	4,785,887	5,340,708	5,287,901	4,606,628	4,931,076
CO_2 ('000 tonnes)	457,930	379,375	436,867	411,291	388,283	377,018
SO_2 ('000 tonnes)	2,532	2,090	2,371	2,270	2,141	2,078
NO_X ('000 tonnes)	2,413	1,996	2,269	2,165	2,043	1,984

Table 5: Comparison of Various Scenarios During 2006

	Business as Usual	DSM	CCT	Cogen-eration	T&D loss reduction	IRP
Total Capacity Reqd. (MW)	200,590	174,635	190,084	193,398	181,275	165,974
Emissions						
Particulates ('000 tonnes)	4,847,121	4,482,879	4,833,057	5,173,227	4,773,921	4,639,175
CO_2 ('000 tonnes)	693,645	518,439	568,955	568,430	550,503	501,976
SO_2 ('000 tonnes)	3,857	2,869	2,857	3,149	3,049	2,634
NO_X ('000 tonnes)	3,669	2,735	2,781	2,998	2,905	2,539

Table 6: Comparison of Various Scenarios During 2011

	Business as Usual	DSM	CCT	Cogen-eration	T&D loss reduction	IRP
Total Capacity Reqd. (MW)	288,281	245,182	267,090	271,210	254,800	234,218
Emissions						
Particulates('000 tonnes)	5,843,211	4,786,761	4,854,890	5,208,129	4,766,722	4,704,719
CO_2 ('000 tonnes)	1,078,980	715,7681	715,485	715,203	715,817	711,528
SO_2 ('000 tonnes)	6,023	3.975	2,926	3,973	3,975	3,421
NO_X('000 tonnes)	5,721	3,781	3,005	3,778	3,780	3,364

CONCLUSION

This article has clearly highlighted the fact that the IRP option not only reduces the requirements of total installed capacity to meet forecast demand but also that environmental emissions are considerably reduced in comparison to the other alternatives. Even though integrated resource planning is the most suitable alternative for the Indian power sector, pursuing this option will require considerable change in the structure, operation, regulation, and decision making practices currently governing electric power development in India.

Many of the SEBs in India are reforming and restructuring, and some of the changes required to pursue the IRP option have started coming about. But unless the pace of reforms is quickened, India may be heading to a future of growing power shortages and declining electricity system reliability.

References

1. Ministry of Non-conventional Energy Sources, Government of India, *Annual Report,* 1996-97.

2. Energy Management Centre, Ministry of Power, Government of India, *Policy Guidelines for Energy Efficiency Promotion in Asia.*

3. Planning Commission, Government of India, *Annual Report on the Working of State Electricity Boards and Electricity Departments,* 1995.

4. Central Electricity Authority, Ministry of Power, Government of India, *General Review, Public Electricity Supply, All India Statistics,* 1994-95.

5. Jack S. Siegel, George Rudins, Jerome Temchin and Barbara McKee, U.S. Department of Energy, *Benefits and Barriers to Development of Clean Coal Technologies,* presented at the International Conference on Coal, the Environment and Development: Technologies to Reduce Greenhouse Gas Emissions, Sydney, Australia, November 18-21,1991.

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