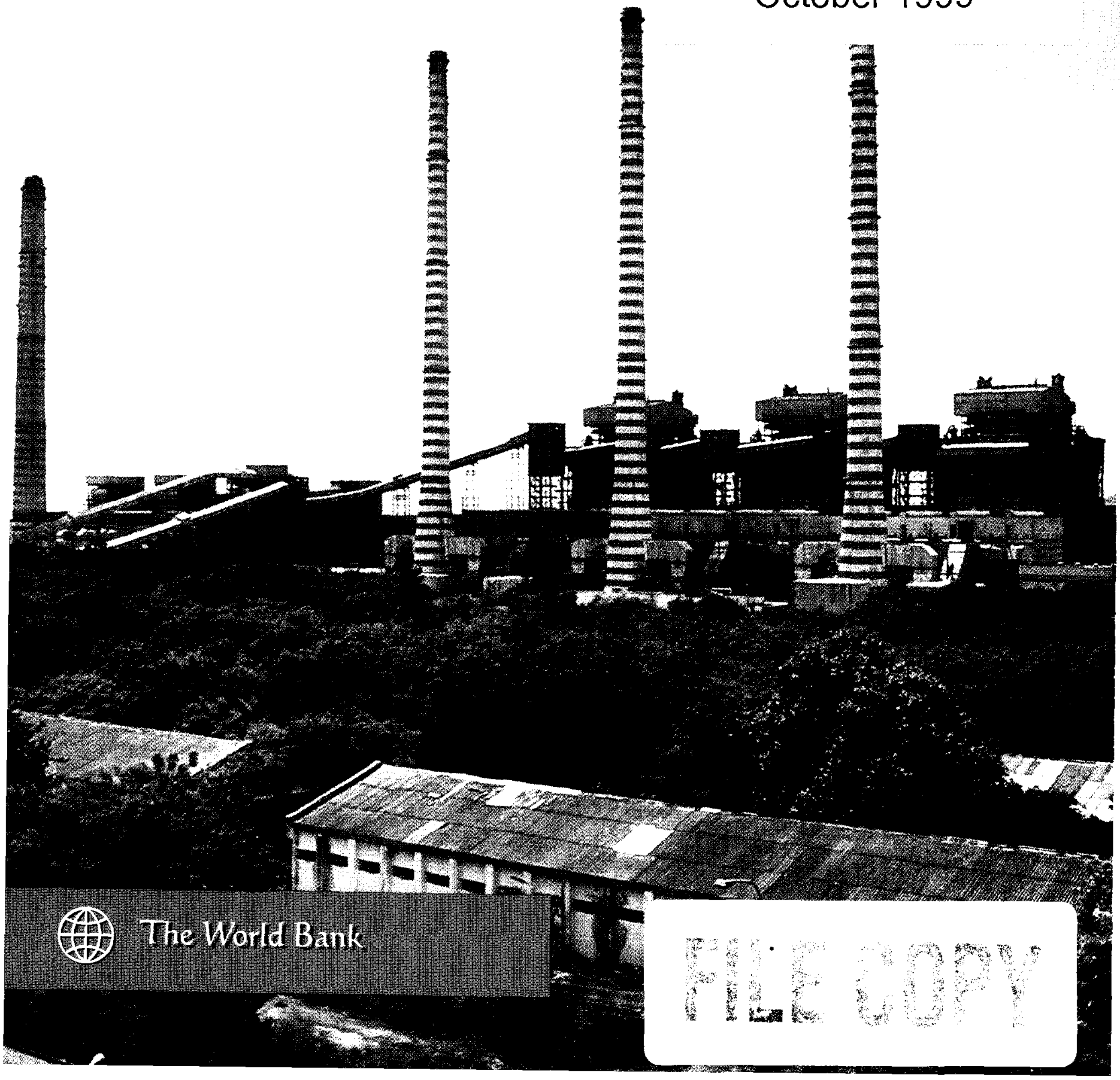
Meeting India's Future Power Needs

Planning for Environmentally Sustainable Development

October 1999



The World Bank

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Cover photograph: NTCP power station at Ramagundam, courtesy of National Thermal Power Corporation, Ltd.

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A Time for Decisions

Unquestionably, power plays a fundamental role in the economic development process. All countries seek to ensure a supply of electricity that is affordable, reliable, and secure in order to sustain modern ways of living. Producing electricity to meet modern needs affects the environment on a local, regional, and global basis. As developing countries, including India, demand increasing amounts of electricity to sustain their economies, long-term planning is needed to balance this growing need for power and environmental concerns. Practical strategies are needed to minimize the impact of growth on the environment and, through the environment, on human health and well-being.

India's large reserves of coal are a major asset to the country, accounting for 70 percent of India's current production of electricity. However, excessive use of this form of energy production—especially without the use of strategies to mitigate its effects—will cause the quality of the country's air, land, and water resources to deteriorate. Specifically,

- Small particles from combustion eventually reach the ground, threatening human health and property.
- Disposing of the ash that is produced as a byproduct of combustion requires large amounts of land; leaching ash can contaminate ground water.
- Carbon dioxide released from fuel by combustion contributes to global warming and climate change.
- Power stations may require large, and frequently environmentally valuable, land areas.
- Large hydro and coal projects require resettlement and rehabilitation, and affect people.
- Acid gases that are produced when fossil fuels are burned are eventually precipitated as acid rain.

Avoiding environmental damage from the development of energy resources is among the key priorities of the South Asia environmental strategy for the energy sector. Other priorities include the following:

- Dealing with indoor air pollution from the use of traditional fuels, especially in rural households
- Protection from urban air pollution
- Developing better environmental governance
- Mitigating the potential impacts of global climate change
- Making the Bank more responsive to energy-environment impacts.

Studies to date have clearly demonstrated that continuation of current policies and practices in the power sector is not sustainable in financial terms. Prices today for electricity and fuels in India are distorted; electricity is often sold to agricultural consumers at prices that are well below the costs of production. This practice leads to waste of electricity and also impairs the finances of state electricity boards. The poor financial condition of the boards may make it difficult to invest in new plants and maintain existing plants properly, especially environmental control equipment not essential to plant operation.

Case studies for Andhra Pradesh and Bihar, states facing different energy challenges with varying resources, show that the financial performance of the power sectors in both states will impose an insupportable financial burden on their respective state governments. The rate of return on capital in Andhra Pradesh will become increasingly negative, reaching –18 percent by 2015; in Bihar it will average –14 percent from 1996 through 2015. The financial resources needed to maintain and operate the power plants at the level needed to meet the projected demand are unlikely to be forthcoming.

Under current policies, emissions of environmentally damaging combustion products may be expected to increase rapidly, doubling in Bihar and quadrupling in Andhra Pradesh by the year 2015. Extrapolating the results to India as a whole reveals serious conditions (box 1 and figure 1).

Emissions on the scale described above are bound to affect air quality and have major human health impacts. The damages caused by particulate matter to the respiratory system are a particular cause for concern. Consequences include significant increases in mortality, hospital admissions for respiratory infections, emergency room visits for bronchitis and other chronic pulmonary diseases, the number of days asthmatics experience shortness of breath, and the number of days residents experience restricted activity.

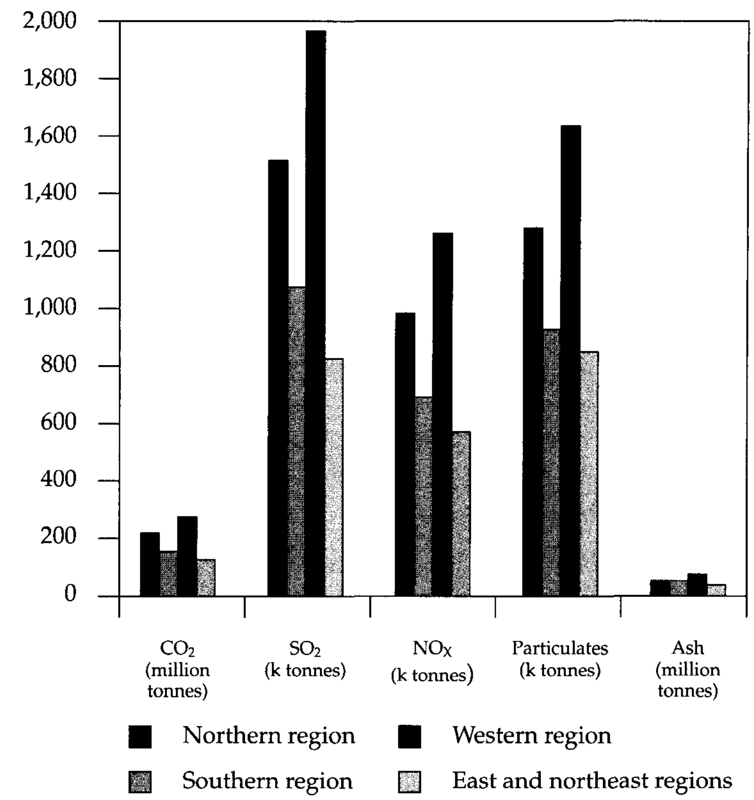
Although the power sector contributes to the problem, most of the pollution, especially in the urban areas, stems from other sources, notably residential and commercial stoves, industrial boilers, inefficiencies in the transport sector and the liquid fuel chain, the extensive use of traditional fuels in city slums, and emissions from nonenergy sources. Urban air pollution is, therefore, a cross-sectoral issue that requires a citywide approach to achieve comprehensive air quality management. Thus, a strategy to address urban air pollution must integrate a range of activities at the municipal level, especially at small sources of energy and

Box 1. The Year 2015—The "Business as Usual" Scenario

Without significant changes in power sector policy, by the year 2015

- India will be producing SO_2, NO_x, particulate emissions, and ash at three times the current levels
- Ash disposal facilities around power plants will require 1 square meter of land per person
- CO_2 emissions will be 775 million metric tons per year, as compared with 1,000 million metric tons per year now produced by power generation in the entire European Union.

Figure 1. "All India" Emissions by Region in 2015



Source: ESMAP (Joint UNDP/World Bank Energy Sector Management Assistance Programme), *India: Enviromental Issues in the Power Sector,* Report no. 205/98 (Washington, D.C.: Energy, Mining and Telecommunications Department, the World Bank, 1998).

power stations located in densely populated areas and in the transport sector. This strategy should also include a major focus on the petroleum subsector.

Currently the power sector in India is on the verge of fundamental and significant reforms that have profound implications for environmental management. India is moving from a publicly owned, vertically integrated, monopolistic power system with highly distorted prices for fuels and electricity to a more liberal system with market prices, competition, a greater role for the private sector, and commercial incentives. These changes will affect every aspect of the energy production system: the demand for electricity, the financial viability for all the entities involved, the choice of fuel and technologies, pricing decisions, and the respective roles and relationships among the state, the power sector, regulators, and fuel suppliers. During this time of transition, it is critical to determine how best to take advantage of the opportunities it presents to protect the environment and avert threats to public health.

To find a more appropriate balance between the need to support economic development and environmental concerns, stakeholders must begin immediately to take environmental impacts into account as long-term plans for power generation are developed.

Depending on the unique needs and situation of the geographic area, different strategies for reducing negative environmental consequences from power generation may be more or less effective. Decisionmakers can choose from a range of measures, using modeling tools to determine which combination of options will have the greatest positive impact. For example, the environmental impacts of power development may be reduced by using less electricity, preventing waste products from reaching the environment, adopting cleaner technologies for coal production, or using alternative forms of energy production that cause less environmental damage. Sound pricing strategies for electricity and fuel, changes in the structure of the power sector, and ways of looking at the cost of energy production that take environmental impacts into account would also help preserve environmental quality.

While power system expansion planning has previously been conducted at the national level using state-provided data on regional needs, the decisionmaking process in India is being decentralized. Some state electricity boards are being unbundled into separate generation, transmission, and distribution entities. Corporatization and, to an increasing degree, privatization are an integral part of this process. The unbundled institutions will assume the responsibility for the critical functions of planning and decisionmaking. To meet the need for tools and data to support state-level decisionmaking during this important transition, the government of India, the World Bank, and the U.K. Department for International Development have collaborated to

develop a decisionmaking framework. They tested a participatory planning process and analytical tools that can help decisionmakers in India both to improve the planning and management of their power systems, taking into account the major environmental impacts, and to assess the economic and environmental tradeoffs associated with different options for power generation. This report summarizes what has been learned through this process in two very different states, Andhra Pradesh and Bihar, and assesses the broader implications of these findings for energy planning in other states in India.

The case studies were supported by a set of special studies dealing with interfuel substitution; the welfare effects of increases in electricity tariffs; the technical and economic potential for renewable energy technologies; demand-side management; the possibilities of adopting market-based instruments in India; the options available to mitigate the environmental impacts of coal-fired power stations and coal mining; and the management, disposal, and utilization of ash from thermal power plants. The special studies provided basic generic data to supplement the detailed state-specific information collected under the case studies.

2
Options for Reducing Environmental Impacts

This section is based on a review of available data, including special studies and lessons learned from other countries. A particularly important source of data is provided by case study material relating to two contrasting Indian states, Andhra Pradesh and Bihar. While no two states can adequately represent the richness and complexity of the Indian subcontinent, these two states and their distinctive situations offered researchers an opportunity to explore a range of issues and options. Bihar is relatively poor, and its state electricity board is in a precarious situation, financially and technically. Heavy industry accounts for about 40 percent of the demand for power in Bihar, while agriculture accounts for a similar percentage of the requirements of Andhra Pradesh. Although both areas have depended primarily on coal as a power source, Andhra Pradesh has more ready access to other supply options than Bihar. The contrasts between them, explored through different scenarios using computer models, have yielded insights and examples that will be cited throughout this section.

Options available to India as it seeks to reduce the environmental impacts of power generation include the following strategies:

- Reforming and restructuring the power sector
- Rehabilitating generating plants and transmission and distribution networks
- Managing demand
- Using renewable energy supplies
- Internalizing the costs of pollution
- Reducing and recycling combustion by-products
- Siting plants to reduce environmental damage.

The following section explores the relative merits of these strategies and the obstacles to their use.

Reforming and Restructuring the Power Sector

Though it is moving toward reform, India's current government policies continue to maintain some fuel prices at artificial levels, with inevitable and harmful consequences to the environment. While most coal prices have been deregulated, power station grades of domestic coal are still priced below the cost of production. The true value of the better grades is underestimated. Cleaner imported fuels are priced too high by comparison with domestic coal. Prices for the transport of goods by rail, including coal, are generally subsidized, further encouraging the use of the domestic product and its high ash content. As a result,

- Indian coal is preferred as a fuel for power generation over other fuels with lower ash content.
- The relative prices of different grades of coal give no incentive to the coal producer to increase output of the better-quality coals.
- Distorted prices for transport affect the choice between pit-head and load-center plants, shifting the location of environmental impacts.
- Demand is maintained at artificially high levels.

As government reform progresses and prices for fuel rise to a level that reflects their true "economic" cost, stakeholders in the energy system will have reason to make different choices:

- When the tariff structure is changed to reflect the economic costs of production, higher prices for electricity in the residential and agricultural sectors will dampen demand.
- As electricity producers are motivated by commercial incentives rather than dependence on government subsidies, they will have adequate cash flow to rehabilitate transmission and distribution systems and to modernize generating plants, reducing electricity loss through inefficiency.
- Commercial incentives will encourage power utilities to offer higher prices for better coal and spur coal suppliers to invest in coal beneficiation plants.
- Commercially motivated producers will search for cost-effective ways to encourage ash utilization and disposal. They will improve metering, monitoring, billing, and collection procedures, which will increase the amount of available cash.
- Power system reliability will increase; consequently, many consumers who now install their own power sources will be able to rely on the grid system.

The fact that electricity once lost or sold to agriculture at a subsidized price can instead be sold to agriculture at higher prices or to industry at a profit will contribute strongly to improved financial performance for energy providers. Clearly the change in tariff policy makes the difference between a system doomed to failure and one that has the capacity to meet future demand efficiently.

Improving the cash flow of utilities has significant environmental impacts. One major impact will be that providers can build new plants, which will obviously increase the volume of environmental impacts. However, these plants will be intrinsically cleaner and more efficient, displacing old plants; available cash will also enable producers to bring the plants in line with standards. The latter effects will tend to bring down specific emissions of pollutants. The Bihar case study demonstrates that reform would have an overall beneficial effect on pollution levels and at the same time produce more electricity (table 1). Results for the Andhra Pradesh Case Study were comparable (ASCI Consultancy 1998).

While reforms will have a beneficial effect on the environment, what other major effects could they have on public welfare? Data are limited, but there could be significant impacts on residential consumers and on agriculture. First, costs may go up for households with access to

Table 1. Summary of Emissions under the Reform Scenario in Bihar, 2014/2015

Scenario	*Cumulative CO_2 (million t)*	*NO_x (kt, PV)*	*SO_x (kt, PV)*	*Total SPM (kt, PV)*	*Ash (million t)*
"Business as Usual"	142	804	929	62	36
Reform	127	685	828	54	34

Note: CO_2 = carbon dioxide, kt = metric kilotons, PV = present value, SO_x = sulfur oxide, and t = metric tons.
Source: SCADA 1998.

electricity, but the quality of their supply will improve. Also, with proper metering, demand will adjust to efficient levels. As reforms improve the cash flow of electricity companies, they should be able to offer power to new consumers.

Second, increased electricity prices to agricultural customers could result in a more efficient use of water. This, in turn, could lead to improved yields, since overwatering dilutes the effectiveness of fertilizers. Metering could also have an equalizing effect on access to energy. Currently, small farmers often experience long waits for pump connections, while more wealthy farmers are able to use diesel to meet their energy needs. Recent studies suggest that farmers are willing to pay more for reliable access to energy (based on unpublished findings from ongoing studies of power supply to agriculture for the World Bank).

Rehabilitating Generating Plants and Transmission and Distribution Networks

Losses of energy as a result of weaknesses in India's transmission and distribution system were reported by public sector utilities to be as high as 21 percent. This figure is generally recognized by experts familiar with the power sector in India as a serious underestimate. Most state-level studies cite a much higher percentage—perhaps even double the public utility figure. The losses in India are much greater than in East Asian countries. The best performers were Singapore (9.1 percent) and the Republic of Korea (10.2 percent).

Factors that contribute to the high rate of loss in India include the following:

- Lack of investment in rehabilitation of the transmission and distribution system
- Weak transmission and distribution lines
- Long transmission and distribution lines
- Low power factor operation
- Too many transformation stages
- Pilferage and theft.

Modeling suggests that the percentage of power lost through transmission and distribution could be reduced in most states to as low as 10 percent by 2010. If energy providers are motivated to make improvements through price reform, changes in maintenance, metering, monitoring, and billing and collection would make more money available to rehabilitate the system—clearly a win-win prospect. System rehabilitation not only would result in across-the-board reductions in environmentally damaging emissions, but would yield high rates of return both in financial terms and in economic benefits to society.

Case studies found system improvements to be cost-effective both in Andhra Pradesh and in Bihar, which has a smaller system that is in worse condition. Both are currently experiencing energy losses of 30 percent or more. By rehabilitating the existing transmission and distribution system, both could significantly reduce operating costs and achieve measurable environmental benefits for area residents.

In Andhra Pradesh, measured environmental impacts—"attributes"—would be reduced by 3 percent and operating costs by 4 percent. In Bihar, attributes would be reduced by 5 to 6 percent. Expenditures on operations would fall by more than 6 percent.

Managing Demand

Energy use is currently less efficient and less cost-effective than the best available technology would allow. Consequently, a more negative environmental impact is occurring than is actually necessary to meet load requirements. Demand-side management refers to the use of policies to reduce energy consumption, with a resulting decrease in energy production and new plants. Modeling studies show that demand-side management programs could reduce total system costs (in present value terms) and power consumption by approximately 6 percent by 2015, resulting in an Indiawide reduction of measurable environmental impacts (or attributes) of about 10 percent. Specifically, sulfur dioxide (SO_2) and nitrogen oxide (NO_x) would be reduced by 9 percent, total suspended particulate matter (SPM) and carbon dioxide (CO_2) by 10 percent, and ash by 11 percent.

Many diverse technologies are available to reduce energy consumption. Those that are most likely to significantly reduce demand will vary by region, depending on the residential and commercial mix of energy consumers and other factors. Table 2 contains some examples of energy savings that the Andhra Pradesh case study shows would be achieved in the tenth year of a demand-side management program in that state (ASCI Consultancy 1998).

Other governments have tried different policy strategies to encourage demand-side management. Examples that may also work well in India, although they are not among the conclusions of this work, include the following:

- Promoting energy service companies to fund and manage investments in energy efficiency and to share savings with users
- Placing levies on utilities to fund energy conservation programs
- Requiring utilities to engage in demand reduction activities as a condition of construction permits or tariff increases.

Demand-side management programs can be implemented or funded by utilities, the state, the private sector, or other institutions. Once price reforms are in place, however, utilities lose their financial

Table 2. Estimated Tenth-Year Savings from Technologies in Andhra Pradesh

Technology	*Savings in Year 10 (gigawatt-hours)*	*Percentage in total savings*
High-efficiency pumps	3,453	10.01
Fluorescent lamp standards	1,007	0.00
Industrial cogeneration	806	1.34
Metering pump sets	597	1.75
Commercial fluorescent lighting	493	1.32
More efficient rural lighting	475	1.53
More efficient urban lighting	206	0.14
High-efficiency refrigerators	167	0.29
Others	911	2.45
Total	8,115	16.38

Source: ASCI Consultancy 1998.

interest to reduce demand. Consequently, the role of the private sector in promoting changes in consumer behavior may increase. For example, an independent energy service company could promote such programs on a commercial basis, a strategy that has been used in the United States and in Western Europe (table 3).

Using Renewable Energy Supplies

Over the next fifteen years renewable energy supplies could increase by more than seven times, and their share in the country's total power generation capacity could nearly triple. At roughly 1,378 megawatts, renewable energy technologies currently account for about 1.5 percent of total power generation capacity (Ministry of Non-Conventional Energy Sources 1999), of which wind power accounts for about 72 percent (992 megawatts) and small hydro roughly 13 percent. Biomass and solar energy sources account for the rest. The Ministry of Non-Conventional Energy Sources has estimated that 126 gigawatts of power generation capacity is available from renewable energy sources in the long term. Although the technical potential for the use of renewable energy sources in India is vast, the prospects for expansion may be limited in the short

Table 3. Estimated Electricity Saved through Demand-Side Management
(percent)

Study	*2001/2002*	*2006/2007*	*2011/2012*	*2014/2015*
Andhra Pradesh	4.5	11.3	8.3	5.6
Bihar	2.1	7.0	8.1	9.8
CERI	7.4	7.7	8.2	

CERI = Canadian Energy Research Institute and Tata Energy Research Institute.
Source: Canadian Energy Research Institute and Tata Energy Research Institute 1995.

and medium terms because of a number of constraints (see box 3). A special study of renewable energy technologies (Environmental Resources Management 1997) has found that continuation of government policy can give a boost to the penetration of renewable energy technologies to 11,440 megawatts, roughly 4 percent of total generation capacity in 2011–12 (see table 4). Sensitivity analysis on capital costs show that capacity addition of 8,560 megawatts (nearly 3 percent to the country's total generation capacity) is feasible through renewable energy technologies in 2011–12 even in the absence of any incentive and subsidy scheme (see box 2). The special study, therefore, concludes that government incentives will need to continue in the short and medium term to enable renewable energy technologies to provide an increasing share of the nation's power supply. These incentives are outlined in box 2. The renewable energy technologies could become more attractive economically if energy sector reform

Box 2. Incentives and Subsidies

A number of incentives are offered for renewable energy technology projects, which include soft loans, reduced customs duties on imported material and equipment, 100 percent depreciation allowance, exemptions from excise and sales tax, remunerative price with escalation clause for power fed into the grid, facilities for wheeling and banking power, and large capital subsidies. For example, in Maharashtra, up to 30 percent capital subsidy is being offered to private developers of wind power projects. For biomass, a capital subsidy of up to 50 percent of the cost of projects (subject to a maximum of Rs. 2.5 crores per megawatt) is being offered. In the northeastern region, the recently announced a government incentive package for the promotion of small hydro projects includes a capital subsidy of up to Rs. 3 crores per megawatt or 50 percent of the project cost. Regarding SPV, the Ministry of Non-Conventional Energy Sources provides two thirds of the project cost (subject to a maximum of Rs. 2 crores per 100 kW) for the procurement of SPV modules, structures, cables, power conditioning units and grid interfacing equipment, while the balance is required to be met by implementing agencies. The solar thermal power plant in Rajasthan would be supported by grants from the central government of up to Rs. 50 crores and from the Global Environment Facility of $49 million, including a technical assistance component of $4 million.

Table 4. Potential Contribution of Renewable Energy Technologies
(gigawatts)

Installed capacity in gigawatts (electrical)	*2001/2002*	*2006/2007*	*2011/2012*
With government financial incentives	4.5 (3.4%)	7.1 (3.5%)	11.0 (3.8%)
Without government financial incentives	3.1 (2.3%)	4.9 (2.4%)	6.7 (2.3%)

Note: Percentages of the totals for India are in parentheses.
Source: Environmental Resources Management 1997.

Box 3. Constraints

Although the cost of generation of small hydro at about Rs. 1.43 per kilowatt-hour is highly competitive with conventional technologies, some renewable energy technologies, such as solar photo voltaic (SPV) and solar thermal, are far less economically attractive than conventional technologies. For example, despite the rapid declines in SPV costs, the current estimated cost of SPV modules are around $4 to $5 Wp (peak watt). Even if the cost declines by 50 percent to approximately $2.5 per Wp, the technology would remain uncompetitive compared with $1.05 to $1.35 Wp (Rs. 3.5–4.5 crores per megawatt) for other renewables and conventional technologies, notwithstanding the low variable costs associated with SPV technology.

Several other factors constrain the use of renewable energy technologies. They are classified as technological, institutional, financial and economic, and infrastructural, as follows:

Technological

- Most renewable energy technologies have not achieved maturity within the country, and a large portion are imported.
- Renewable energy sources are site-specific, and the supply may not be continuous.
- Technical information is not easily available either for the entrepreneur or the consumer.

Institutional

- A top-down centralized government approach is generally adopted for this potentially highly decentralized option.
- Little encouragement has been received from the state electricity boards.
- There is a lack of awareness about the potential environmental benefits.
- There is a lack of serious education and training for operation and upkeep.
- Incentives are misused; they are related to investment rather than to performance of plants.

Financial and economic

- Diesel and electricity are subsidized for use by agriculture and residential consumers.
- Funds allocated to renewable energy sector are minimal when compared with fossil fuel and nuclear energy options.
- In some cases, large initial investments are required.

Infrastructural

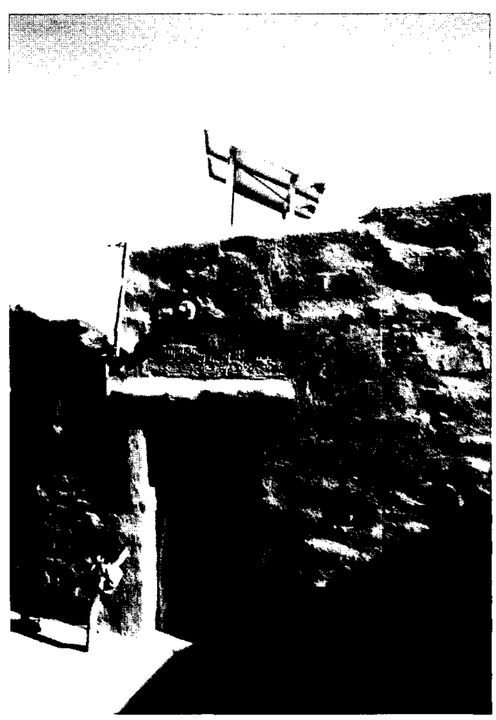
- The land requirement for renewable energies could be very high.
- Poor grid availability proves to be a major deterrent.
- There is a lack of proper maintenance and servicing facilities at the local level.

A number of options to address the constraints exist, some of which are already at various stages of implementation: the collection of information; dissemination and training campaigns; the reorienting of the investment portfolios of power utilities to develop decentralized power options and encouragement for the utilities to ensure grid connection to private developers; formulation of a policy for power purchase; promotion of the financing of economically viable renewable energy technologies by developing and introducing innovative financing schemes, such as lines of credit, revolving funds, and hire-purchase plans, to the conventional loan schemes; and formulation of government policy and legal and regulatory frameworks that encourage private sector participation.

becomes more widespread and the subsidies associated with conventional energy are reduced. Agriculture and residential consumers of power are heavily subsidized by the state governments. Net subsidies to power consumers—revenue requirements less the contributions state electricity boards require from state governments—amounted to roughly $3.7 billion in 1995–96, about 1.4 percent of gross domestic product.

Water, wind, and biomass are the most economically feasible renewable sources of energy for the near term in India. Solar energy, however, has enormous potential if it can be made more economically viable. Even in the near term, it may be an economically competitive option for many remote areas where the cost of grid connection is very high.

- **The high rate of photosynthesis from available biomass** in India, such as crop residues, makes this a prospective resource. **Bagasse-based cogeneration** uses a combination of direct combustion and gasification of biomass to generate energy. At the time of this report, eighteen biomass projects have been installed and another seventeen are under construction. There are technical challenges, however, in using this resource effectively, as well as logistical ones in ensuring an adequate and timely supply of fuel on a year-round basis. The estimated potential for bagasse conversion in India is approximately 3,500 megawatts.
- The first **wind farms** in India were installed in the coastal areas of Tamil Nadu, Gujarat, Maharashtra, and Orissa. The main potential is for use in these and other states within South India. Ninety-eight sites have been identified with annual mean wind speeds of more than 18 kilometers per hour. Together they would provide 5,000 megawatts of energy. Constraints include operational problems in matching supply and demand, since wind power often varies seasonally.
- The potential for small **hydro power** in India is also strong, with an estimated potential to contribute 10,000 megawatts. The Ministry of Non-Conventional Energy Resources, which has examined 2,679 sites that have potential capacities of up to 3 megawatts each, estimates that small hydro power could represent 1 percent of the likely installed Indiawide capacity for power generation by the year 2015.
- The technical potential of **solar energy** in India is huge. The country receives



enough solar energy to generate more than 500,000 terawatt-hours of electricity, assuming 10 percent conversion efficiency. *This is three orders of magnitude greater than the likely demand for electricity in all of India by 2015.* However, even though the cost of photo voltaic cells is falling and unit costs of production are expected to decline, the cost of solar energy is still higher than that of other renewable energies. As further technical progress is made, it will probably become a significant long-term energy source. Even in the near term, it may be an economically competitive option for many remote rural areas.

Internalizing the Costs of Pollution

The government is responsible for setting the rules for how the costs of environmental pollution are apportioned between society and the polluting agency. The principle of "the polluter pays," which has generally been adopted in environmental regulation, obliges the polluting agency to bear the cost of reducing or maintaining its environmental waste at an acceptable level. This is called "internalizing" the costs. If the rules of environmental management set by the government were both adequate and enforced, all costs would be internalized within the agency. The agency would be motivated, by whatever means chosen by the policymakers, to fully bear these costs, and would therefore make the changes needed to reduce its emissions. This can be accomplished by using **technical standards** that require the polluter to reduce its emissions to target levels or face significant consequences (the "command and control" strategy), and **market-based instruments** that seek to change the nature of the incentives and disincentives faced by polluters to perform acts that benefit society.

Guidelines and standards are intended to be a means of forcing a business to change its operations in order to reach prescribed levels, increasing the cost to the business. In principle, the adverse environmental impacts of decisions in the power sector could be reduced by implementing more stringent standards than those currently applied in India. For this reason, the study attempted to estimate the incremental costs of implementing the World Bank's new standards for air quality and emissions, which are more stringent for SO_2 and SPM than current Indian standards. Analysts concluded that the incremental costs associated with meeting World Bank standards need not be substantial if plants are properly sited.

More significant benefits, however, will result from improved implementation of existing standards than from adoption of new and stricter standards (table 5). Participants in the National Decisionmakers Workshop held as part of this study stressed that better implementation of monitoring and enforcement procedures will be of more immediate benefit to India.

Market-based instruments attempt to meet environmental objectives by working through market mechanisms. The common element of all market-based instruments is that they work through the market, attempting to alter the behavior of economic decisionmakers, such as firms and households, by changing the

Table 5. Existing Air Quality Standards for the Ministry of Environment and Forestry

Air quality standard (mg/m^3)	*Residential and rural areas*			*Industrial and mixed areas*		
	SO_2	*NO_x*	*SPM*	*SO_2*	*NO_x*	*SPM*
24-hour average	80	80	200	120	120	500
Annual average	60	60	140	80	80	360

incentives and disincentives they face. For example, if ash disposal permits were allocated equally to all new power plants, regardless of their circumstances, some permits might be sold by those that find it easiest to meet the targets, which would reduce the total cost of compliance for all power plants. Other examples of market-based instruments include pollution or input taxes, product charges, and differential tax rates. Market-based instruments are most easily applied in situations where there are few "actors" and where impacts can be measured easily. They also work best when polluters must face hard budget constraints.

A number of studies have demonstrated the cost-effectiveness of market-based instruments over traditional "command and control" regulatory strategies that require all polluters to meet the same discharge standards. Market-based instruments acknowledge and use the key fact that the costs of reducing pollution are not the same across all firms. Simulations done in the United States show that these instruments can be between 1.5 and 4 times as cheap as a "command and control" regime across a range of pollutants and locations. Realizing these potential savings, however, will require careful design and implementation.

Several significant barriers exist to successful use of market-based instruments in India:

- Misconceptions among stakeholders about market-based instruments
- A vested interest in the status quo on the part of both regulatory agencies and firms
- A lack of good governance, including an ineffective institutional framework, a lack of local-level capability, and insufficient technical understanding of issues at the state board level
- The challenge of changing the current legal system
- The "soft" budgets of the state-owned enterprises that dominate the power sector
- The potential for malpractice in the use of funds raised through market-based instruments
- The potential for higher costs to the industry in some instances.

Before market-based instruments can do their work, a suitable legislative and regulatory framework for administering them must be established. Further, it is essential to recognize that unless power plants and companies have strong commercial incentives to make the desired choices, market-based instruments will not produce the desired effects.

Reducing and Recycling Combustion By-Products

Two specific clean coal technologies were considered in the case studies conducted in this project: Pressurized Fluidized Bed Combustion in Bihar and Integrated-Gasification Combined Cycle in Andhra Pradesh. The two technologies, considered the most feasible in current circumstance, do improve combustion efficiency and reduce emissions to the environment. Case study data suggest that the use of these technologies would result in only marginal reductions in ash and CO_2, but that they would have more substantial impacts on total SPM and SO_2, reducing them by as much as 17 percent in Bihar. Their use would also reduce NO_x emissions by 8 to 10 percent. Both require higher capital and operating costs, however, which exceed those of power plants that do not use these technologies by 10 to 15 percent. Consequently, neither technology would be implemented on the basis of normal market incentives.

In 1996/97 alone, coal production generated 62 million metric tons of ash. **The high ash content of Indian coal makes ash disposal one of the most pressing environmental problems India faces as a result of its reliance on coal-powered energy.** The steady increase in open-cast mining, which now supplies the bulk of Indian coal, has been a major factor in the falling calorific value and rising ash content of Indian coal. Storage of fly ash demands large land areas; once land is used for this purpose, it is expensive to reclaim the land so that it can be used in other ways.[1] Often, this financial investment in land recovery is not made and the land is simply lost.

The Andhra Pradesh and Bihar case studies clearly highlight the environmental hazards associated with current practice. In Andhra Pradesh, only 5 percent of the ash stock piled outside thermal plants is used by industries. The rest is dumped in ash ponds or left in a pile outside the plants. In Barauni (Bihar), ash ponds are located on permeable sand, allowing groundwater contamination. Ash has spilled to local agricultural lands. Rivers in Patratu are said to be full of ash; during dry seasons, there are significant emissions of fugitive dust.

Not only does the ash cause environmental damage, but it also increases the

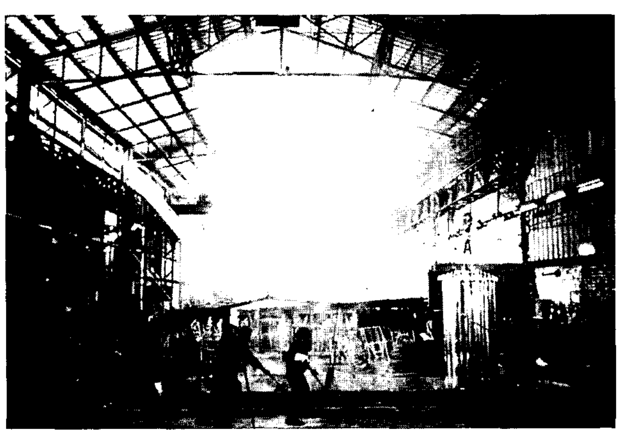
1. During combustion in power plants, the pulverized coal particles are injected into the furnace and ignited in suspension. The mineral matter in coal is transformed, leading to the formation of ash. The ash residues of combustion possess a wide range of both physical and chemical properties that depend on the coal utilized, the combustion regime under which they are generated, and the method of collection. The ash that enters the flue gas stream is called fly ash, and the ash that falls through to the furnace bottom is called bottom ash. Fly ash generally constitutes about 80 percent of the total ash produced. Coal ash is a complex material in terms of specific gravity, size, morphology, microstructure, and mineralogy. The ash matrix consists of a mixture of aluminosilicates, silicates, iron oxides, and a certain amount of alkali-silicates in both amorphous and crystalline form. The mineralogical constituents of coal ash are SiO_2, Al_2O_3, Fe_2O_3, and CaO.

cost of transport to the power station site and causes wear and tear on equipment. Plants that burn the high ash coal are intrinsically more expensive and less efficient because they must handle large quantities of noncombustible and abrasive matter.

To date, limited use has been made of coal washing, a process that removes some of the mineral matter that would result in ash prior to burning. Because of the properties of Indian coal (it is difficult to separate mineral matter from carbon without also losing carbon), the economic tradeoffs for coal washing make it a controversial option. Consequently, situational analysis is needed to determine when transport is economically feasible. The Andhra Pradesh Case Study concluded that washing coal with marginally high ash content (30–38 percent) or with calorific values greater than 4,000 kilocalories per kilogram may not be advantageous. However, as long as the total cost remains competitive with that of imported coal, coal washing is a viable alternative for coal with high ash content and low calorific value that must be transported over distances of more than 1,000 kilometers. Cost recovery incentives are essential, however, to make this option attractive (ASCI Consultancy 1998).

The major economic benefit resulting from the use of the washed coal is the lower capital cost experienced by plants specifically designed to burn this coal. However, the waste carbon must be disposed of, contributing to environmental damage. Much of the large volume of solid waste products is in the form of fine carbon particles suspended in water. Ash from improperly designed ash ponds can enter the aquatic ecosystem, contaminating groundwater, as well as reservoirs, streams, and rivers. While well-designed and well-managed ash disposal systems would result in minimal pollution, most ash ponds in use at India's power plants are not properly designed or operated and do not comply with Central Pollution Control Board standards.

Some of this lost coal can be burned in a fluidized bed process or used as backfill in mines. **An alternative approach to the fly ash problem is to encourage its use in a wide variety of commercial applications. To date, however, India has been less successful than other countries in encouraging commercial use of this waste material.**



In 1996/97, only 2 percent of the 62 million metric tons of ash produced by burning coal in India was used commercially. By comparison, China produced 55 million metric tons of ash and recycled 25 percent of it. This poor record is not for any lack of possible applications relevant to the country's needs. The greatest emphasis has been placed on its use in construction materials, since India has a chronic shortage of housing, and building materials are always needed. It is necessary to add binding reagents to ash and clay, however, to meet applicable standards. As a result, the production of bricks from fly ash appears to be economical only when production exceeds 25,000 bricks per day and when the bricks are used within 50 kilometers of the production site.

A variety of other applications are also promising. For example, it may be used as filler, as a soil conditioner, or as a replacement for cement. Some buildings in India have already been built with concrete that contains ash. A report prepared for the World Bank sees the greatest potential for environmental benefits in "low value-added" uses of fly ash (uses that do not require significant processing) (Water and Earth Science Associates 1996). Examples include uses in industrial effluent treatment, road making, embankment construction, and plantation raising (box 4).

There are, however, obstacles to the use of these productive variations that planners must take into account. These include quality variations in the coal, transportation costs, technological limitations, impaired quality as a result of wet methods of coal collection and disposal, and consumer resistance to products that contain coal ash. Potential users must also consider the following:

Box 4. Applications for Coal Ash

Agriculture: As an absorbent, artificial aggregate, fertilizer, and soil conditioner.

Building materials: For aggregate, bricks, building blocks, ceramic products, paving materials, roofing tiles, wallboards, and paneling.

Cement and concrete: In cement, cement extender, cement substitute, concrete, concrete filler, foamed concrete, and mortar.

Civil engineering: Aggregate, asphalt filler, backfill, embankment materials, foundations and road construction, grout, and hydraulic barriers.

Industrial materials: Abrasives, absorbents, artificial sand and aggregate, ceramic materials, decorative materials, filter media, gas cleaning, and industrial fillers.

Materials recovery: Recovery of alumina, iron and silicon, and trace elements.

Waste treatment: Grout and waste stabilization.

Source: Water and Earth Science Associates 1996.

- The price that industry must pay to the generators for the ash (if any), plus the cost of transport
- The cost of alternative materials
- The impact of using coal ash on the quality of the end product
- The impact that using coal ash has on the cost of the production process.

The National Thermal Power Corporation, which runs thirteen coal-fired power plants in India, has been successful in increasing the utilization of fly ash by developing policies to encourage entrepreneurs to make use of the waste. In 1991 it established an Ash Utilization Division at the corporate level, with Ash Utilization Cells at each power plant. Its six-year program to promote the internal use of ash in construction and to facilitate the use of ash by private companies succeeded in increasing ash utilization in its plants from 2 to 3 percent in 1991 to 10 percent in 1996/97. The corporation's incentives for entrepreneurial use included such policies as the following:

- Dry fly ash is provided free of cost to users in and around the power station for an initial period of five years.
- Surplus land is made available for a discounted rent to companies that use ash.
- The corporation invests equity in joint venture companies for ash utilization.

The National Thermal Power Corporation's experience suggests that the use of fly ash can be encouraged by changes in plant policy. Most plants, however, do not appear motivated to pursue these policies. While in theory power plants are required to meet standards for ash disposal, in practice these standards are often not met. The poor compliance implies that the actual cost of ash disposal in Indian power plants is much lower than the costs in well-designed and well-managed systems. Many state electricity boards are apparently more likely to save money through poor ash pond management than by encouraging industry to use ash. Consequently, the economic potential for the use of ash in India is far from realized. The previously cited "Review of Coal Ash Utilization" (Water and Earth Science Associates 1996) suggests that **the current problems of ash disposal and management could in part be corrected through stronger enforcement of present environmental standards.**

Currently the government of India provides some fiscal incentives to encourage the use of ash. Bricks and other building materials using 25 percent or more fly ash as raw material are exempt from excise duty. Also, import machinery needed to produce building materials from ash is exempt from customs duty if it is not available within the country. The government has also taken several administrative actions:

- It has asked state governments to prepare action plans for using 50 percent of fly ash by the year 2000.
- It has asked State Pollution Control Boards to be lenient with industries that use industrial wastes.
- It has required environmental clearances of thermal power plants, which emphasizes the need to arrange for dry ash collection and use.

Two additional policy options could be used to increase the use of fly ash:

- **Binding utilization levels.** Binding targets imposed by the central government could be effective, provided that the targets are well designed and geographically differentiated to reflect the economic potential for the use of ash in different areas.
- **A tax on ash disposal.** Such a tax would have to be combined with power sector reform and commercial and regulatory incentives to have a significant effect. If environmental standards are enforced more strictly, however, an ash disposal tax will be unnecessary.

Siting Plants to Reduce Environmental Damage

Since the construction of many new coal-fired plants will be needed to meet forecast demand, it is important to consider the environmental impacts attributable to plant location. It is instructive to consider the relative disadvantages and advantages of two types of power plant sites: at a load center (that is, in an area where a high population of power users is concentrated), and at the pit-head (in a sparsely populated area).

In many cities, other significant sources of pollution will already be present, such as vehicle emissions, residential coal burning, small generators used in power shortages, and pollution from nonenergy sources. It is important to measure the background levels of pollutants to determine whether a plant can be added without exceeding target levels. One reason for siting plants in load areas, despite the high levels of pollution that may already exist, is to reduce the costs of transmitting and distributing energy. Currently, India's system is inefficient in many areas. For example, in Bihar, transmission lines could lose as much as 9 percent of the energy transmitted from a new power plant, compared with less than 1 percent loss in the best international practice. If not corrected, this loss will require the production of more electricity, which will further increase pollution.

Though siting new plants at load centers does reduce the amount of energy lost in transmission, the coal itself must be transported farther to reach the load center (predominantly by rail). The environmental impact of this transport is comparatively slight, however. Similarly, though sources of pollution also exist at the pit-head, the levels are much less significant. In rural areas, existing background pollution includes SPM. At the

coal mine itself, SPM will arise from the mine itself and as a result of vehicles transporting material from the mine. These background SPM levels could be reduced to acceptable limits through the use of high-efficiency electrostatic precipitators.

When new plants are sited, the characteristics of the terrain must also be considered. Air dispersion modeling in the Bihar case study led to the conclusion that concentrations of SPM, NO_x, and SO_2 tend to be higher on hilltops than flat terrain, though any area will have specific geographic characteristics that increase or decrease its ability to disperse pollutants. Planners will need to model the type and quantity of pollutants released in relation to areas where people are living in the greatest numbers.

Using Options in Combination

When these options are used together, significant environmental benefits can be achieved even though the individual impact of each option may be modest.

In Andhra Pradesh, a combination of options consisting of greater use of renewable energy sources, demand-side management, coal washing and clean coal technologies, and rehabilitation of the transmission and distribution system could reduce coal-based power generation by 18 percent by 2015. Total system costs (in present value terms) would fall by about 4.5 percent, with significant environmental benefits: SO_2 and NO_x levels would fall by 27 percent and 21 percent, respectively, while the decline in total SPM, CO_2, and ash would be on the order of 16–18 percent (tables 6 and 7).

In Bihar, a mixture of demand-side management, greater use of renewable energy sources, and rehabilitation of the transmission and distribution system would reduce coal-based power generation by 15 percent by 2015. Total system costs would fall by about 7.5 percent, with striking environmental impacts. SO_2 levels would decline by 7 percent, NO_x by 4 percent, total SPM by 8 percent, and CO_2 by 10 percent.

Participants in the National Decisionmakers Workshop and the National NGO Workshop stressed that options will not be used or sustainable without some measure of reform. Four critical strands must be woven together to achieve success:

- **Getting the price of electricity right** so as to send the correct signals to consumers to encourage them to invest in energy-saving practices and technology
- **Getting the price of fuels right** to "create a more level playing field" for natural gas and renewable energy sources
- **Increasing the commercial motivation of utilities** to give them the incentives to make choices that benefit the environment, such as improving ash management and rehabilitating transmission and distribution systems
- **Increasing the funds available to utilities** to make improvements by raising tariffs.

Introduced as an integrated package within the framework of sector reform, case studies and other evidence suggest that an appropriate combination of options can succeed together in significantly reducing environmental damage from power generation, with its associated negative impacts on the quality of life and health of residents.

Table 6. Andhra Pradesh—Cumulative Pattern of Generation Mix
(over the study period 1997–2015)

Scenario		*CoalHydrocarbons*			*HydroOther Renewables*			
	Gigawatt-hour	*%*	*Gigawatt-hour*	*%*	*Gigawatt-hour*	*%*	*Gigawatt-hour*	*%*
IFS	965,474.0	70.0	232,923.0	16.9	181,182.0	13.1	—	—
Combinations	786,548.0	63.5	246,261.0	19.9	181,183.0	14.6	24,352.0	2.0
Memo: reduction in coal-based generation	178,926.0	18.5						

— Not available.
Notes: 1. IFS refers to interfuel substitution. The scenario assumes that current tariff policies and demand trends will continue and that traditional supply side planning and choices between fuels will be made on the basis of economic cost. 2. Combinations: The scenario examines the combined effort of demand and supply side measures. On the demand side, the scenario considers demand-side management (DSM) and transmission and distribution (T&D) loss reduction (T&D losses assumed to decline from 20 percent under the reference case to 10 percent), the impact of which is manifested in reductions in generation equivalents. The supply-side measures consider such options as clean coal, new technologies (pressurized fluidized-bed combustion in Andhra Pradesh), and a reasonable amount of renewables introduced.

Table 7. Andhra Pradesh—Impact on Cost and the Environment

		Emissions					
Scenario	*Total cost (Rs. billions)*	*CO_2 (million metric tons)*	*SO_x (metric kilotons)*	*NO_x (metric kilotons)*	*Total SPM (million metric tons)*	*Ash (million metric tons)*	*Land (ha)*
IFS	742.2	1,235	2,552	2,576	252	251	2,008
Combination	708.4	1,011	1,851	2,027	212	207	1,656
Memo: % reductions in present value of cost and environmental impact	4.6	18.1	27.5	21.3	15.9	17.5	17.5

Notes: 1. The present value (PV) of Total Cost = PV of (Investment in committed and new plans + Variable Costs + Investments in T&D – Salvage Value). 2. Variable costs include fuel, variable operations and maintenance, and fixed operations and maintenance costs. 3. The land required for ash disposal is 8 hectares per million metric tons of ash. 4. The discount rate is 12 percent for local pollutants, such as SO_x, NO_x, and total SPM. 5. No discounts are given for CO_2 emissions, ash, and land. 6. The PV of DSM is estimated from the IRP report (Meier 1996). Associated T&D costs are adjusted downward to reflect reduced investments corresponding to lower demand. 7. The PV of T&D rehabilitation cost is estimated independently at one third the generation cost.

3
From Knowledge to Action

Applying the Decisionmaking Process and "Toolkit"

The study yielded two key products that are immediately applicable in other situations in which power system planners use data to guide their decisions and minimize the serious impact of power production on the environment. The first is a tested decisionmaking process to help planners develop sound plans for power development.

The second key product is a "toolkit" consisting of a series of planning "modules" that can be used flexibly and that provide a variety of choices to users in different states with a wide range of concerns. Although the software programs used in the project performed well, alternative software programs, which experts believe would work equally well, are also available. To help states choose the best planning tools for their situation, the local and international consultants who worked on the activity produced a practical description of the toolkit in the *Manual for Environmental Decisionmaking*, recently published by the Energy Sector Management Assistance Programme (ESMAP Report 213/99, June 1999).

In disseminating the process and associated tools, planners and consultants will benefit by applying the lessons learned from the experience gained in this study:

- Workshops are an important part of the consultative process. They can be used effectively to raise planners' awareness of the environmental impact of power generation, achieve consensus among participants on project activities, and show planners how to identify the best strategies to mitigate negative impacts in their planning areas.
- Workshops are effective vehicles for publicizing findings. They provide opportunities to make relevant agencies in target states aware of the decisionmaking process and the analytical tools available to accompany it; to encourage them to adopt similar approaches to achieve their corporate planning, environmental, and regulatory objectives; and to help them design a program to enable them to use the process and tools successfully.
- Sound corporate planning in power system expansion is essential to manage adverse environmental impacts effectively.
- The planning process will work best if reforming states are targeted. Without progress toward power sector reform, the developmental impact of the process will be significantly hampered.

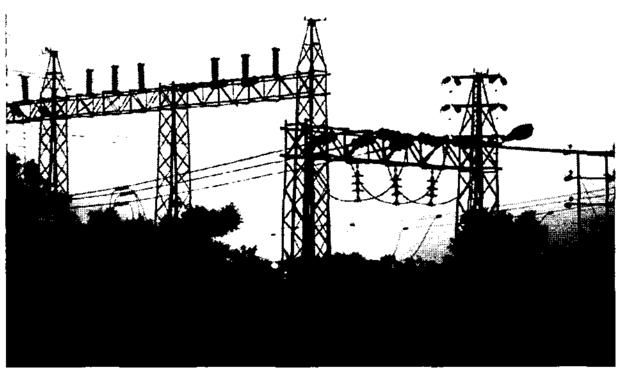
People involved in the planning process may include representatives from state agencies, state electricity boards, unbundled transmission and generation companies, independent power producers, academic institutions, nongovernmental organizations (NGOs), and central power agencies, as well as consultants (box 5). Their work is best structured around a set of questions that may be answered through the appropriate application of modeling tools. For example, to explore the environmental impact of reform, questions could include what the consequences would be of choosing plants on the basis of economic costs and allowing environmental costs to be internalized? Or, to explore the feasibility of technical options, questions could include how much it would cost to use new clean coal technologies to wash coal, what the potential would be for renewable energy supplies, and what level of environmental benefits could be achieved by using these methods?

Once the questions are clear, it is essential to determine basic parameters, such as the study boundary (which consumers and power plants will be studied), the study period, and assumptions to be used for modeling. Scenarios can then be developed to determine what results would occur in specific sets of circumstances of interest to planners—for example, given stated economic policies, energy sector policies, policy instruments, and power sector options.

Having defined the questions to be answered, the project parameters, and the scenarios to be explored, specific tools can be applied to carry out the necessary studies. Special studies can also be carried out as needed to research issues outside the scope of the existing "toolkit."

The toolkit consists of a series of linked modules (box 6). Computer modeling enables planners to determine what would occur under each of the identified scenarios. Key modules tested in this study may be used to generate "outputs" in the general areas of demand forecasting, power system planning, environmental analysis, and financial analysis.

As results are reached, those participating in the planning process should not only be informed of these results, but also be actively assisted in understanding their importance for decisionmaking and in using them appropriately in the planning area.



Box 5. Elements of the Participatory Planning Process

- Disseminate a questionnaire to senior officials in the energy and environment sector, as well as to nongovernmental organizations, and to private investors to obtain their views on issues and priorities.
- Establish an advisory group to guide the report development process.
- Conduct technical workshops for specialists to reach consensus on methodology for projections and modeling.
- Conduct seminars for nongovernmental organizations and decisionmakers to exchange information and encourage involvement and interest in the planning process.
- Disseminate results on an ongoing basis to state contacts, nongovernmental organizations, and other key officials through designated coordinators and periodic seminars.
- Hold workshops for decisionmakers and nongovernmental organizations to disseminate findings, elicit feedback on results, and determine next steps.

Box 6. A "Toolkit" for State-Level Energy Planning

Tools tested in this project that are available to help other states in India to integrate environmental concerns in power planning and to assess the impact of future energy production strategies on the environment include four modeling activities:

- ***Demand forecasting:*** To examine historic demand and project future demand, taking into account the impact of such variables as growth in income, price reform, demand-side management, and rehabilitation of transmission and distribution networks.
- ***Power system planning:*** To calculate the schedule of investments in power plants that will meet the forecast demand at the least cost. AS-PLAN software was used to project system production costs and emissions of SO_2, NO_x, SPM, ash, and coal requirements, taking into consideration such parameters as reserve margins, reliability constraints, and loss of load probability.
- ***Environmental analysis:*** To indicate the impact of emissions from power plants on local air quality. An air dispersion model was used to estimate concentration of SO_2, NO_x, and SPM in the air.
- ***Financial analysis:*** To calculate the financial impact of alternative power development options. A simple spreadsheet model was constructed from AS-PLAN and other sources showing such key data as capital and operating costs, revenues, and debt service requirements.

References

ASCI Consultancy. 1998. "Environmental Issues in the Power Sector: Andhra Pradesh Case Study." ASCI Consultancy, Centre for Infrastructure Management, Administrative Staff College of India, Hyderabad.

Canadian Energy Research Institute and Tata Energy Research Institute. 1995. "Planning for the Indian Power Sector: Environmental and Developmental Considerations." Canadian Energy Research Institute and Tata Energy Research Institute, Ontario.

Environmental Resources Management. 1997. "Renewable Energy in India: A Special Study." Environmental Resources Management, London. March.

ESMAP (Energy Sector Management Assistance Programme). 1999. India: Environmental Issues in the Power Sector. ESMAP report 213/99. Washington, D.C.

Meier, Peter. 1996. "Integrated Resource Plan for Andhra Pradesh." U.S. Agency for International Development (USAID), Office of Energy, Environment, and Technology, Washington, D.C., May.

Ministry of Non-Conventional Energy Sources. 1999. *Annual Report, 1998–99.* Ministry of Non-Conventional Energy Sources, Government of India, New Delhi.

SCADA (Sone Command Area Development Agency). 1998. "Environmental Issues in the Power Sector: A Case Study of Bihar." SCADA, Bihar, India.

Water and Earth Science Associates. 1996. "Review of Coal Ash Utilization." Water and Earth Science Associates, Ontario.

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