Greenhouse Gas Mitigation in the Power Sector: Case Studies From India

ESM237

Energy

Sector

Management

Assistance

Programme

ESMAP

Report 237/01

February 2001

JOINT UNDP / WORLD BANK
ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) is a special global technical assistance program run as part of the World Bank's Energy, Mining and Telecommunications Department. ESMAP provides advice to governments on sustainable energy development. Established with the support of UNDP and bilateral official donors in 1983, it focuses on the role of energy in the development process with the objective of contributing to poverty alleviation, improving living conditions and preserving the environment in developing countries and transition economies. ESMAP centers its interventions on three priority areas: sector reform and restructuring; access to modern energy for the poorest; and promotion of sustainable energy practices.

GOVERNANCE AND OPERATIONS

ESMAP is governed by a Consultative Group (ESMAP CG) composed of representatives of the UNDP and World Bank, other donors, and development experts from regions benefiting from ESMAP's assistance. The ESMAP CG is chaired by a World Bank Vice President, and advised by a Technical Advisory Group (TAG) of four independent energy experts that reviews the Programme's strategic agenda, its work plan, and its achievements. ESMAP relies on a cadre of engineers, energy planners, and economists from the World Bank to conduct its activities under the guidance of the Manager of ESMAP, responsible for administering the Programme.

FUNDING

ESMAP is a cooperative effort supported over the years by the World Bank, the UNDP and other United Nations agencies, the European Union, the Organization of American States (OAS), the Latin American Energy Organization (OLADE), and public and private donors from countries including Australia, Belgium, Canada, Denmark, Germany, Finland, France, Iceland, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, Switzerland, the United Kingdom, and the United States of America.

FURTHER INFORMATION

An up-to-date listing of completed ESMAP projects is appended to this report. For further information, a copy of the ESMAP Annual Report, or copies of project reports, contact:

ESMAP
c/o Energy and Water
The World Bank
1818 H Street, NW
Washington, DC 20433
U.S.A.

Greenhouse Gas Mitigation in the Power Sector: Case Studies From India

February 2001

Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP)

Manufactured in the United States of America
First printing February 2001

Contents

Annexes

Tables

Figures

Units of Measurement

At the time the work was conducted, the exchange rate between the US$ and Indian Rupees (Rs.) was:

US$1=Rs. 43

In India, it is common to express numbers in terms of crores and lakhs, where:

1 crore = 10 million (10^7)

1 lakh = 100,000 (10^5)

Greenhouse Gas Mitigation In The Power Sector: Case Studies From India

A. Introduction

Genesis of the Work

Case studies were completed for two states in India in 1998, as part of an activity on *India: Environmental Issues in The Power Sector* (EIPS). The activity was undertaken by the World Bank, on behalf of the Government of India (GoI), through the Ministry of Power (MoP). Liaison with MoP on day-to-day matters was facilitated by MoP's Energy Management Centre (EMC). The activity was supported by funding from the UK Department for International Development (DFID), through the Joint World Bank/UNDP Energy Management Assistance Programme (ESMAP), and by the World Bank's South Asia Region. A final report was issued as ESMAP Report No. 205/98 in June 1998.

The Administrative Staff College of India (ASCI) and the Sone Command Area Development Agency (SCADA), with the assistance of Metallurgical & Engineering Consultants (India) Ltd. (MECON), carried out the case studies in Andhra Pradesh (AP) and Bihar, respectively. The case studies identified the environmental impacts of alternative options for the development of the power sector in those states. In particular, they estimated the atmospheric emissions of particulate matter (PM) and oxides of sulphur and nitrogen (SO_2 and NO_x, respectively), as well as the production of ash and the preemption of land. But the case studies gave only limited attention to greenhouse gas (GHG) emissions and global warming issues, by tracking CO_2 and including some preliminary analysis of the possible effects of a carbon tax. A detailed discussion of the methodology used in the case studies, including a description of the set of analytical tools and the decisionmaking process that were developed for the case studies under EIPS, was published in *India: Environmental Issues in The Power Sector, Manual for Environmental Decision Making*, ESMAP Report No. 213/99 in June 1999.

The present study extends the previous work through applying a global overlay, i.e., by (i) including GHG emission impacts; (ii) including GHG mitigation analysis; and (iii) estimating the incremental costs of GHG reduction. The global overlay was conducted in accordance with the World Bank's *Guidelines for Climate Change Global Overlays* (Environment Department Paper No. 047, Climate Change Series, February 1997). It was funded by the World Bank's Global Overlay Programme, with help from Denmark, Norway, ESMAP, and the World Bank's South Asia Region. The AP case study was again conducted by ASCI, while MECON had the responsibility for Bihar. The two consulting teams worked under common terms of reference that were provided by the World Bank. However, the teams were given discretion in developing their methodology for the case studies, wherever the differences in approach did not compromise the comparability of the results. The task managers were Robin Bates (INFEG) and Mudassar Imran (SASEG), who also prepared this synthesis report.

Basic Information on the Case Study States

AP and Bihar were chosen as case studies for EIPS because they offered a good cross-section of the issues and options related to the environmental impacts of power generation in India.

(i) Bihar

Bihar is one of the poorest states in India, and the Bihar State Electricity Board (BSEB) is in a particularly precarious financial and technical condition. It experiences heavy financial losses and requires burdensome state subsidies; its thermal plants are old and poorly maintained; and transmission and distribution (T&D) losses, estimated at nearly 40%, are high. About 50% of electricity sales are to heavy industry; 21% to agriculture; and 11% to domestic consumers. The power sector depends heavily on coal, with more than 90% of power generation coming from that fuel. The state is also comparatively remote from alternative domestic sources of energy, although it is reasonably well placed to import energy from Bangladesh and Nepal in the longer term and it has significant biomass potential.

(ii) Andhra Pradesh

In contrast to Bihar, AP has a wider range of supply options for its power sector: apart from coal (54%), they include hydropower (43%) and small amounts of nuclear (from the central sector), wind, and solar energy. Furthermore, its long coastline and good ports offer better possibilities for importing fuels, including LNG and coal. Agriculture accounts for some 45% of electricity sales; industry 36%; and domestic consumers 15%. The financial, technical, and operational performance of the AP State Electricity Board (APSEB) has been better than that of BSEB, although (as in Bihar) T&D losses (estimated at 32%) are still high.

B. The Concept and Scope of a Global Overlay

Concept

The World Bank routinely carries out energy sector work in its client countries, often in association with restructuring efforts. Such sector work analyzes the implications of pursuing existing policies under a business-as-usual (BAU) scenario as well as changes that are associated with energy sector reform and restructuring. These analyses will cover economic, financial, and technical issues, but not necessarily environmental impacts. The objective of a global overlay is to add to these analyses—or "overlay" them with—a systematic process for assessing the GHG implications of BAU and reform; and to design and cost a new scenario, known as the GHG Mitigation Scenario, to reduce GHG emissions.

Scope

Usually a global overlay covers the energy sector for an entire country. It calculates GHG emissions for the production, transmission, distribution, and consumption of both imported and indigenous fuels, i.e., the related emissions are calculated wherever they occur in the world; and its scope is limited to carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). In this work, only two states within India were covered, although it should be noted that the population in each state is greater than that of many entire countries: the population of Bihar is about 100 million, and that of AP about 70 million. The work also limited its scope to the power sector in AP and Bihar, although it traced back down the entire fuel chain to calculate GHG emissions caused by the production, transmission, and distribution of all fuels used by the power sector, both in India and overseas. However, it did estimate the contribution of the power sector to total GHG emissions in each state. In Bihar, it was found that the power sector contributed 4.9 million metric tons (Mt) of carbon equivalent in 1995-96 out of a total of 16.6 Mt, i.e., 30%. Most of the carbon emitted from the power sector (4.7 Mt) came from coal burning. In AP, for the base year 1996-97, the total emissions of carbon equivalent were estimated at 18.4 Mt, to which the power sector contributed 9.2 Mt or 50% of the total.

C. Methodology

Overview

The implementation of the global overlays required load forecasts and power development plans (investment program and operating regime) for both the BAU and the Reform scenarios. The GHG emissions associated with those load forecasts and power development plans were then estimated. Next, a set of GHG mitigation options was identified and appropriate GHG mitigation scenarios formulated. The difference between GHG emissions and total power system costs under the BAU, Reform, and GHG Mitigation scenarios were compared; and the end result was an estimate of the incremental cost of GHG reduction. In general, that result is important for the World Bank's clients, because it could form the basis for (i) financing from the World Bank and the Global Environment Facility (GEF); (ii) the creation of opportunities under joint implementation or carbon trading arrangements; and (iii) the clearer identification of the "win-win" opportunities presented by energy pricing and energy sector reform. It is emphasized that no attempt was made to link the Reform scenario with any particular institutional or managerial model in either AP or Bihar, nor to patterns of ownership. Rather, the global overlays proceeded on the basis of reasonable assumptions and judgements about the likely economic and technical consequences of reform, in terms of the growth rate of the economy, electricity tariffs, and the efficiency of the power system.

Load Forecasts

The two case studies projected the unconstrained energy (GWh) and power (MW) demand over a 20-year planning horizon for the BAU and Reform scenarios, broken down by the main consumer categories, viz.:

- Domestic
- Commercial
- Low tension (LT) and high tension (HT) industry and
- Agriculture.

Econometric modeling, combined with judgements based on experience in other countries, was used to estimate the income and price elasticities for each consumer category. Given specific assumptions and projections about income growth and likely tariff changes for each consumer category, it was possible to forecast sales of energy and maximum demand.

(i) Bihar

In the case of Bihar, BAU load forecasts were made for both low-growth and high-growth assumptions about Gross State Domestic Product (GSDP), maintaining the existing sectoral shares constant over the planning period. The projected GSDP growth rates are in Annex I.1. As far as electricity prices are concerned, it was anticipated that tariff increases would be modest and confined to the residential and agricultural sectors, where tariffs are currently set well below costs. The assumptions are in Annex I.2. The sectoral income and price elasticities are those derived for EIPS (*India: Environmental Issues in The Power Sector, ESMAP Report No. 205/98, June 1998*, Table 2:14), reproduced in Table 1.

Table 1: Price and Income Elasticities by Sector in Bihar under BAU and Reform[1]

Sector	Income Elasticity	Price Elasticity
Residential	1.75	-0.30
Commercial	1.27	-0.26
Industrial	1.5	-0.20
Agriculture	1.5	-0.20[2]

1. Econometric techniques were used to estimate the price and income elasticities. Time-series data for 1985-86 through 1993-94 were pooled over 19 states in India for each consumer sector. The study considered two types of linear models, one with a lagged effect of electricity price on the explanatory variable and another without the lagged effect. Since the available data covered nine years, a lag model of only one year could be considered to estimate the long-run price elasticities for each sector. However, the estimates for income and short-run price elasticities were made using an unlagged functional form.

Source: "Elasticities of Electricity Demand in India," TERI, New Delhi, March 1997.

2. The Agriculture price elasticity is (–0.10) under Reforms.

For the purposes of the global overlay, in approaching the Reform scenario, it was assumed that power sector reform would start in Bihar in the year 2000 and be completed over a seven-year period. It can be expected that reform would induce faster growth rates for GSDP, under both low-growth and high-growth assumptions, as depicted in Annex I.3. Furthermore, under reform, it should be possible to increase the tariff level, to allow the utility to earn an acceptable return on equity (taken as 16%). However, bearing in mind the experience so far in reforming states such as AP and Haryana, it was assumed that there would be constraints on adjusting the tariff structure. In particular, agricultural tariff increases are limited, going from the existing level of Rs. 0.15/kWh to Rs. 1.50/kWh from 2003 to 2006 and reaching only about 50% of the supply cost by 2007. Accordingly, the tariffs of other sectors were adjusted so as to achieve a 16% return on equity, as shown in Annex I.4.

Finally, the sectoral income and price elasticities are kept the same under Reform as in the BAU scenario, except for agriculture, which is reduced to reflect the expectation that an integrated agricultural demand-side management (DSM) program would already have been implemented as part of the reform package (see Table 1). This program would include the metering of agricultural pumpsets and a variety of technical measures—see the discussion of Power Development Plans, Section (ii)a below.

The combined results of these different assumptions underlying the load forecasts for Bihar are summarized in Table 2.

Table 2: BAU and Reform: Forecasts of Energy (GWh) and Maximum Demand (MW) for Bihar, 1997-2015

Scenario	1997	2015	Growth Rate (% p.a.)
BAU Low Growth			
MW	2,374	5,751	5.0
GWh	12,205	27,473	4.6
BAU High Growth			
MW	2,374	6,937	6.1
GWh	12,205	32,900	5.7
Reform Low Growth			
MW	2,374	4,471	3.6
GWh	12,205	25,635	4.2
Reform High Growth			
MW	2,374	5,988	5.3
GWh	12,205	34,500	5.9

(ii) Andhra Pradesh

In the case of AP, load forecasts were based on a single projection for the growth rate of GSDP, maintaining the shares of each consumer category constant over time. The GSDP growth rate assumptions for BAU and Reform are in Annex I.5. As far as electricity tariffs are concerned, it was anticipated that there would be no real price increases under BAU, with the tariff being merely adjusted for inflation. The specific assumptions for tariff increases made for the Reform scenario were as follows: for the industrial sector, the nominal tariff was capped by the assumed nominal cost of self-generation (about Rs. 4.4/kWh at 1998 prices). The LT industrial tariff was assumed to decline from the present Rs. 3.3/kWh to about Rs. 3.0 /kWh by 2007 and remain constant thereafter. The agricultural tariff was assumed to increase to 50 percent of supply cost by 2008 (about Rs. 1.5 /kWh at 1998 price levels). The domestic tariff was increased to Rs. 2.25 /kWh (1998 price levels) by 2007 and kept constant in real terms thereafter. The commercial tariff was increased to Rs. 4.3/kWh by 2001, and then allowed to decline to Rs. 3.8 /kWh by 2007 and kept constant thereafter. The sectoral income and price elasticities, summarized in Table 3, were taken from the analytical work carried out for the World Bank's ongoing *First AP Power Sector Restructuring Project* and EIPS. In the AP global overlay, no explicit program of DSM was envisaged under Reform, beyond the energy conservation induced by tariff increases. The combined results of these different assumptions underlying the load forecasts for AP are summarized in Table 4.

Table 3: BAU and Reform: Price and Income Elasticities for AP by Sector

Sector	Price Elasticity	Income Elasticity
Domestic	-0.4	0.33
Commercial	-0.4	1.01
Agriculture	-0.2	1.58
LT Industry	-0.3	0.49
HT Industry	-0.3	1.06

Table 4: BAU and Reform: Forecasts of Energy (GWh) and Maximum Demand (MW) for AP, 1998-2018

Scenario	1998	2018	Growth Rate (% p.a.)
BAU			
MW	5,581	13,840	4.7
GWh	37,060	91,900	4.7
Reform			
MW	5,581	25,546	7.9
GWh	37,060	169,630	7.9

Power Development Plans

In principle, the supply-side candidate options available for the power development plans covered the following fuels in Bihar and AP: coal, gas, petroleum products, nuclear, and renewables. For Bihar, the information on supply-side options is summarized in Annexes

II.1 and II.2; and for AP in Annexes II.3 and II.4. All the costs shown are the estimated economic costs of the supply options, using the results of the earlier work published in EIPS. Also, energy efficiency options are available to reduce the generation requirements at the busbars, i.e., DSM (energy conservation) and T&D loss reduction programs. In practice, all these options had to be carefully adapted to the conditions in each state, under the BAU, Reform, and GHG Mitigation scenarios.

(i) Business as Usual (BAU) Scenario

The power development plans for Bihar and AP under the BAU scenario are based on actual plans, known projects, and judgments about the investments that are likely to take place in the sector in the absence of reform. The supply options are selected, therefore, from a highly restricted menu. The resulting power development plans do not reflect least-cost solutions to meet the anticipated demands, but rather evaluations of what is feasible, given the financial situation of the sector. Inevitably, due to the poor financial situation in both the case study states, new capacity under BAU is insufficient to meet growth in potential demand.

In Bihar, the power development plan under the BAU scenario includes only the emergency rehabilitation of existing coal plants (Patratu, Barauni, and Muzaffarpur) and some extensions (2x210MW) at the Tenughat coal-fired plant run by the National Thermal Power Corporation (NTPC) in 2003 and 2005. Otherwise, the purchases of power from the central sector (NTPC) remain constant at the current level. Given the inevitable supply shortages, the capacity of captive power plants is assumed to increase to 50% of the incremental HT industrial and commercial loads. In AP, a similar approach was used by allowing the power development plan to include only certain committed coal-fired plants, known to be under implementation through the year 2005. Captive generation is assumed to increase to meet 60% of the shortfall in energy. No investment in T&D loss reduction occurs under BAU in either AP or Bihar.

(ii) Reform Scenario

The power development plans for the Reform scenario, in contrast to BAU, are offered more supply options, because the financial situation of the sector is assumed to improve. Consequently, power shortfalls are gradually eliminated and all power requirements eventually met. In that sense, the power development plan can be constructed based on a least-cost solution, although the range of supply options made available is limited to known plans (if any) and the options that are judged to be feasible (on economic, financial, and political grounds) in a newly reforming system. Hence, some options are still constrained in amount or excluded entirely from the Reform scenario, as discussed below.

a. *Bihar*

In Bihar, starting in the year 2000, the target under Reform is to eliminate curtailments over a seven-year period. At present, BSEB draws only half of its entitlements (in energy terms) from NTPC as a consequence of its financial distress (about 3,700 GWh in 1996). Under the reform scenario, tariff increases would help to restore the sector's financial strength, and power supplies could progressively increase from NTPC plants, until the sector reaches its full entitlement of 6,500 GWh by 2004. Rehabilitation of BSEB's thermal plants (Patratu, Barauni, and Muzzafarpur) could commence immediately, targeted at remedying the most serious environmental and operational problems: plant availability could increase from the present levels of 18-25% to 50%. However, the old 50 MW units are assumed to be retired gradually by 2004. In line with current practice in reforming states in India, and to offset the uncertainty related to hydro plants, open-cycle combustion turbines (OCCT), fuelled by naphtha, are forced into the expansion plan for peaking purposes: the first is commissioned in 2005. Bihar has substantial quantities of coal to supply extensions to the existing thermal plants (at Patratu, Tenughat, and Muzzafarpur) and new base-load power stations (e.g., Katihar, Chandil, and Nabinagar). For convenience, a generic coal plant, based on the characteristics of Nabinagar, was used to represent new candidate coal-fired stations (Annex II.1).

Preliminary screening analysis demonstrated that neither nuclear power nor clean-coal technologies, such as IGCC or PFBC, would compete with Nabinagar: they were therefore not candidate options under Reform, but were considered as GHG mitigation candidates. Similarly, Bangladesh gas and coal washing were not made available, because the former hinges on decisions outside the power sector and the latter would require a much broader set of reforms across the energy sector: they were analyzed only as GHG reduction candidates.

As far as renewables are concerned, there is considerable uncertainty over Bihar's remaining major hydro projects (Annex II.2). The largest of these is the 710-MW Koel-Karo project, which has recently been given to the National Hydro Power Corporation (NHPC) for implementation. This project involves the resettlement of some 50,000 people in a tribal area, as a result of which little progress has been made over the past 20 years. The project is therefore omitted from the Reform case and considered for GHG mitigation. The most attractive of the other large hydro options is Kadwan, a 450-MW project that could be built at the Kadwan irrigation scheme. Power generation would be incidental to irrigation, and it is considered as a candidate powerhouse-only project for Reform. A large number of potential mini-hydro schemes exist in Bihar and were considered as candidate options for Reform. However, the import of electric power from hydro plants in Nepal, like Bangladesh gas, will depend on decisions outside the power sector; solar photovoltaics (PVs) are still uneconomic for grid supply; and the use of bagasse appears unlikely to be taken up under Reform: these supply options were therefore retained only for GHG mitigation.

The energy efficiency measures introduced under Reform cover DSM and T&D loss reduction. Specifically, the rehabilitation of the T&D network is expected to reduce technical losses from the existing level of 28% to 18% by 2004, while nontechnical losses fall from 9% to 4% by 2004. The DSM program in the Bihar Reform scenario is based on the Integrated Agricultural DSM Project proposed for the state of AP. It combines improvement of the power distribution system, by converting low voltage (LV) feeders to high voltage (HV) feeders; the introduction of automated load control, to facilitate the supply of nonagricultural customers; and the installation of high-efficiency pumpsets and associated pipes and valves. Due to the substantial investment requirements, the program is implemented in a phased manner: 15% of total customers are covered in 2000, and an additional 30%, 45%, 60%, 75%, and 100% of customers are covered in 2001, 2002, 2003, 2004, and 2005, respectively. Starting in 2005, all customers are assumed to be covered under this scheme for the total study period. At the same time, the number of customers grows by 1% p.a. The main characteristics and outcome of the DSM program are in Table 5.

Table 5: Estimated Characteristics and Outcome of DSM Program in Bihar under Reform, 2000-2015

Parameters	2000	2002	2007	2012	2015
Total number of Customers ('000s)	276	282	295	311	321
DSM Coverage (%)	15	45	100	100	100
Energy savings (GWh)	181	553	1290	1356	1397
Cost of energy savings (Rs./kWh)	0.85				

Note: The cost of energy savings is defined as the ratio of the present value (PV) of the cost of energy saved to the PV of energy saved.

b. Andhra Pradesh

In AP, all plants currently scheduled for construction or under consideration were allowed under the Reform scenario. These plants consume either naphtha or coal, as shown in Annex II.5. Additionally, the candidate options in Annex II.3 cover the Jurala hydroelectric plant; generic conventional coal plants, located at the pit-head or near load centers and using domestic coal (from Singareni or Talcher) or imported coal; clean-coal technology (PFBC); LNG, naphtha and nuclear plants; and plants using various forms of renewable energy, such as wind, bagasse, solar, and mini-hydro. The possibility of generating power using refinery residues was also explored. In terms of the energy efficiency measures introduced under Reform in AP, T&D losses were assumed to drop from the current level of about 32% to 15%, although no explicit program was implemented for DSM.

(iii) Greenhouse Gas (GHG) Mitigation Scenario

The power development plans for the GHG Mitigation scenario in Bihar and AP essentially force in the options that were constrained or excluded under Reform, or even rejected under Reform as not part of the least-cost solution. These options are forced in so that their effectiveness as GHG mitigation options can be explicitly examined. In most cases, it is expected that special policies or initiatives would normally be required to overcome the obstacles to their implementation. Initially, each option is forced into the Reform development plan individually, to assess its cost per metric ton of GHG emissions mitigated. This cost is defined as the change in total power system costs, relative to the Reform scenario, divided by the reduction in GHG emissions, relative to the Reform scenario. In a second stage, combinations of individual options are formed, to evaluate the cost per metric ton of alternative mitigation scenarios. The GHG mitigation options considered in Bihar are shown in Annex II.6 and those for AP in Annex II.7.

a. *Bihar*

As already discussed under the options provided for the Reform scenario in Bihar, nuclear power, Bangladesh gas, and coal washing were not included as candidates for the Bihar Reform scenario, but instead were considered as GHG mitigation options. Nuclear power is considered a candidate because of the absence of GHG emissions, despite other obvious environmental problems and considerable uncertainty surrounding the costs. For Bangladesh gas, it is assumed that the gas would be imported by pipeline and burned in combined cycle gas plants at Calcutta. An allowance has been made for the additional cost of transmission lines and for transmission losses from Calcutta to Jamshedpur. Two alternatives were considered in estimating the sensitivity of the cost of GHG reduction with respect to the cost of gas imports. For the coal washing option, the costs were taken from the EIPS (ESMAP Report No. 213/99, p. 103).

In terms of renewables, as explained above, solar PVs, bagasse, the large Koel-Karo hydroelectric project, mini-hydro, and imports of hydroelectric power from Nepal were retained as supply options only for GHG mitigation. Although solar PVs are still uneconomic for grid supply, they have obvious environmental benefits, especially from a GHG reduction viewpoint. On the expectation that further substantial technical progress can be anticipated to reduce their capital costs, their low operating costs may bring total costs per kWh down to a competitive level in the future. The global overlay for Bihar therefore took two alternatives, with the capital costs of solar PVs at about US$5/Wp in one case (in line with current technology), and the capital costs reduced by 50% in the other. The abundant supply of sugarcane in the Ganga plains of North Bihar and in eastern Uttar Pradesh make bagasse available in large quantities. However, the economic use of this solid residue from sugarcane crushing will be limited by its value in alternative uses, like paper manufacture, and the cost of transportation, given its low calorific value. In face of the uncertainties about supply and costs for power generation, the total likely available capacity was restricted to two units of 210 MW (a net capacity addition of 380 MW), which were analyzed under two alternative assumptions using differing costs. To assess the impact of the Koel-Karo project as a GHG reduction measure, it was forced into the plan in 2010, after the Kadwan project.

For the purposes of the global overlay, two tranches of mini-hydro projects were considered, based upon projections made by the Bihar Hydroelectric Power Corporation (BHPC). Only the first was offered in the Reform scenario, as the cost figures projected for the second tranche were regarded as much more uncertain. The second tranche was therefore forced into the development plan as a GHG mitigation option, with a higher capital cost than the first tranche.

For Nepal hydro, the global overlay collected information on projects that had been identified by the Government of Nepal for future development and that might be suitable for export to India. The results are in Annex II.8. Out of the identified projects, Kaligandaki-A and Kaligandaki-II were identified as the most likely sources of power imports from Nepal to reduce GHG emissions. The total capacity imported was restricted to a maximum of 500 MW until 2015. The additional transmission line costs were included in the total project costs and allowance was also made for additional transmission losses. The option was considered under two alternatives, to reflect different possible timings for Kaligandaki-II.

PFBC and IGCC were selected as the possible clean-coal technologies for GHG emission reduction. While the thermal efficiencies and environmental benefits of both of the processes are comparable, the capital costs of PFBC are lower at present. However, both alternatives were examined under the GHG mitigation scenario, by forcing all new Bihar coal-based units to incorporate either IGCC technology from 2004 onward, with the costs shown in Annex II.1, or PFBC technology, from the same date, but with the capital cost per kW being 20% lower than for IGCC.

Finally, more aggressive energy efficiency measures were introduced under the GHG Mitigation scenario than under Reform, both for DSM and T&D loss reduction. Further rehabilitation of the T&D network was envisaged to bring technical losses down to 13% by 2010; while nontechnical losses fall from the existing 9% to 4% by 2004. After reviewing the work done under EIPS, taking into account administrative and financial constraints, an additional DSM program was designed for the Bihar GHG Mitigation scenario, adding energy-efficient refrigerators and urban lighting by compact fluorescent lamps (CFL) with electronic ballast. The salient features of the program are in Tables 6 and 7.

Table 6: Salient Characteristics and Outcome of DSM Program for High-Efficiency Refrigerators in Bihar under GHG Mitigation Scenario, 1997-2015

Parameter	1997	2002	2007	2012	2015
Participants ('000s)	7.1	104.5	542.4	1068.1	1340.2
Energy Savings (GWh)	1.3	19.1	99.3	195.5	245.3
Benefit to Consumers (Rs. Million)	(-) 2.12	8.08	226.67	481.95	612.19
Benefit to Utility (Rs. Million)	0.90	22.49	27.45	64.74	83.47
Cost of Energy Saved (Rs./kWh) 0.40					

Note: The cost of energy savings is defined as the ratio of the present value(PV) of the cost of energy saved to the PV of energy saved.

Table 7: Salient Characteristics and Outcome of DSM Program for Urban Lighting in Bihar under GHG Mitigation Scenario, 1997-2015

Parameter	1997	2002	2007	2012	2015
Participants ('000s)	11.51	32.14	88.67	209.31	274.38
Energy Savings (GWh)	2.3	6.3	17.5	41.2	54.1
Benefit to Consumers (Rs. Million)	2.25	8.01	44.55	108.06	140.95
Benefit to Utility (Rs. Million)					
Cost of Energy Saved (Rs./kWh)	0.59				

Note: The cost of energy savings is defined as the ratio of the present value (PV) of the cost of energy saved to the PV of energy saved.

b. *Andhra Pradesh*

The broad range of candidate plants considered in AP for the GHG Mitigation scenario was similar to that in Bihar, although some differences are worth mentioning. These arise partly from differences in the particulars of the situation, the quality of available information, and the methodology used. As in Bihar, nuclear power, clean-coal technologies (IGCC and PFBC), and renewable energy options such as wind and solar PVs were found to be too expensive to form part of the least-cost solution for Reform. Again as in Bihar, coal washing could not reasonably be included in the Reform development plan, because it would require a much broader set of reforms, outside the power sector. These options were therefore forced into the development plan for the GHG Mitigation scenario in AP.

Plant rehabilitation, the Jurala hydroelectric scheme, and bagasse generation were considered under the GHG Mitigation scenario because it was judged unlikely that they would be taken up without special initiatives. The performance of power plants in AP is for the most part better than in Bihar, so that a general program of rehabilitation is unnecessary. However, the particular case of Kothagudam A was selected for detailed study to represent the possible GHG reduction benefits of plant rehabilitation. The Jurala hydroelectric scheme served as a proxy for other medium-sized hydroelectric power stations. Cogeneration from bagasse may not be large in AP, and in any case has not been developed, because the sugar industry has preferred to supply such wastes to the paper manufacture industry. In contrast to Bihar, available evidence for AP on mini-hydro was not encouraging and for reasons of cost these schemes were regarded as interesting for GHG reduction rather than as candidates for construction under Reform. Several mini-hydro projects are under consideration and even under construction, and generation is available from mini-hydro schemes, especially during periods of peak agricultural demand. However, one of the most formidable obstacles faced by irrigation canal drop schemes is the need for coordination with the state irrigation departments. LNG was considered under Reform but it was judged more realistic to set limits on the total capacity that might be installed, given the need for associated infrastructure at the LNG terminals and likely political concerns over extending too far India's dependence on a relatively new source of imports. The constraint was removed only to investigate the impact of increased LNG usage on GHG emissions.

The option of using refinery residues for power generation was not considered in the Bihar global overlay. As mentioned under Reform, it was given consideration in AP, due to strong interest in establishing a plant at Visakhapatnam. According to the detailed work carried out under the AP case study for EIPS, this option would use refinery residual fuel oil having a gross calorific value of 7400 kcal/kg. Power could be generated using conventional steam generators, Fluidized Bed Combustion Technology (FBC), or the Integrated Gasification and Combined Cycle System (IGCC). The main benefits would come from reducing local pollution, but GHG emissions would also be reduced. From an efficiency and environmental perspective, IGCC, with a plant efficiency of about 43%, scores over the other technologies. The costs for power generation would be sensitive to the location and it is difficult to arrive at generic generation costs. With the costs shown in Annex II.3, which incorporate the data available to ASCI from its special study of refinery residues, the option would not be picked up under the Reform scenario. Hence, it was forced into the development plan for the GHG Mitigation Scenario, with residual fuel oil being used for power generation with the IGCC process.

Although the AP global overlay had no explicit DSM program under Reform, two ambitious sets of measures were provided for GHG mitigation. Detailed information for both was drawn from earlier work identified by the Integrated Resource Planning (IRP) study of APSEB, conducted by consultants in 1996 and funded by USAID. The first set of measures relates to lighting, including lighting for urban, municipal, commercial, and rural situations. The main features are summarized in Table 8 and the details are shown in Annex III.1. The second set is based on the Integrated Agricultural DSM Project for AP, which also informed the Bihar Reform Scenario, as described above. The main features are summarized in Table 9 and the details are shown in Annex III.2. To complement these energy efficiency measures, the AP GHG Mitigation scenario postulated a more far-reaching T&D loss reduction program than under Reform, to bring down losses further, from 15% to 10% by 2010.

Table 8: Main Features of DSM Lighting Program in AP under GHG Mitigation Scenario, 1999-2015

	1999	2002	2005	2010	2015
Urban Lighting	4.3	48.1	125.3	160.9	43.9
Municipal Lighting (Sodium Vapor)	0.2	3.7	12.6	21.6	9.8
Municipal Lighting (Fluorescent)	0.5	8.0	26.8	46.1	20.9
Commercial Light (Electronic Ballast)	2.7	50.1	233.4	484.4	259.6
Commercial Lighting (CFL)	1.5	26.0	100.5	52.0	52.0
Fluorescent Lamp Standards	49.7	366.0	774.3	1292.0	2080.7
Rural Lighting	6.1	97.0	269.0	475.0	456.1
Total Savings (GWh)	65	598.9	1541.9	2532.0	2923.0

Modeling the Power Systems

In order to examine the implications of these power development plans for GHG emissions, a computational tool is needed to:

- Simulate the operating regime of the BAU scenario;
- Construct and simulate the least-cost solution to meet the unconstrained demand of the Reform scenario, albeit limiting the least-cost solution to a subset of the full range of potential options represented by any known plans and the options that are judged to be feasible;
- Calculate emissions of GHG for both BAU and Reform;
- Simulate the incremental impact of individual GHG reduction options; and
- Simulate the incremental impact of selected GHG mitigation scenarios (i.e., using combinations of options to achieve target reductions in GHG emissions).

Both of the case studies relied heavily on a least-cost power system expansion planning software called A/SPLAN (designed by Analytical Solutions – A/S – of Bayport, New York). A/SPLAN is based on the WASP model (the Wien Automatic Simulation Package, produced by the International Atomic Energy Agency) and employs a dynamic programming algorithm.

Table 9: Main Features of Integrated Agricultural DSM Project for AP under GHG Mitigation Scenario, 1999-2015

		1999	2002	2005	2010	2015
Number of Pumpsets (Millions)		1.791	1.901	2.017	2.227	2.459
Energy Savings (GWh)		0	132	955	4,304	4,788
Capital Costs (Rs. Million)		0	1,860	5,579	5,114	0
Operating Costs (Rs. Million)		0	28	201	908	1,010
Misc. Benefits[1] (Rs. Million)		0	-62	-446	-2,009	-2,235
Total costs (Rs. Million)		0	1,826	5,334	4,013	-1,225
NPV[2] (Rs. Million)	16947					

Notes:
1. Miscellaneous benefits include: reduced motor rewinding costs, deferred purchase of pumps, and reduced transformer and Power Factor correction costs.
2. A 12% discount rate was used to calculate the net present value (NPV).

A/SPLAN has three primary modules, viz.:

- A load module
- A production cost module, and
- A report module.

(i) The Load Module

The basic inputs for the load module are the hourly time series data for energy, according to the season (rainy, dry, winter) and consumer category (residential, commercial, industrial, and agricultural). A/SPLAN then constructs stylized annual, seasonal, and daily load duration curves (LDCs), which feed directly into the production cost module.

(ii) The Production Cost Module

The production cost module carries out a probabilistic simulation to minimize the total discounted system costs of the power system over a given time horizon, using a 12% discount factor. It combines the scheduled and forced plant outage rates with the LDCs to calculate the Loss of Load Probability (LOLP) and the Energy Not Served (ENS). LOLP is a measure of power system reliability and is defined as the probability that load shedding will occur in any given year. It takes a value between zero and one. It is possible to specify LOLP and A/SPLAN will optimize the power system to achieve that particular level of reliability. For example, in Bihar, LOLP was set at 0.05 (5%), meaning that load shedding would occur on average in 438 hours per year, compared with an LOLP that currently exceeds 40%, or 3504 hours per year. Alternatively, as in AP, the analyst can specify a cost per unit of ENS and the model will select a value for LOLP to optimize the power system, i.e., by balancing the cost of increasing the reserve margin against the savings in cost of a consequent reduction in the amount of ENS. In AP, LOLP also now exceeds 40%, and the cost of ENS was fixed at ten times the average tariff for the purposes of the global overlay. It is interesting to note that this assumption led to the same result as in Bihar, i.e., an LOLP of 5%. The key results of the system simulation are estimates of system production costs (for operation, maintenance, and investment); the consumption of different fuels (based on inputs for the heat rates and unit costs of the fuels); and undiscounted emissions of GHG for the simulated power sector.

A/SPLAN can be run using either financial or economic costs. In these two global overlays, economic costs were used for all investments and fuels, i.e., they exclude taxes and add back subsidies. Furthermore, they include estimates of the costs necessary to meet environmental standards in the electric power and coal mining sectors and to that extent internalize the costs of local environmental impacts.

The emissions of GHG for the simulated power sector are calculated directly from the consumption of different fuels, as estimated by A/SPLAN, using emissions factors. The CO_2, CH_4, and N_2O emissions factors used in the two case studies are based on the IPCC default values, as reported in the World Bank's *Guidelines for Climate Change Global Overlays* (Environment Department Paper No. 047, Climate Change Series, February 1997), Exhibits 4-6 and 4-9, except for the burning and mining of coal, where the coefficients were adapted to fit the particular conditions in India. The emissions factors used for CO_2 attributable to coal burning in the power sector, the single most important source of GHG emissions in the power sectors in Bihar and AP, were 25.9 metric tons of carbon per TJ in Bihar and 26.3 metric tons of carbon per TJ in AP. The IPCC default emissions factors for CO_2 from other fuels are in Table 10.

Generation of electricity from captive power generation and the corresponding emissions, which increase under BAU and decrease under Reform, respectively, were calculated outside A/SPLAN, by estimating the amount of captive generation, in KWh, and applying the same emissions factors. Methane emissions associated with the mining of coal as well as emissions during postproduction stages also had to be calculated outside A/SPLAN, for both domestic and imported coals. A/SPLAN estimates the amount of coal-based power generation, in GWh, from imported and domestic coal separately. From these, it is possible to derive estimates of the quantity of imported and domestic coal required by the power sector. Methane emission factors for domestic coal mining in India are summarized in Table 11, according to the type of mining employed. Most of the coal used in Bihar and AP is produced from open-cast or Degree I underground mines. It is anticipated that this will remain true in the future, and further assumed that the same factors can be applied to imported coal. The case studies ignored the emissions of methane associated with the production of liquid fuels because of their low contributions to the overall methane generated.

Table 10: Carbon Emissions Factors for Liquid Fuels

Product	Carbon fraction (metric tons/TJ)
Natural Gas	15.3
Diesel Oil	20.2
Residual Fuel Oil	21.1
Naphtha	20.0

Source: IPCC Guidelines for National GHG Inventories, Vol. 3: GHG Inventory Reference Manual, cited in the World Bank's Guidelines for Climate Change Global Overlays (Environment Department Paper No. 047, Climate Change Series, February 1997).

Table 11: Methane Emissions from Coal Mining Activities

Mining Category	Methane Emissions (m^3/metric ton)	
	During Mining	Post Mining
Open Cast	1.00	1.09
Underground		
Degree I	1.00	0.09
Degree II	10.00	1.07
Degree III	23.03	3.50

Note: "Degree" is a measure of "gassiness" in the mine, with higher degrees representing higher concentrations and emissions of inflammable gas.

Source: The Climate Change Agenda—An Indian Perspective, TERI, 1993.

Further adjustments were required outside A/SPLAN to combine the three different types of GHG emissions and express them as CO_2 or carbon equivalent (using weights reflecting their relative global warming potential). For the purposes of the analysis, the GHG potential of N_2O was considered to be 320 times that of CO_2, while the GHG potential of CH_4 was taken to be 24.5 times when compared to CO_2, using the 100-year time-frame recommended by the IPCC (see the World Bank's *Guidelines for Climate Change Global Overlays*, Environment Department Paper No. 047, Climate Change Series, February 1997, Exhibit 3-2). The AP results were expressed in terms of CO_2, but this is easily converted to carbon, using the molecular ratio of CO_2 to carbon, i.e., 44/12.

(iii) The Report Module

The report module prepares and prints out the detailed results for every year in the planning horizon. Most importantly, it includes for each plant in the system, and for the system as a whole, the generation (in kWh); emissions (SO_2, CO_2, N_2O, PM and CH_4); consumption of each fuel; and operating and investment costs. It also reports, for the overall system, the reserve margin and LOLP.

D. Results

GHG Emissions Under Bau and Reform

Table 12 summarizes the results of the GHG emissions analysis for BAU and Reform in AP and Bihar, and the LOLP that results for the given demand projections and permissible supply options. The main conclusion from Table 12 is that BAU cannot be applied as a meaningful baseline scenario for GHG mitigation analysis in these two case studies. While GHG emissions are lower under BAU than under Reform in AP and in Bihar (under the high-growth demand projection), the expected energy served is also substantially less. LOLP increases dramatically under BAU in both states: from 42% in 1998 to nearly 100% in 2015 in AP; and from 41% in 1996 to 73% and 86% in 2015 under the low-growth and high-growth scenarios, respectively, in Bihar. Under Reform, LOLP improves to a reasonable value of less than 5%. The massive expected failures in supplying electric power that would take place under BAU conditions could not be regarded as an acceptable GHG control policy in India or elsewhere. Hence, only the Reform scenario was selected as a baseline reference point for all GHG reduction analysis, especially when calculating the incremental costs.

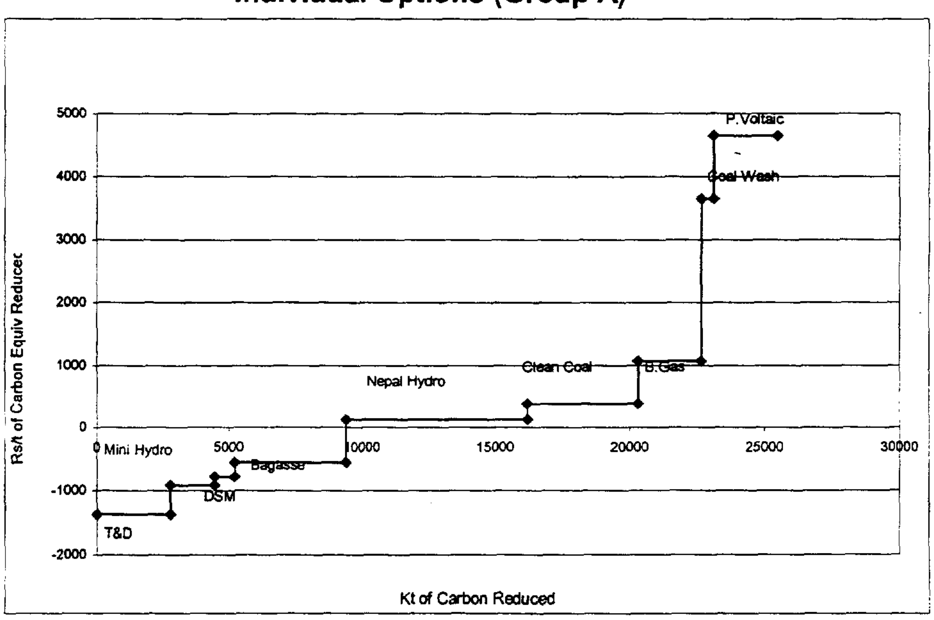
Table 12: GHG Emissions and LOLP under BAU and Reform: AP and Bihar

Scenario	Equivalent Carbon (Mt)	LOLP in 2015 (%)
AP		
BAU	323.5	99.6
Reform	520.1	4.2
Bihar		
BAU (LG)	100.7	73.4
BAU (HG)	101.7	86.4
Reform (LG)	91.1	4.5
Reform (HG)	105.9	3.9

Incremental Impact of Individual GHG Reduction Options: GHG Mitigation Option Supply Curves

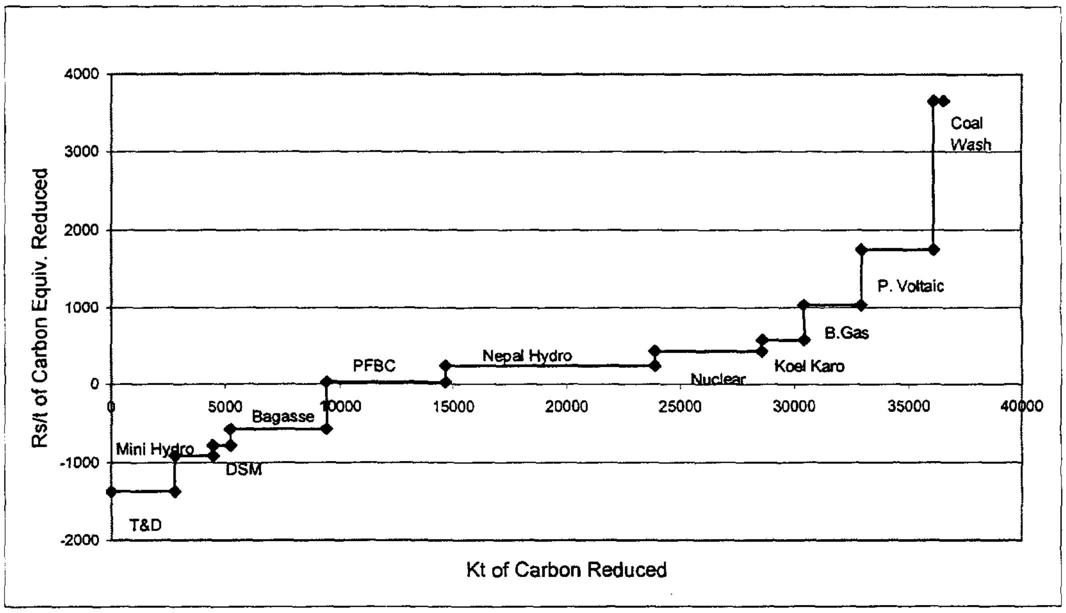
In light of the above conclusion, the individual GHG reduction options are initially evaluated against the Reform scenario by inserting them, one at a time, into the optimal power development program for Reform and assessing the impact on undiscounted GHG emissions and the present value of total system costs, using a 12% discount rate. For any specific option, the ratio of the change in undiscounted GHG emissions to the change in the present value of total system costs provides a preliminary screening value for the cost-effectiveness of that option, expressed as a cost per metric ton of carbon or per metric ton of CO_2. The results of the individual options considered for Bihar are in Figures 1 and 2; and those for AP are in Figure 3.

Figure 1: Bihar — GHG Mitigation Option Supply Curve — Individual Options (Group A)



In the case of Bihar, the set of possible options was divided into two groups: Group A included the options that were judged more likely to be achieved; and Group B considered some alternative assumptions, that were mutually exclusive, and regarded as less likely to be achieved. The Groups are identified in Table 13. The GHG mitigation option supply curve for Group A is in Figure 1; and that for Group B in Figure 2. These supply curves rank the options, from the lowest to the highest cost, by the cost per US$ per metric ton of carbon equivalent reduced. The high-growth assumptions for the growth of GSDP were used throughout the analysis of GHG mitigation options in Bihar.

Figure 2: Bihar — GHG Mitigation Option Supply Curve — Individual Options (Group B)



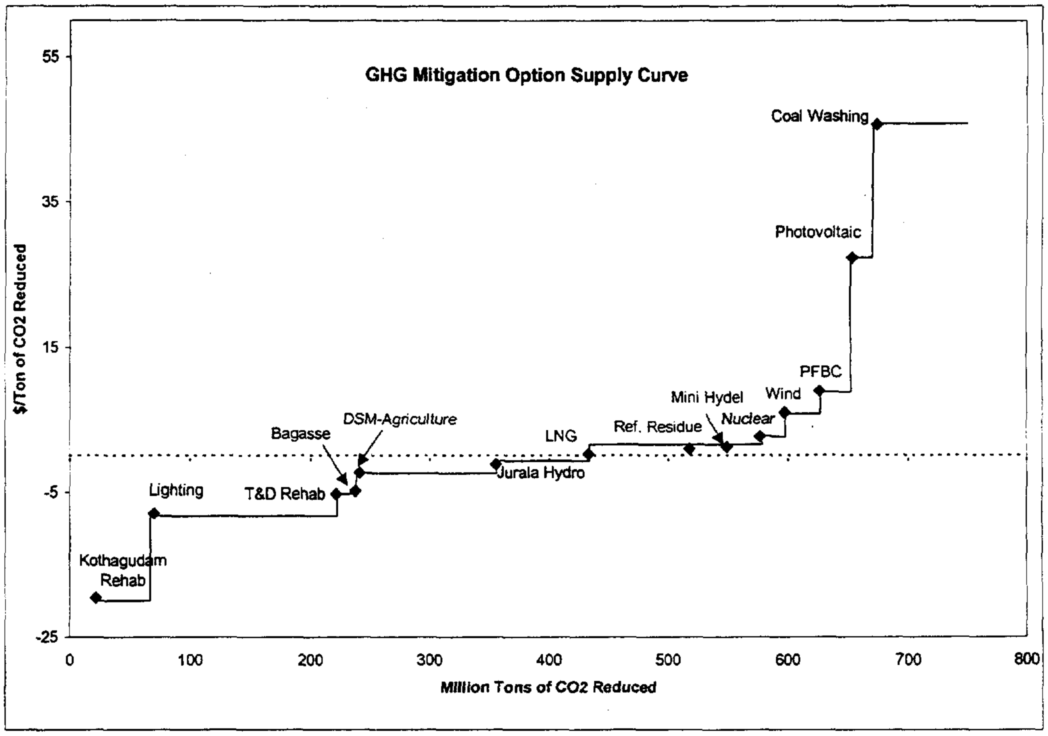
The ranking of options in Figure 1 shows that the following have a negative cost and would therefore be classified as "win-win": T&D rehabilitation beyond the degree assumed under Reform; mini-hydro; the additional DSM measures beyond Reform; and bagasse. The remaining options reduce GHG emissions at a cost: imported Nepal hydro; clean coal (PFBC); imported Bangladesh gas; coal washing; and solar PVs. The change in the ranking of options in Figure 2 corresponds to (i) the introduction of more optimistic assumptions about the costs of PFBC compared with IGCC, which bring the costs of clean coal below Nepal hydro, and of solar PVs, which move ahead of coal washing; and (ii) forcing in nuclear capacity, along with the Koel Karo hydroelectric plant, which appear in the upper-middle portion of the supply curve. The positions of bagasse and Bangladesh gas do not change in the ranking, despite the lower costs taken in Figure 2.

In the case of AP, the options are ranked in Figure 3 from the lowest to the highest cost, expressed in US$ per metric ton of CO_2 reduced, rather than carbon (as in the Bihar results), as follows: rehabilitation of the existing coal-fired plant at Kothagudam; DSM measures to increase the efficiency of lighting; T&D rehabilitation (representing a further reduction from the level of losses assumed under Reform); bagasse; DSM in the agriculture sector; Jurala hydro; LNG (with additional quantities made available, compared with Reform); the use of refinery residues; a program of mini-hydro plants; nuclear capacity; wind; PFBC; solar PVs; and, finally, coal washing. Those options with a negative cost in Figure 3 are again classified as "win-win," because they permit a simultaneous reduction in GHG emissions and a savings in total system costs. The other options, with a greater cost than Jurala in the ranking, reduce GHG emissions but at a cost, and therefore had to be forced into the plant program.

Table 13: GHG Mitigation Scenarios for Bihar

Group – A	Group - B
Mini Hydro (second tranche forced in 2002 with 30% capital cost increase)	Mini Hydro (same as Group A)
Koel Karo - not included	Koel Karo (forced in 2010)
Nepal Hydro (force in Kaligandaki A in 2000 and Kaligandaki - II in 2007)	Nepal Hydro (force in Kaligandaki A in 2000 Kaligandaki - II in 2003)
Clean-Coal Technology (all plants have IGCC from 2004)	Clean-Coal Technology (all plants have PFBC from 2004 but capital cost falls by 20%)
Bangladesh Gas (gas price US$4.50/MBTU)	Bangladesh Gas (gas price US$4.00/MBTU)
DSM (efficient lighting & refrigerators)	DSM (efficient lighting & refrigerators)
Coal washing (washed coal from 2001 onward)	Coal washing (washed coal from 2001 onward)
Bagasse (first tranche 2004, second tranche 2007 with 20% increase in fuel cost)	Bagasse (full amount in 2004 with no cost penalty)
Nuclear - not included	Nuclear (capital cost US $ 2,000/kW)
Photo-voltaic (force in 200 MW in 2004 with capital cost of Rs. 200,000/kW)	Photo-voltaic (capital cost of Rs. 100,000/kW: force in 200 MW in 2004; 2nd tranche of 200 MW in 2012)
T & D Rehabilitation (losses fall to 13% by 2010)	T & D Rehabilitation (losses fall to 13% by 2010)

Figure 3: Andhra Pradesh — GHG Mitigation Option Supply Curve — Individual Options

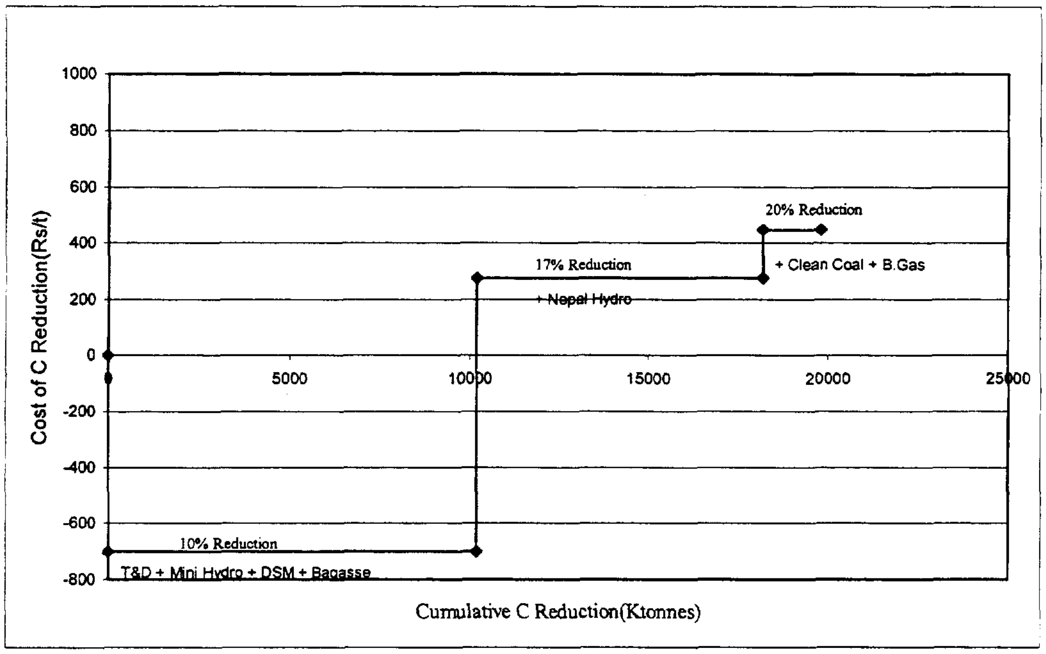


Incremental Impact of Combinations of GHG Reduction Options: GHG Mitigation Scenarios

Based on the preceding screening analysis, combinations of options were put together in the case studies to form GHG mitigation scenarios. The combinations were selected according to the cost-effectiveness ranking of the options, as measured by cost per metric ton of carbon reduced. In forming the combinations, the goal was to achieve reductions of roughly 10%, 15%, and 20% in GHG emissions. The results could not be exact, due to discontinuities between the combinations (i.e., "lumpiness" was encountered), so that sometimes the goal was overachieved and sometimes underachieved. The results for Bihar are in Figures 4 and 5 and those for in AP are in Figure 6. Before discussing these results, it is convenient to convert the cost data into consistent units, so that comparisons between the two case studies can be drawn more easily. The following presentation is therefore expressed in US$ per metric ton of carbon reduced, converting CO_2 to carbon, using the molecular ratio of CO_2 to carbon, i.e., 44/12. It is useful to note that the GEF guidelines for evaluating projects suggest that cost-effective projects (options) would typically mitigate GHG emissions for approximately US$10/metric ton of carbon or less (see the World Bank's *Guidelines for Climate Change Global Overlays*, Environment Department Paper No. 047, Climate Change Series, February 1997, Exhibit 1-1).

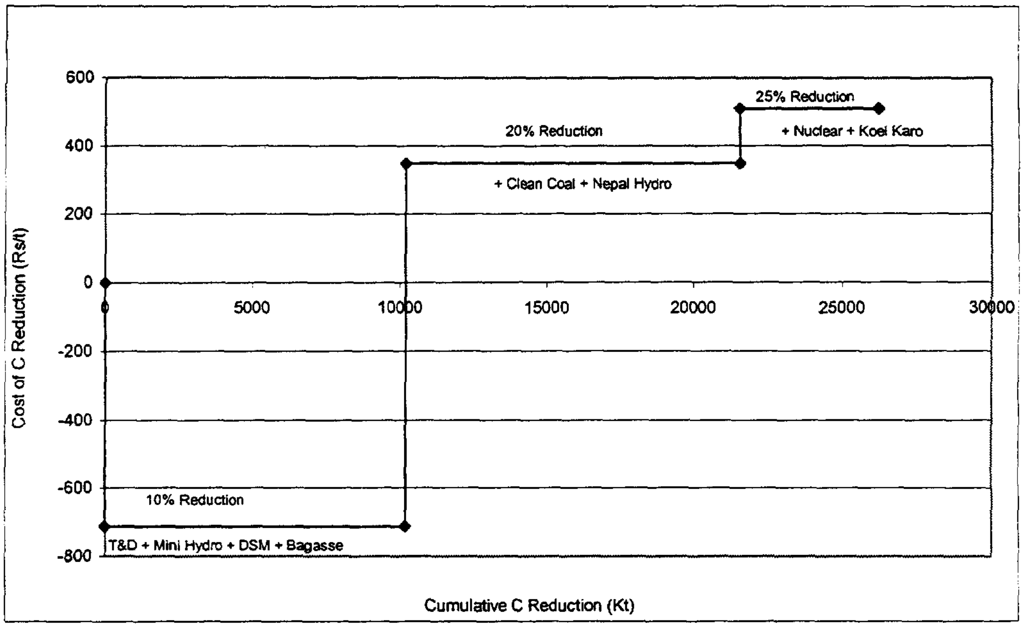
In the case of Bihar, relative to the reform scenario, it is possible to achieve a 10% reduction in GHG emissions and reduce total system costs at the same time. The Group A options would include: DSM, T&D, mini-hydro, and bagasse (Figure 4). Logically, that combination should become part of the reform scenario itself, once proper incentives for its implementation have been put in place. In the second step, the movement from a 10% to a 17% reduction in GHG emission occurs at an incremental cost of US$6.4 per metric ton of carbon, using the option of Nepal hydro. Finally, in the third step, GHG emissions can be cut by 20% at an incremental cost of US$10.4 per metric ton of carbon, using clean-coal technologies (PFBC) and the opportunity to import Bangladesh gas.

Figure 4: Bihar — GHG Mitigation Option Supply Curve — Combination Scenarios Group A



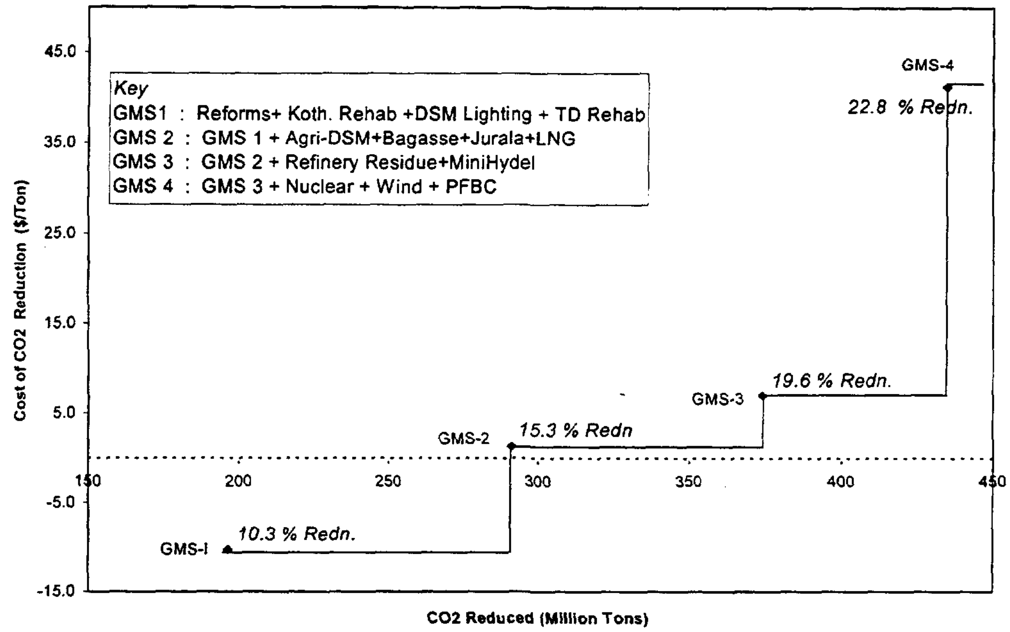
The Group B options in the first step (giving a reduction of 10% in GHG emissions) are the same as in Group A (Figure 5). However, the much more favorable assumptions made about the likely technical progress of clean-coal technology bring in clean coal along with hydro from Nepal at a cost of US$8.1 per metric ton of carbon in the second step. Both options are in relatively abundant supply when selected, so there is a discontinuity in the supply curve, which jumps from 10% to 20%. At the third step, the cost-effectiveness of GHG mitigation becomes marginal: as GHG emissions are cut from 20% to 25%, incremental cost rises to US$11.8/metric ton of carbon, and is realized with a large hydro plant (Koel Karo) and nuclear power. Although not shown in Figure 5, Bangladesh gas could have been used in place of Koel Karo at much the same cost.

Figure 5: Bihar — GHG Mitigation Option Supply Curve — Combination Scenarios Group B



In the case of AP, relative to the Reform scenario, it is again possible to achieve a 10% reduction in GHG emissions and reduce total system costs at the same time, i.e., it is a "win-win" option (Figure 6) .Again, the combination relies on priority DSM measures and more far-reaching T&D rehabilitation. The rehabilitation of existing coal-fired plant is also one of the first-tranche measures in AP. Although it is not clear from the curve, bagasse could be part of the first tranche measures, if the goal is to go beyond a 10% reduction in GHG emissions. For convenience, bagasse was clubbed with the second step in the supply curve, which moves from a 10% to a 15% reduction in GHG emissions, and includes the use of further DSM, along with renewables and cleaner fuels (LNG). The incremental costs increase, although modestly, and are still less than US$5 per metric ton of carbon. If the goal is to achieve GHG emissions reductions beyond 15%, the cost increases are more significant. Incremental costs rise to more than US$25 per metric ton of carbon, to get a 20% reduction in GHG emissions (adding refinery residues and mini-hydro to the combination) and US$150 per metric ton of carbon to go beyond 20% (as it becomes necessary to bring in nuclear, wind, and clean-coal technologies). These costs are well beyond the benchmark figure of US$10 per metric ton of carbon used by the GEF.

Figure 6: AP — GHG Mitigation Option Supply Curve — Combination Scenarios



E. Conclusions

Methodology

The construction of GHG mitigation option supply curves for individual GHG mitigation options was an important first step in applying the methodology of the global overlays in Bihar and AP (Figures 1, 2, and 3). These curves permitted the initial screening of the individual options and assisted the analysts in developing GHG mitigation scenarios. However, the costs per metric ton of carbon reduced for the individual options in Figures 1, 2, and 3 will typically underestimate the cost of GHG mitigation, because they do not allow for the system effects when options are added cumulatively. System effects cause the overall impact of a combination of options on GHG reduction to differ from the arithmetical sum of the impacts of the individual options considered separately. The interactions arise when the options are taken cumulatively because the background generation mix changes as further options are added and the dispatch of all plants in the system may be altered.

In the case of Bihar, a good example of the system effects of a power plant is the Koel Karo hydroelectric scheme. Koel Karo was added to the system (along with nuclear power) rather than Bangladesh gas in the final step of Scenario B (Figure 5) because it was shown to be more cost-effective than Bangladesh gas as an individual option (see the ranking in Figure 2). However, the benefits of Koel Karo are vitiated because some of the energy is dispatched ahead of energy generated from the clean-coal-based power plants that were installed earlier in the sequence. As a consequence, it was found that essentially the same results could have been achieved by adding Bangladesh gas in place of Koel Karo, even though the cost of the former was 80% higher when taken as an individual option. There is a further important conclusion related to the issue of system effects. A cumulative addition of options may be appropriate to achieve successive increments in GHG reduction over time, e.g., from 10% to 20% to 25%. However, a different investment program may be appropriate if it is decided at the outset that the goal is to achieve a large reduction, say 25%, rather than a succession of incremental reductions in GHG emissions. There may be no point in installing a succession of thermal plants based on clean-coal technologies if it will be necessary subsequently to install a large hydro scheme to meet the required (significant) target. The clean-coal plants might become redundant.

In the case of AP, system effects are also apparent in the final step of Figure 6. The cost of GHG mitigation per metric ton of CO_2 is substantially higher for the addition of nuclear power, wind, and clean coal than the cost of each option individually (see Figure 3). First, by adding these options cumulatively, total CO_2 equivalent is reduced by only 61 million metric tons compared with the arithmetic sum of 77 million metric tons for the three options taken individually. The reason is that a substantial impact has already been made on the CO_2 equivalent of the system by the previous introduction of measures such as DSM, T&D rehabilitation, hydro, and bagasse. Second, the reserve margin of the system must be increased to maintain the required value of LOLP, given the variable nature of wind energy, so that the capital costs of the combination are multiplied.

Results

According to the results of these two global overlays, the options identified could reduce GHG emissions by 20% in Bihar and AP (i.e., by about 1 million and 19 million metric tons annually, respectively) at an incremental cost of roughly US$8 to US$10 per metric ton of carbon equivalent in Bihar; and about US$26/metric ton of carbon equivalent in AP. The costs of the individual measures vary widely:

- Even if power sector reforms are implemented, there are likely to be unexploited opportunities to reduce GHG emissions and total system costs in tandem. The analysis shows that more aggressive DSM measures, additional T&D loss reduction, and a focus on renewables such as bagasse are highly cost-effective or even "win-win." Ideally, these opportunities would be taken up under Reforms as a matter of good business practice, once the incentive system has been rationalized, but realistically, special policy measures may be required in the short- and even medium-term if GHG emissions are to be brought down as a matter of priority.

- Mini-hydro is "win-win" in Bihar and offers the low GHG mitigation cost of US$4/metric ton of carbon equivalent in AP and should therefore be examined closely as a GHG reduction strategy. However, it is case-specific and its potential in practice is probably small relative to the size of the goals for GHG reduction that are likely to face most countries.

- Large and medium hydro schemes may also be effective, with costs of US$13.4/metric ton of carbon for Koel Karo in Bihar and minus US$8.4/metric ton of carbon for Jurala in AP. But their feasibility depends very much on specific circumstances and the social and environmental costs they create may be much more significant than recognized here.

- For Bihar, imported energy supplies from Nepal and Bangladesh promise to yield significant environmental benefits. Obviously prices would have to be negotiated that would make them sufficiently attractive, from an economic and financial viewpoint, to be adopted in a reformed power system. The Bihar case study suggests that Nepal hydro imports would be the higher priority, based on existing information. For AP, imported LNG needs special mention. Although total system costs increased when LNG was added to the Reform scenario, the effect was marginal. The results are very sensitive to the assumptions made about capital and operating costs. The sensitivity analysis indicates that, for relatively small reductions in these costs, the LNG option would displace imported coal in the Reform scenario, reducing total system costs and thereby joining the list of "win-win" options. The cost of LNG as a fuel choice for carbon reduction was estimated at less than US$1/metric ton of carbon equivalent.

- Clean-coal technologies, such as PFBC and IGCC, seem to be among the more costly options at present for GHG emission reduction, especially in AP (nearly US$33/metric ton of carbon equivalent). But the more favorable assumptions for PFBC used for the Group B options in Bihar show that clean-coal technologies may well have a significant future role to play in seeking larger reductions of GHG emissions because they could offer a way to use the substantial availability of domestic coal more efficiently.

- Solar PVs, wind, and coal washing seem to be the most expensive carbon reduction options, with costs exceeding US$100/metric ton of carbon equivalent for solar PVs (in both AP and Bihar), US$22/metric ton of carbon equivalent for wind (in AP), US$85/metric ton of carbon equivalent for coal washing in Bihar, and nearly US$170/metric ton of carbon equivalent for coal washing in AP. While these options are not cost-effective for reducing GHG emissions, they certainly have other advantages, such as offering a decentralized power supply and a reduction of local pollution, such as ash.

- The work done in the course of the AP case study for EIPS and the AP global overlay strongly suggests that the use of refinery residues for power generation is worth exploring further. Preliminary analysis indicated that it might be economical at most refinery locations in India, and a number of existing and proposed refineries have prepared feasibility reports and identified joint venture partners. At the time of the case study, there were proposals to set up almost 3,500 MW of capacity, using residual fuel oil in India. It was expected that some percentage of this would be located in AP. While the associated environmental problems are not well documented, sulphur dioxide and NO_2 emissions could be a problem. In terms of GHG emissions, the AP global overlay placed refinery residues very high in the cost-effectiveness ranking, at US$3.3/metric ton of carbon equivalent.

- Nuclear power appears to be a relatively unattractive carbon reduction option on cost grounds. Although the specific cost of carbon reduction for nuclear power as a single option, in both Bihar and AP, was about US$10/metric ton, it appeared in the mitigation scenarios only when very substantial target reductions were envisaged. Furthermore, both global overlays clearly recognized that the economic and environmental case for nuclear power would be further undermined if further allowance is made for the costs of handling nuclear fuel and disposing of nuclear waste fuel and the risks of nuclear accidents.

Finally, both case studies found a close correlation between the local and global benefits of the options. The emissions of local pollutants (NO_x, SO_x, and PM) decline almost uniformly in step with GHG emissions, as seen in Annex IV.1 for Bihar and Annex IV.2 for AP. The decline reflects the steady drop in coal consumption in both power sectors as carbon reduction proceeds (Annex IV.3). The only exception, which is very minor, occurs in Bihar's Group A combination: when GHG emissions are reduced from 17% to 20%, NO_x emissions go up by 0.2%. Although at first sight the result seems counter-intuitive, it is another of the system effects mentioned in the previous section, combined with the choice of time horizon and discounting. The reason is that the GHG mitigation options displaced new low-NO_x thermal units and, in some instances, more energy will be dispatched from existing higher-NO_x thermal units in the short term. If the time horizon for discounting local pollutants were extended beyond 20 years, these short-term dispatching effects could be expected to disappear.

Annex 1: Load Forecasts

Annex I.1 ***BAU: GSDP Growth Rates 1996-2015 by Sector for Bihar*** ***(% per annum)***			
	1996-2002	*2003-2007*	*2008-2015*
BAU High Growth			
GSDP	*3.5*	*3.75*	*4.5*
GSDP (Agriculture)	*2.0*	*2.3*	*2.5*
GSDP (Industries)	*3.5*	*4.0*	*4.5*
GSDP (Services)	*4.3*	*5.0*	*5.5*
BAU Low Growth			
GSDP	*3.5*	*3.25*	*3.0*
GSDP (Agriculture)	*2.0*	*1.25*	*1.0*
GSDP (Industries)	*3.5*	*3.5*	*3.25*
GSDP (Services)	*4.3*	*4.75*	*4.5*

Annex I.2 ***BAU: Electricity Price Increases 1996-2015 by Sector for Bihar*** ***(% per annum)***			
	1996-1997	*1998-2003*	*2004-2015*
Residential	*0*	*2.5*	*0*
Commercial	*0*	*0*	*0*
Industrial	*0*	*0*	*0*
Agriculture	*0*	*10.0*	*0*

Annex I.3 ***Reform: GSDP Growth Rates 1996-2015 by Sector for Bihar*** ***(% per annum)***			
	1996-2002	*2003-2007*	*2008-2015*
Reform High Growth			
GSDP	*3.5*	*4.75*	*6.0*
GSDP (Agriculture)	*1.5*	*2.75*	*4.0*
GSDP (Industries)	*4.0*	*5.25*	*6.5*
GSDP (Services)	*5.0*	*6.0*	*7.0*
Reform Low Growth			
GSDP	*3.5*	*3.75*	*4.5*
GSDP (Agriculture)	*2.0*	*2.3*	*2.5*
GSDP (Industries)	*3.5*	*4.0*	*4.5*
GSDP (Services)	*4.3*	*5.0*	*5.5*

Annex I.4
Reform: Electricity Price Increases 1996-2015 by Sector in Bihar
(% per annum)

	1996-2002	*2003-2007*	*2008-2015*
Residential	*0*	*20*	*0*
Commercial	*0*	*14*	*0*
Industrial	*0*	*6*	*0*
Agriculture	*0*	*56*	*0*

Annex I.5
BAU and Reform: GSDP Growth Rates for AP, 1998-2018
(% per annum)

Year	***BAU***	***Reform***
1998	*4.1*	*5.0*
1999	*4.0*	*5.4*
2000	*3.9*	*5.4*
2001	*3.7*	*5.6*
2002	*3.5*	*5.8*
2003-2018	*3.5*	*6.0*

Annex 2: Supply-Side Options

Annex II.1:
Supply-Side Candidate Options for Bihar (Thermal)

Project	*Capacity* Min MW	Max MW	*Heat rate BTU/MWh*	*Capital cost Rs./kW*	*Fuel cost Rs./MBTU*	*O & M cost* Variable Rs./MWh	Fixed Rs./KW/ Month	*Maint. days/ year*	*Life (years)*
Patratu - Extension	*78*	*195*	*10352*	*26,000*	*86.1*	*8.9*	*70.7*	*45*	*25*
Muzaffarpur - Extension	*78*	*195*	*10352*	*26,000*	*95.5*	*8.9*	*70.7*	*45*	*25*
Tenughat - Extension	*78*	*195*	*10352*	*26,000*	*85.4*	*14.8*	*94.6*	*45*	*25*
Bihar Coal-based generic plant	*78*	*195*	*10160*	*31,800*	*77.9*	*10.9*	*86.5*	*55*	*25*
Naphtha based generic plant (open cycle)	*78*	*195*	*10860*	*16,000*	*164.0*	*6.0*	*229.0*	*45*	*15*
Bangladesh Gas based plant (closed cycle)	*78*	*195*	*7799*	*21,200*	*193.5/172*	*5.6*	*54.8*	*45*	*15*
Bagasse-based co-generation plant	*10*	*190*	*12342*	*25,000*	*28.6/34.3*	*11.1*	*87.8*	*45*	*25*
Bihar Coal-based generic plant with IGCC	*78*	*195*	*8407*	*54,960*	*77.9*	*10.9*	*86.5*	*55*	*25*
Bihar Coal-based generic plant with PFBC	*78*	*195*	*8407*	*43,970*	*77.9*	*10.9*	*86.5*	*55*	*25*
Nuclear	*85*	*212*	*13271*	*86,000*	*15.1*	*11.2*	*66.3*	*47*	*25*
Photovoltaic	*10*	*200*	-	*200,000/ 100,000*	-	*91.3*	*157.5*	*90*	*25*

Note: The Bangladesh gas-based combined cycle gas turbine (CCT) also serves as a proxy for generic CCTs using LNG.

Annex II.2: Supply-Side Candidate Options for Bihar (Hydro)

Project	Capacity		Annual Energy (Gwh/Year)	O & M Cost		Capital cost
	Minimum (MW)	Maximum (MW)		Variable (Rs/MWh)	Fixed (Rs./KW/ Month)	(Rs./kW)
Mini-Hydro-I	37	74	486.18	3.7	32.7	35,300
Mini-Hydro-II	37	74	486.18	3.7	32.7	45,890
Kadwan	0	450	858.0	4.3	18.3	23,400
Koel-Karo	20	710	1,058.0	9.7	29.1	37,100
Kaligandaki-A (Nepal)	60	144	823.20	3.7	32.7	71,180
Kaligandaki-2 (Nepal)	142	352	1,406.0	9.7	29.1	60,160

Annex II.3: Supply-Side Candidate Options for AP

Plant Type	Capacity MW	Economic Cost Rs./kW	Life Yrs.	Primary Fuel	Heat Rate MBTU/kWh	Fuel Cost Rs./MBTU	Variable O & M Rs./MWh	Fixed O & M Rs./kW/Mth
Pit Head	500	32,300	30	Singareni coal	11000	75	106	13
Pit Head	500	46,300	30	Talcher coal	11000	48	115	21
Load Center [1]	500	32,300	30	Talcher coal	11000	79	115	21
Load Center [2]	500	49,000	30	Imported coal	9890	93	115	21
LNG-CCT [3]	400	30,000	20	LNG	7580	193	21	64
LNG-Open Cycle	400	14,000	20	LNG	11370	193	21	64
Naphtha	400	25,000	20	Naphtha	7580	223	15	63
Wind	100	35,000	20	Wind	-	-	3	63
Mini Hydro	100	35,000	20	Hydro	-	-	-	22
Nuclear	440	57,000	30	Nuclear	11371	58	15	119
Bagasse	210	25,000	25	Bagasse	12342	29	11	88
Photovoltaic	210	200,000	25	Solar	-	-	91	158
Refinery Residue	250	45,800	20	Refin. Residue	8810	73	15	63
Jurala Hydro	110	29,200	25	Hydro	-	-	-	22
PFBC [5]	250	45,000	30	Coal	9000	75	135	22

Notes:

1. *Capital costs of Pit Head –Talcher plant include cost of evacuating power from Talcher to A.P.*
2. *Capital costs of imported coal plants include the cost of pier construction.*
3. *Costs of Combined Cycle Turbines (CCT) taken from Proceedings of the Joint Power Generation Conference and Exhibition, 1998.*
4. *Costs of plants using renewable energy taken from India: Environmental Issues in The Power Sector, ESMAP Report No. 205/98, June 1998*
5. *Information for Pressurized Fluidized Bed Combustion (PFBC) plants taken from "Clean Coal Technologies For Developing Countries," World Bank Technical Paper 286, 1995.*

Annex II.4: Estimated Fuel Availability for AP, 1998-2018				
Fuel Type	***Incremental Availability (MW):***			
	Until 2001	***2002-2006***	***2007-2011***	***2011-2018***
Coal:				
Singareni Coal	*800*	*700*	*500*	*-*
Talcher Coal	*800*	*1500*	*2000*	*2000*
Imported Coal	*750*	*2250*	*3750*	*3750*
Hydrocarbons:				
Indigenous Gas	*600*	*200*	*-*	*-*
LNG	*-*	*1800*	*2400*	*2400*
Naphtha	*1200*	*1500*	*1500*	*1500*
Refinery Residues	*500*	*-*	*300*	
Renewables:				
Wind	*100*	*500*	*200*	*-*
Mini-Hydel	*100*	*200*	*100*	*-*
Bagasse	*200*	*200*	*-*	*-*
Note: In the table, the availability of the different fuels is expressed in terms of the capacity of each plant type that can be supported (MW).				

Annex II.5: Plants Currently Scheduled for Construction or under Consideration in AP				
Plant	***Year***	***Capacity***	***Fuel Type***	***Capital Cost (Rs./kW)***
Kondapalli	*1999*	*355*	*Naphtha*	*25,000*
Snehalata	*2000*	*200*	*Naphtha*	*25,000*
Oakwell Power	*2000*	*200*	*Naphtha*	*25,000*
Gautami	*2000*	*300*	*Naphtha*	*25,000*
Ispat	*2001*	*468*	*Naphtha*	*25,000*
HNPC – I	*2002*	*520*	*Coal*	*32,300*
Simhadri - I	*2002*	*500*	*Coal*	*32,300*
NTPC Talcher II (1)	*2002*	*500*	*Coal*	*32,300*
HNPC – II	*2003*	*520*	*Coal*	*32,300*
Simhadri – II	*2003*	*500*	*Coal*	*32,300*
NTPC Talcher II (2)	*2003*	*500*	*Coal*	*32,300*
NTPC Talcher II (3)	*2004*	*500*	*Coal*	*32,300*
NTPC Talcher II (4)	*2004*	*500*	*Coal*	*32,300*
NTPC – Ramagundam Ext.	*2006*	*500*	*Coal*	*32,300*

Annex II.6: Options Considered under GHG Mitigation Scenario — Bihar	
Option	***Description***
Mini Hydro	*Force the second tranche of 74 MW in 2002 with increase in capital cost by 30%*
Koel-Karo	*Force in 2010 after Kadwan*
Nepal Hydro	*(1) Force Kaligandaki-A in 2000 & Kaligandaki-II in 2003* *(2) Force Kaligandaki-A in 2000 & Kaligandaki-II in 2007*
Clean Coal Technologies	*(1) All units of coal-based plants beyond 2004 have IGCC (clean coal)* *(2) All units of coal-based plants beyond 2004 have PFBC but with capital cost reduced by 20% below IGCC*
Bangladesh Gas	*Bangladesh gas units available from 2004 (up to a limit of 1000MW):* *(1) delivered cost of gas US$4.50/MBTU* *(2) delivered cost of gas US$4.00/MBTU*
DSM	*Efficient fluorescent lamps in urban areas and high-efficiency refrigerators*
Coal Washing	*All new coal-based units work with washed coal costing Rs.125/metric ton from 2001 onward (improved heat rate and increased fuel cost)*
Bagasse	*(1) Introduce 2x210 MW in 2004* *(2) Introduce 1x210 MW in 2004 and a further 1x210 MW in 2007, with a 20% escalation in fuel cost*
Nuclear Power	*Two units of 250MW capacity each forced into the plan in 2010 and 2011 with capital cost of US$2000/kW*
Photovoltaic/ Renewables	*(1) Costed at Rs.200,000/kW with 200 MW forced in the year 2004* *(2) Costed at Rs. 100,000/kW with 200 MW forced in 2004 and additional 200 MW forced in 2012*
T&D Rehabilitation	*T&D loss reduction to bring down technical losses from 18% under Reform to 13% from 2005 to 2010. Considered costs at Rs. 10 million/GWh reduced*

Annex II.7: Options Considered under GHG Mitigation Scenario — AP	
Option	***Description***
Energy Efficiency:	
T&D Rehabilitation	*T&D losses assumed to decrease from 15% under Reforms to 10% by year 2010. Capital cost of T&D rehabilitation costs taken at 1/3rd the generation cost.*
DSM-Lighting	*DSM measures include commercial lighting, municipal lighting, fluorescent lamp standards, urban lighting (see AnnexIII.1).*
DSM-Agriculture	*Option developed on the basis of the ongoing Integrated Agricultural DSM Project (see Annex III.2). Four technical measures combined in an integrated package. Measures include: conversion of low voltage feeders to high voltage feeders; automated load control for loss reduction; provision of customer meters; and improved end-use efficiency. Cost of implementation in all districts of AP estimated at Rs. 170 million.*
Renewables:	
Wind	*Total potential taken at 800 MW for the duration of the study period. Capacity additions begin 2003 and continue every subsequent year in blocks of 100 MW.*
Mini Hydro	*Potential taken at 400 MW for the duration of the study period. Capacity additions in blocks of 100 MW in the years 2001, 2003, 2004, and 2006.*
Jurala Hydro	*Jurala taken as a proxy for similar hydro plants. Plant of 110 MW forced in the year 2008.*
Bagasse	*Total potential of 400MW considered. A plant of 200 MW added in 2001 and a further 200 MW in 2002.*
Photovoltaics	*Total capacity added limited to one representative plant in view of the high capital cost, existing technology, and institutional barriers. A typical plant of 210 MW considered in 2006.*
Others:	
PFBC	*PFBC taken as a proxy for new coal technologies such as IGCC. Generic plants using Singareni coal taken as PFBCs. A total of 2000 MW added in steps of 250 MW.*
Coal Beneficiation	*Coal washing made mandatory for all candidate plants using Indian coal. Coal washing costs taken at Rs. 125 per metric ton. Ash content assumed to drop by 7% and calorific value to improve from 3300 to 4000 Kcal/Kg*
LNG	*Unrestricted supply of LNG assumed, in order to maximize GHG reduction. Imported coal replaced with LNG from 2005 onward.*

Annex II.7 (Continued) *Options Considered under GHG Mitigation Scenario — AP*	
Others continued:	
Refinery Residues	*Potential taken as 800 MW for the duration of the study period. Two plants of 250 MW forced in 2001 and a third of 250 MW in 2010.*
Nuclear	*A plant of 440 MW forced in. Plant parameters based on existing Kaiga nuclear power plant. Capacity added in 2008. Plant decommissioning and spent fuel disposal costs not included. Hence the costs considered are likely to be understated.*
Plant Rehabilitation	*Kothagudam A unit repowered under a plant rehabilitation program. Measures include replacement of boiler valves, high-pressure rotors in steam turbines, change of generator feed coils, and modifications in the coal handling equipment. Rehabilitation cost of Rs. 1200 million.*

Annex II.8
Possible Nepal Hydroelectric Power Imports

Project	*Capacity (MW)*	*Energy (GWh per year)*	*Load factor (%)*
Kaligandaki - A	*144*	*840*	*67*
Seti-III	*107*		
Middle Bhote Koshi	*120*		
UpperMarsyandgdi-3	*121*		
Andi Khola	*154*		
Tila-2	*203*		
Tama Koshi-3	*287*	*1813*	*50*
Upper Trishuli-2	*300*		
Burhi Gandaki	*600*		
Arun-III	*402*	*2891*	*82*
Upper Arun	*335*	*2050*	*70*
Lower Arun	*308*	*2275*	*84*
Kaligandaki-II	*660*	*2660*	*46*

Note: The table does not include large hydroelectric projects such as Karnali (10,800 MW) and Pancheswar (6000 MW).

.Annex III.1: Demand-Side Management in AP — Lighting (GWh Savings)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Urban Lighting	4.3	13.3	27.7	48.1	69.8	92.8	125.3	155.2	182.1	205.6	183.9	160.9	124.2	85.3	43.9	43.9	43.9
Municipal Lighting (Sodium Vapor)	0.2	0.8	1.8	3.7	6.6	9.5	12.6	15.7	19	22.4	22.1	21.6	20.6	18.6	15.8	12.9	9.8
Municipal Lighting (Fluorescent)	0.5	1.6	3.9	8	14	20.3	26.8	33.5	40.5	47.7	47.2	46.1	43.8	39.7	33.7	27.4	20.9
Commercial Lighting (Electronic Ballast)	2.7	8.6	21.6	50.1	97.3	162.1	233.4	311.8	398.1	493	490.3	484.4	471.4	442.8	395.7	330.9	259.6
Commercial Lighting (CFL)	1.5	4.7	11.8	26	48.6	77.1	100.5	117.6	129.4	142.3	99.3	52	52	52	52	52	52
Fluorescent Lamp Standards	49.7	131.8	240.2	366	504.4	656.6	774.3	876.4	970.7	1067.8	1174.5	1292	1241	1563.3	1719.6	1891.6	2080.7
Rural Lighting	6.1	18.9	46.2	97	150.9	208.2	269	333.6	402.2	475	475	475	475	475	475	469	456.1
Total Savings (GWh)	65	179.7	353.2	598.9	891.6	1226.6	1541.9	1843.8	2142	2453.8	2492.3	2532	2428	2676.7	2735.7	2827.7	2923

Annex III.2
Cost and GWh Savings from Integrated Agricultural DSM Project in AP

Energy Savings/pumpset	[kWh /pumpset/year]	2527
Economic Cost/pumpset	[Rs/pumpset]	26657
Misc.Benefit/pumpset/year	[Rs/pumpset/year]	1180
Opcost/PS/year	[Rs/pumpset/year]	533
Pumpsets/scheme	[pumpsets]	5813
Annual Growth Rate in Pumpsets	[%]	0.02

		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Number of Pumpsets (Millions)		1.791	1.827	1.864	1.901	1.939	1.978	2.017	2.058	2.099	2.141	2.183	2.227	2.272	2.317	2.363	2.411	2.459	2.508	2.558	2.609
Pumpsets Added (Millions)			0.036	0.037	0.037	0.038	0.039	0.040	0.040	0.041	0.042	0.043	0.044	0.045	0.045	0.046	0.047	0.048	0.049	0.050	0.051
Fraction of Growth in New Pumpsets			0.0	0.0	0.1	0.1	0.2	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Old Pumpsets Added (Millions)			0.036	0.037	0.035	0.034	0.031	0.020	0.012	0.004	0.002	0	0	0	0	0	0	0	0	0	0
Stock of Old Pumpsets Eligible for Rehabilitation (Millions)		1.791	1.827	1.864	1.899	1.933	1.964	1.984	1.996	2.000	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.002
Number of Schemes			3	6	12	20	24	36	48	48	48	48	33								
Pumpsets Rehabilitated (Millions)			0.017	0.035	0.070	0.116	0.140	0.209	0.279	0.279	0.279	0.279	0.192	0	0	0	0	0	0	0	0
Total Energy Savings (GWh/Year)	11592	0	0	44	132	308	602	955	1484	2189	2894	3599	4304	4788	4788	4788	4788	4788	4788	4788	4788
Capital Costs (Rs Million/Year)		0	465	930	1860	3099	3719	5579	7438	7438	7438	7438	5114	0	0	0	0	0	0	0	0
Operating Costs (Rs Million/Year)			0	9	28	65	127	201	313	462	611	759	908	1010	1010	1010	1010	1010	1010	1010	1010
Miscellan. Benefits (Rs Million/Year)			0	-21	-62	-144	-281	-446	-693	-1022	-1351	-1680	-2009	-2235	-2235	-2235	-2235	-2235	-2235	-2235	-2235
Total Costs (Rs Million/Year)		0	465	918	1826	3020	3565	5334	7059	6878	6698	6517	4013	-1225	-1225	-1225	-1225	-1225	-1225	-1225	-1225
Discount Rate	0.12																				
NPV (Rs Million)	16947																				

Note: Miscellaneous benefits include: reduced motor rewinding costs, deferred purchase of pumps, and reduced transformer and Power Factor correction costs

Annex 4: Local Emissions

Annex IV.1: Bihar: Present Value of Emissions of SO_2, NO_X and PM			
Scenario	***SO_2 (metric tons)***	***NO_X (metric tons)***	***PM (metric tons)***
Reform	*876,550*	*732,619*	*58,195*
GHG Mitigation:			
Group A			
10% Reduction in CO_2	*800,406*	*689968*	*52,606*
17% Reduction in CO_2	*749,551*	*655,103*	*48,909*
20% Reduction in CO_2	*738,811*	*656,672*	*48,407*
Group B			
10% Reduction in CO_2	*800,406*	*689,968*	*52,606*
20% Reduction in CO_2	*718,869*	*639,368*	*47,057*
25% Reduction in CO_2	*707,976*	*629,329*	*46,052*

Annex IV.2: AP: Present Value of Emissions of SOx, NOx and PM			
Scenario	***NOx (metric tons)***	***SOx (metric tons)***	***PM (metric tons)***
Reforms	*3,006*	*3,316*	*380*
10.3% Reduction in CO_2	*2,606*	*2,627*	*259*
15.3% Reduction in CO_2	*2,577*	*2,474*	*258*
19.6% Reduction in CO_2	*2,403*	*2,384*	*241*
22.8% Reduction in CO_2	*2,326*	*2,303*	*233*

Annex IV.3: Coal Consumption in the Power Sector for the Reform and GHG Mitigation Scenarios — Bihar and AP	
State/Scenario	***Coal Consumption (million metric tons)***
Bihar	
Reform Scenario	*263*
GHG Mitigation Scenario:	

Group A:	
10% Reduction in CO_2	*228*
17% Reduction in CO_2	*221*
20% Reduction in CO_2	*199*
Group B:	
10% Reduction in CO_2	*228*
20% Reduction in CO_2	*198*
25% Reduction in CO_2	*183*
Andhra Pradesh	
Reforms	*977*
10.3% Reduction in CO_2	*872*
15.3% Reduction in CO_2	*803*
19.6% Reduction in CO_2	*753*
22.8% Reduction in CO_2	*722*

Joint UNDP/World Bank

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

LIST OF REPORTS ON COMPLETED ACTIVITIES

Region/Country	*Activity/Report Title*	*Date*	*Number*
	SUB-SAHARAN AFRICA (AFR)		
Africa Regional	Anglophone Africa Household Energy Workshop (English)	07/88	085/88
	Regional Power Seminar on Reducing Electric Power System Losses in Africa (English)	08/88	087/88
	Institutional Evaluation of EGL (English)	02/89	098/89
	Biomass Mapping Regional Workshops (English)	05/89	--
	Francophone Household Energy Workshop (French)	08/89	--
	Interafrican Electrical Engineering College: Proposals for Short- and Long-Term Development (English)	03/90	112/90
	Biomass Assessment and Mapping (English)	03/90	--
	Symposium on Power Sector Reform and Efficiency Improvement in Sub-Saharan Africa (English)	06/96	182/96
	Commercialization of Marginal Gas Fields (English)	12/97	201/97
	Commercilizing Natural Gas: Lessons from the Seminar in Nairobi for Sub-Saharan Africa and Beyond	01/00	225/00
Angola	Energy Assessment (English and Portuguese)	05/89	4708-ANG
	Power Rehabilitation and Technical Assistance (English)	10/91	142/91
Benin	Energy Assessment (English and French)	06/85	5222-BEN
Botswana	Energy Assessment (English)	09/84	4998-BT
	Pump Electrification Prefeasibility Study (English)	01/86	047/86
	Review of Electricity Service Connection Policy (English)	07/87	071/87
	Tuli Block Farms Electrification Study (English)	07/87	072/87
	Household Energy Issues Study (English)	02/88	--
	Urban Household Energy Strategy Study (English)	05/91	132/91
Burkina Faso	Energy Assessment (English and French)	01/86	5730-BUR
	Technical Assistance Program (English)	03/86	052/86
	Urban Household Energy Strategy Study (English and French)	06/91	134/91
Burundi	Energy Assessment (English)	06/82	3778-BU
	Petroleum Supply Management (English)	01/84	012/84
	Status Report (English and French)	02/84	011/84
	Presentation of Energy Projects for the Fourth Five-Year Plan (1983-1987) (English and French)	05/85	036/85
	Improved Charcoal Cookstove Strategy (English and French)	09/85	042/85
	Peat Utilization Project (English)	11/85	046/85
	Energy Assessment (English and French)	01/92	9215-BU
Cape Verde	Energy Assessment (English and Portuguese)	08/84	5073-CV
	Household Energy Strategy Study (English)	02/90	110/90
Central African Republic	Energy Assessement (French)	08/92	9898-CAR
Chad	Elements of Strategy for Urban Household Energy The Case of N'djamena (French)	12/93	160/94
Comoros	Energy Assessment (English and French)	01/88	7104-COM
	In Search of Better Ways to Develop Solar Markets: The Case of Comoros	05/00	230/00
Congo	Energy Assessment (English)	01/88	6420-COB
	Power Development Plan (English and French)	03/90	106/90
Côte d'Ivoire	Energy Assessment (English and French)	04/85	5250-IVC
	Improved Biomass Utilization (English and French)	04/87	069/87

Region/Country	Activity/Report Title	Date	Number
Côte d'Ivoire	Power System Efficiency Study (English)	12/87	--
	Power Sector Efficiency Study (French)	02/92	140/91
	Project of Energy Efficiency in Buildings (English)	09/95	175/95
Ethiopia	Energy Assessment (English)	07/84	4741-ET
	Power System Efficiency Study (English)	10/85	045/85
	Agricultural Residue Briquetting Pilot Project (English)	12/86	062/86
	Bagasse Study (English)	12/86	063/86
	Cooking Efficiency Project (English)	12/87	--
	Energy Assessment (English)	02/96	179/96
Gabon	Energy Assessment (English)	07/88	6915-GA
The Gambia	Energy Assessment (English)	11/83	4743-GM
	Solar Water Heating Retrofit Project (English)	02/85	030/85
	Solar Photovoltaic Applications (English)	03/85	032/85
	Petroleum Supply Management Assistance (English)	04/85	035/85
Ghana	Energy Assessment (English)	11/86	6234-GH
	Energy Rationalization in the Industrial Sector (English)	06/88	084/88
	Sawmill Residues Utilization Study (English)	11/88	074/87
	Industrial Energy Efficiency (English)	11/92	148/92
Guinea	Energy Assessment (English)	11/86	6137-GUI
	Household Energy Strategy (English and French)	01/94	163/94
Guinea-Bissau	Energy Assessment (English and Portuguese)	08/84	5083-GUB
	Recommended Technical Assistance Projects (English & Portuguese)	04/85	033/85
	Management Options for the Electric Power and Water Supply Subsectors (English)	02/90	100/90
	Power and Water Institutional Restructuring (French)	04/91	118/91
Kenya	Energy Assessment (English)	05/82	3800-KE
	Power System Efficiency Study (English)	03/84	014/84
	Status Report (English)	05/84	016/84
	Coal Conversion Action Plan (English)	02/87	--
	Solar Water Heating Study (English)	02/87	066/87
	Peri-Urban Woodfuel Development (English)	10/87	076/87
	Power Master Plan (English)	11/87	--
	Power Loss Reduction Study (English)	09/96	186/96
	Implementation Manual: Financing Mechanisms for Solar Electric Equipment	07/00	231/00
Lesotho	Energy Assessment (English)	01/84	4676-LSO
Liberia	Energy Assessment (English)	12/84	5279-LBR
	Recommended Technical Assistance Projects (English)	06/85	038/85
	Power System Efficiency Study (English)	12/87	081/87
Madagascar	Energy Assessment (English)	01/87	5700-MAG
	Power System Efficiency Study (English and French)	12/87	075/87
	Environmental Impact of Woodfuels (French)	10/95	176/95
Malawi	Energy Assessment (English)	08/82	3903-MAL
	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry (English)	11/83	009/83
	Status Report (English)	01/84	013/84
Mali	Energy Assessment (English and French)	11/91	8423-MLI
	Household Energy Strategy (English and French)	03/92	147/92
Islamic Republic of Mauritania	Energy Assessment (English and French)	04/85	5224-MAU
	Household Energy Strategy Study (English and French)	07/90	123/90

Region/Country	*Activity/Report Title*	*Date*	*Number*
Mauritius	Energy Assessment (English)	12/81	3510-MAS
	Status Report (English)	10/83	008/83
	Power System Efficiency Audit (English)	05/87	070/87
	Bagasse Power Potential (English)	10/87	077/87
	Energy Sector Review (English)	12/94	3643-MAS
Mozambique	Energy Assessment (English)	01/87	6128-MOZ
	Household Electricity Utilization Study (English)	03/90	113/90
	Electricity Tariffs Study (English)	06/96	181/96
	Sample Survey of Low Voltage Electricity Customers	06/97	195/97
Namibia	Energy Assessment (English)	03/93	11320-NAM
Niger	Energy Assessment (French)	05/84	4642-NIR
	Status Report (English and French)	02/86	051/86
	Improved Stoves Project (English and French)	12/87	080/87
	Household Energy Conservation and Substitution (English and French)	01/88	082/88
Nigeria	Energy Assessment (English)	08/83	4440-UNI
	Energy Assessment (English)	07/93	11672-UNI
Rwanda	Energy Assessment (English)	06/82	3779-RW
	Status Report (English and French)	05/84	017/84
	Improved Charcoal Cookstove Strategy (English and French)	08/86	059/86
	Improved Charcoal Production Techniques (English and French)	02/87	065/87
	Energy Assessment (English and French)	07/91	8017-RW
	Commercialization of Improved Charcoal Stoves and Carbonization Techniques Mid-Term Progress Report (English and French)	12/91	141/91
SADC	SADC Regional Power Interconnection Study, Vols. I-IV (English)	12/93	--
SADCC	SADCC Regional Sector: Regional Capacity-Building Program for Energy Surveys and Policy Analysis (English)	11/91	--
Sao Tome and Principe	Energy Assessment (English)	10/85	5803-STP
Senegal	Energy Assessment (English)	07/83	4182-SE
	Status Report (English and French)	10/84	025/84
	Industrial Energy Conservation Study (English)	05/85	037/85
	Preparatory Assistance for Donor Meeting (English and French)	04/86	056/86
	Urban Household Energy Strategy (English)	02/89	096/89
	Industrial Energy Conservation Program (English)	05/94	165/94
Seychelles	Energy Assessment (English)	01/84	4693-SEY
	Electric Power System Efficiency Study (English)	08/84	021/84
Sierra Leone	Energy Assessment (English)	10/87	6597-SL
Somalia	Energy Assessment (English)	12/85	5796-SO
South Africa Republic of	Options for the Structure and Regulation of Natural Gas Industry (English)	05/95	172/95
Sudan	Management Assistance to the Ministry of Energy and Mining	05/83	003/83
	Energy Assessment (English)	07/83	4511-SU
	Power System Efficiency Study (English)	06/84	018/84
	Status Report (English)	11/84	026/84
	Wood Energy/Forestry Feasibility (English)	07/87	073/87
Swaziland	Energy Assessment (English)	02/87	6262-SW
	Household Energy Strategy Study	10/97	198/97
Tanzania	Energy Assessment (English)	11/84	4969-TA
	Peri-Urban Woodfuels Feasibility Study (English)	08/88	086/88
	Tobacco Curing Efficiency Study (English)	05/89	102/89
	Remote Sensing and Mapping of Woodlands (English)	06/90	--

Region/Country	*Activity/Report Title*	*Date*	*Number*
Tanzania	Industrial Energy Efficiency Technical Assistance (English)	08/90	122/90
	Power Loss Reduction Volume 1: Transmission and Distribution SystemTechnical Loss Reduction and Network Development (English)	06/98	204A/98
	Power Loss Reduction Volume 2: Reduction of Non-Technical Losses (English)	06/98	204B/98
Togo	Energy Assessment (English)	06/85	5221-TO
	Wood Recovery in the Nangbeto Lake (English and French)	04/86	055/86
	Power Efficiency Improvement (English and French)	12/87	078/87
Uganda	Energy Assessment (English)	07/83	4453-UG
	Status Report (English)	08/84	020/84
	Institutional Review of the Energy Sector (English)	01/85	029/85
	Energy Efficiency in Tobacco Curing Industry (English)	02/86	049/86
	Fuelwood/Forestry Feasibility Study (English)	03/86	053/86
	Power System Efficiency Study (English)	12/88	092/88
	Energy Efficiency Improvement in the Brick and Tile Industry (English)	02/89	097/89
	Tobacco Curing Pilot Project (English)	03/89	UNDP Terminal Report
	Energy Assessment (English)	12/96	193/96
	Rural Electrification Strategy Study	09/99	221/99
Zaire	Energy Assessment (English)	05/86	5837-ZR
Zambia	Energy Assessment (English)	01/83	4110-ZA
	Status Report (English)	08/85	039/85
	Energy Sector Institutional Review (English)	11/86	060/86
	Power Subsector Efficiency Study (English)	02/89	093/88
	Energy Strategy Study (English)	02/89	094/88
	Urban Household Energy Strategy Study (English)	08/90	121/90
Zimbabwe	Energy Assessment (English)	06/82	3765-ZIM
	Power System Efficiency Study (English)	06/83	005/83
	Status Report (English)	08/84	019/84
	Power Sector Management Assistance Project (English)	04/85	034/85
	Power Sector Management Institution Building (English)	09/89	--
	Petroleum Management Assistance (English)	12/89	109/89
	Charcoal Utilization Prefeasibility Study (English)	06/90	119/90
	Integrated Energy Strategy Evaluation (English)	01/92	8768-ZIM
	Energy Efficiency Technical Assistance Project: Strategic Framework for a National Energy Efficiency Improvement Program (English)	04/94	--
	Capacity Building for the National Energy Efficiency Improvement Programme (NEEIP) (English)	12/94	--
	Rural Electrification Study	03/00	228/00

EAST ASIA AND PACIFIC (EAP)

Asia Regional	Pacific Household and Rural Energy Seminar (English)	11/90	--
China	County-Level Rural Energy Assessments (English)	05/89	101/89
	Fuelwood Forestry Preinvestment Study (English)	12/89	105/89
	Strategic Options for Power Sector Reform in China (English)	07/93	156/93
	Energy Efficiency and Pollution Control in Township and Village Enterprises (TVE) Industry (English)	11/94	168/94

Region/Country	*Activity/Report Title*	*Date*	*Number*
China	Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties (English)	06/96	183/96
	Improving the Technical Efficiency of Decentralized Power Companies	09/99	222/999
Fiji	Energy Assessment (English)	06/83	4462-FIJ
Indonesia	Energy Assessment (English)	11/81	3543-IND
	Status Report (English)	09/84	022/84
	Power Generation Efficiency Study (English)	02/86	050/86
	Energy Efficiency in the Brick, Tile and Lime Industries (English)	04/87	067/87
	Diesel Generating Plant Efficiency Study (English)	12/88	095/88
	Urban Household Energy Strategy Study (English)	02/90	107/90
	Biomass Gasifier Preinvestment Study Vols. I & II (English)	12/90	124/90
	Prospects for Biomass Power Generation with Emphasis on Palm Oil, Sugar, Rubberwood and Plywood Residues (English)	11/94	167/94
Lao PDR	Urban Electricity Demand Assessment Study (English)	03/93	154/93
	Institutional Development for Off-Grid Electrification	06/99	215/99
Malaysia	Sabah Power System Efficiency Study (English)	03/87	068/87
	Gas Utilization Study (English)	09/91	9645-MA
Myanmar	Energy Assessment (English)	06/85	5416-BA
Papua New Guinea	Energy Assessment (English)	06/82	3882-PNG
	Status Report (English)	07/83	006/83
	Energy Strategy Paper (English)	--	--
	Institutional Review in the Energy Sector (English)	10/84	023/84
	Power Tariff Study (English)	10/84	024/84
Philippines	Commercial Potential for Power Production from Agricultural Residues (English)	12/93	157/93
	Energy Conservation Study (English)	08/94	--
Solomon Islands	Energy Assessment (English)	06/83	4404-SOL
	Energy Assessment (English)	01/92	979-SOL
South Pacific	Petroleum Transport in the South Pacific (English)	05/86	--
Thailand	Energy Assessment (English)	09/85	5793-TH
	Rural Energy Issues and Options (English)	09/85	044/85
	Accelerated Dissemination of Improved Stoves and Charcoal Kilns (English)	09/87	079/87
	Northeast Region Village Forestry and Woodfuels Preinvestment Study (English)	02/88	083/88
	Impact of Lower Oil Prices (English)	08/88	--
	Coal Development and Utilization Study (English)	10/89	--
Tonga	Energy Assessment (English)	06/85	5498-TON
Vanuatu	Energy Assessment (English)	06/85	5577-VA
Vietnam	Rural and Household Energy-Issues and Options (English)	01/94	161/94
	Power Sector Reform and Restructuring in Vietnam: Final Report to the Steering Committee (English and Vietnamese)	09/95	174/95
	Household Energy Technical Assistance: Improved Coal Briquetting and Commercialized Dissemination of Higher Efficiency Biomass and Coal Stoves (English)	01/96	178/96
	Petroleum Fiscal Issues and Policies for Fluctuating Oil Prices In Vietnam	02/01	236/01
Western Samoa	Energy Assessment (English)	06/85	5497-WSO

Region/Country	*Activity/Report Title*	*Date*	*Number*
	SOUTH ASIA (SAS)		
Bangladesh	Energy Assessment (English)	10/82	3873-BD
	Priority Investment Program (English)	05/83	002/83
	Status Report (English)	04/84	015/84
	Power System Efficiency Study (English)	02/85	031/85
	Small Scale Uses of Gas Prefeasibility Study (English)	12/88	--
India	Opportunities for Commercialization of Nonconventional Energy Systems (English)	11/88	091/88
	Maharashtra Bagasse Energy Efficiency Project (English)	07/90	120/90
	Mini-Hydro Development on Irrigation Dams and Canal Drops Vols. I, II and III (English)	07/91	139/91
	WindFarm Pre-Investment Study (English)	12/92	150/92
	Power Sector Reform Seminar (English)	04/94	166/94
	Environmental Issues in the Power Sector (English)	06/98	205/98
	Environmental Issues in the Power Sector: Manual for Environmental Decision Making (English)	06/99	213/99
	Household Energy Strategies for Urban India: The Case of Hyderabad	06/99	214/99
	Greenhouse Gas Mitigation In the Power Sector: Case Studies From India	02/01	237/01
Nepal	Energy Assessment (English)	08/83	4474-NEP
	Status Report (English)	01/85	028/84
	Energy Efficiency & Fuel Substitution in Industries (English)	06/93	158/93
Pakistan	Household Energy Assessment (English)	05/88	--
	Assessment of Photovoltaic Programs, Applications, and Markets (English)	10/89	103/89
	National Household Energy Survey and Strategy Formulation Study: Project Terminal Report (English)	03/94	--
	Managing the Energy Transition (English)	10/94	--
	Lighting Efficiency Improvement Program Phase 1: Commercial Buildings Five Year Plan (English)	10/94	--
Sri Lanka	Energy Assessment (English)	05/82	3792-CE
	Power System Loss Reduction Study (English)	07/83	007/83
	Status Report (English)	01/84	010/84
	Industrial Energy Conservation Study (English)	03/86	054/86
	EUROPE AND CENTRAL ASIA (ECA)		
Bulgaria	Natural Gas Policies and Issues (English)	10/96	188/96
Central and Eastern Europe	Power Sector Reform in Selected Countries	07/97	196/97
	Increasing the Efficiency of Heating Systems in Central and Eastern Europe and the Former Soviet Union	08/00	234/00
Eastern Europe	The Future of Natural Gas in Eastern Europe (English)	08/92	149/92
Kazakhstan	Natural Gas Investment Study, Volumes 1, 2 & 3	12/97	199/97
Kazakhstan & Kyrgyzstan	Opportunities for Renewable Energy Development	11/97	16855-KAZ
Poland	Energy Sector Restructuring Program Vols. I-V (English)	01/93	153/93
	Natural Gas Upstream Policy (English and Polish)	08/98	206/98

Region/Country	*Activity/Report Title*	*Date*	*Number*
Poland	Energy Sector Restructuring Program: Establishing the Energy Regulation Authority	10/98	208/98
Portugal	Energy Assessment (English)	04/84	4824-PO
Romania	Natural Gas Development Strategy (English)	12/96	192/96
Slovenia	Workshop on Private Participation in the Power Sector (English)	02/99	211/99
Turkey	Energy Assessment (English)	03/83	3877-TU
	Energy and the Environment: Issues and Options Paper	04/00	229/00

MIDDLE EAST AND NORTH AFRICA (MNA)

Arab Republic of Egypt	Energy Assessment (English)	10/96	189/96
	Energy Assessment (English and French)	03/84	4157-MOR
	Status Report (English and French)	01/86	048/86
Morocco	Energy Sector Institutional Development Study (English and French)	07/95	173/95
	Natural Gas Pricing Study (French)	10/98	209/98
	Gas Development Plan Phase II (French)	02/99	210/99
Syria	Energy Assessment (English)	05/86	5822-SYR
	Electric Power Efficiency Study (English)	09/88	089/88
	Energy Efficiency Improvement in the Cement Sector (English)	04/89	099/89
	Energy Efficiency Improvement in the Fertilizer Sector (English)	06/90	115/90
Tunisia	Fuel Substitution (English and French)	03/90	--
	Power Efficiency Study (English and French)	02/92	136/91
	Energy Management Strategy in the Residential and Tertiary Sectors (English)	04/92	146/92
	Renewable Energy Strategy Study, Volume I (French)	11/96	190A/96
	Renewable Energy Strategy Study, Volume II (French)	11/96	190B/96
Yemen	Energy Assessment (English)	12/84	4892-YAR
	Energy Investment Priorities (English)	02/87	6376-YAR
	Household Energy Strategy Study Phase I (English)	03/91	126/91

LATIN AMERICA AND THE CARIBBEAN (LAC)

LAC Regional	Regional Seminar on Electric Power System Loss Reduction in the Caribbean (English)	07/89	--
	Elimination of Lead in Gasoline in Latin America and the Caribbean (English and Spanish)	04/97	194/97
	Elimination of Lead in Gasoline in Latin America and the Caribbean - Status Report (English and Spanish)	12/97	200/97
	Harmonization of Fuels Specifications in Latin America and the Caribbean (English and Spanish)	06/98	203/98
Bolivia	Energy Assessment (English)	04/83	4213-BO
	National Energy Plan (English)	12/87	--
	La Paz Private Power Technical Assistance (English)	11/90	111/90
	Prefeasibility Evaluation Rural Electrification and Demand Assessment (English and Spanish)	04/91	129/91
	National Energy Plan (Spanish)	08/91	131/91
	Private Power Generation and Transmission (English)	01/92	137/91
	Natural Gas Distribution: Economics and Regulation (English)	03/92	125/92

Region/Country	*Activity/Report Title*	*Date*	*Number*
Bolivia	Natural Gas Sector Policies and Issues (English and Spanish)	12/93	164/93
	Household Rural Energy Strategy (English and Spanish)	01/94	162/94
	Preparation of Capitalization of the Hydrocarbon Sector	12/96	191/96
	Introducing Competition into the Electricity Supply Industry in Developing Countries: Lessons from Bolivia	08/00	233/00
	Final Report on Operational Activities Rural Energy and Energy Efficiency	08/00	235/00
Brazil	Energy Efficiency & Conservation: Strategic Partnership for Energy Efficiency in Brazil (English)	01/95	170/95
	Hydro and Thermal Power Sector Study	09/97	197/97
	Rural Electrification with Renewable Energy Systems in the Northeast: A Preinvestment Study	07/00	232/00
Chile	Energy Sector Review (English)	08/88	7129-CH
Colombia	Energy Strategy Paper (English)	12/86	--
	Power Sector Restructuring (English)	11/94	169/94
	Energy Efficiency Report for the Commercial and Public Sector (English)	06/96	184/96
Costa Rica	Energy Assessment (English and Spanish)	01/84	4655-CR
	Recommended Technical Assistance Projects (English)	11/84	027/84
	Forest Residues Utilization Study (English and Spanish)	02/90	108/90
Dominican Republic	Energy Assessment (English)	05/91	8234-DO
Ecuador	Energy Assessment (Spanish)	12/85	5865-EC
	Energy Strategy Phase I (Spanish)	07/88	--
	Energy Strategy (English)	04/91	--
	Private Minihydropower Development Study (English)	11/92	--
	Energy Pricing Subsidies and Interfuel Substitution (English)	08/94	11798-EC
	Energy Pricing, Poverty and Social Mitigation (English)	08/94	12831-EC
Guatemala	Issues and Options in the Energy Sector (English)	09/93	12160-GU
Haiti	Energy Assessment (English and French)	06/82	3672-HA
	Status Report (English and French)	08/85	041/85
	Household Energy Strategy (English and French)	12/91	143/91
Honduras	Energy Assessment (English)	08/87	6476-HO
	Petroleum Supply Management (English)	03/91	128/91
Jamaica	Energy Assessment (English)	04/85	5466-JM
	Petroleum Procurement, Refining, and Distribution Study (English)	11/86	061/86
	Energy Efficiency Building Code Phase I (English)	03/88	--
	Energy Efficiency Standards and Labels Phase I (English)	03/88	--
	Management Information System Phase I (English)	03/88	--
	Charcoal Production Project (English)	09/88	090/88
	FIDCO Sawmill Residues Utilization Study (English)	09/88	088/88
	Energy Sector Strategy and Investment Planning Study (English)	07/92	135/92
Mexico	Improved Charcoal Production Within Forest Management for the State of Veracruz (English and Spanish)	08/91	138/91
	Energy Efficiency Management Technical Assistance to the Comision Nacional para el Ahorro de Energia (CONAE) (English)	04/96	180/96
Panama	Power System Efficiency Study (English)	06/83	004/83
Paraguay	Energy Assessment (English)	10/84	5145-PA
	Recommended Technical Assistance Projects (English)	09/85	--
	Status Report (English and Spanish)	09/85	043/85
Peru	Energy Assessment (English)	01/84	4677-PE

Region/Country	*Activity/Report Title*	*Date*	*Number*
Peru	Status Report (English)	08/85	040/85
	Proposal for a Stove Dissemination Program in the Sierra (English and Spanish)	02/87	064/87
	Energy Strategy (English and Spanish)	12/90	--
	Study of Energy Taxation and Liberalization of the Hydrocarbons Sector (English and Spanish)	120/93	159/93
	Reform and Privatization in the Hydrocarbon Sector (English and Spanish)	07/99	216/99
Saint Lucia	Energy Assessment (English)	09/84	5111-SLU
St. Vincent and the Grenadines	Energy Assessment (English)	09/84	5103-STV
Sub Andean	Environmental and Social Regulation of Oil and Gas Operations in Sensitive Areas of the Sub-Andean Basin (English and Spanish)	07/99	217/99
Trinidad and Tobago	Energy Assessment (English)	12/85	5930-TR

GLOBAL

Region/Country	*Activity/Report Title*	*Date*	*Number*
	Energy End Use Efficiency: Research and Strategy (English)	11/89	--
	Women and Energy--A Resource Guide The International Network: Policies and Experience (English)	04/90	--
	Guidelines for Utility Customer Management and Metering (English and Spanish)	07/91	--
	Assessment of Personal Computer Models for Energy Planning in Developing Countries (English)	10/91	--
	Long-Term Gas Contracts Principles and Applications (English)	02/93	152/93
	Comparative Behavior of Firms Under Public and Private Ownership (English)	05/93	155/93
	Development of Regional Electric Power Networks (English)	10/94	--
	Roundtable on Energy Efficiency (English)	02/95	171/95
	Assessing Pollution Abatement Policies with a Case Study of Ankara (English)	11/95	177/95
	A Synopsis of the Third Annual Roundtable on Independent Power Projects: Rhetoric and Reality (English)	08/96	187/96
	Rural Energy and Development Roundtable (English)	05/98	202/98
	A Synopsis of the Second Roundtable on Energy Efficiency: Institutional and Financial Delivery Mechanisms (English)	09/98	207/98
	The Effect of a Shadow Price on Carbon Emission in the Energy Portfolio of the World Bank: A Carbon Backcasting Exercise (English)	02/99	212/99
	Increasing the Efficiency of Gas Distribution Phase 1: Case Studies and Thematic Data Sheets	07/99	218/99
	Global Energy Sector Reform in Developing Countries: A Scorecard	07/99	219/99
	Global Lighting Services for the Poor Phase II: Text Marketing of Small "Solar" Batteries for Rural Electrification Purposes	08/99	220/99
	A Review of the Renewable Energy Activities of the UNDP/ World Bank Energy Sector Management Assistance Programme 1993 to 1998	11/99	223/99

Region/Country	***Activity/Report Title***	***Date***	***Number***
Global	Energy, Transportation and Environment: Policy Options for Environmental Improvement	12/99	224/99
	Privatization, Competition and Regulation in the British Electricity Industry, With Implications for Developing Countries	02/00	226/00
	Reducing the Cost of Grid Extension for Rural Electrification	02/00	227/00

2/8/01

ESMAP

The World Bank

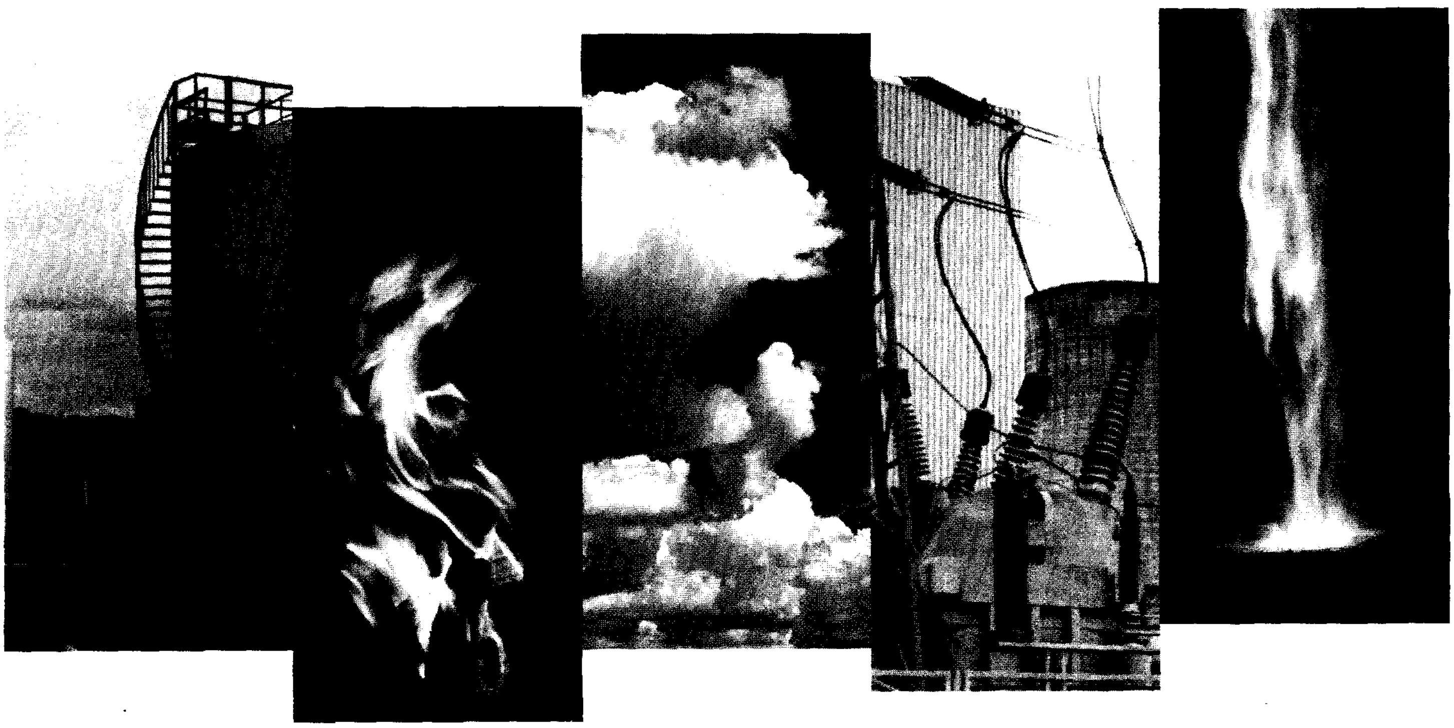
1818 H Street, NW

Washington, DC 20433 USA

Tel.: 1.202.458.2321 Fax.: 1.202.522.3018

Internet: www.esmap.org

Email: esmap@worldbank.org



A joint UNDP/World Bank Programme