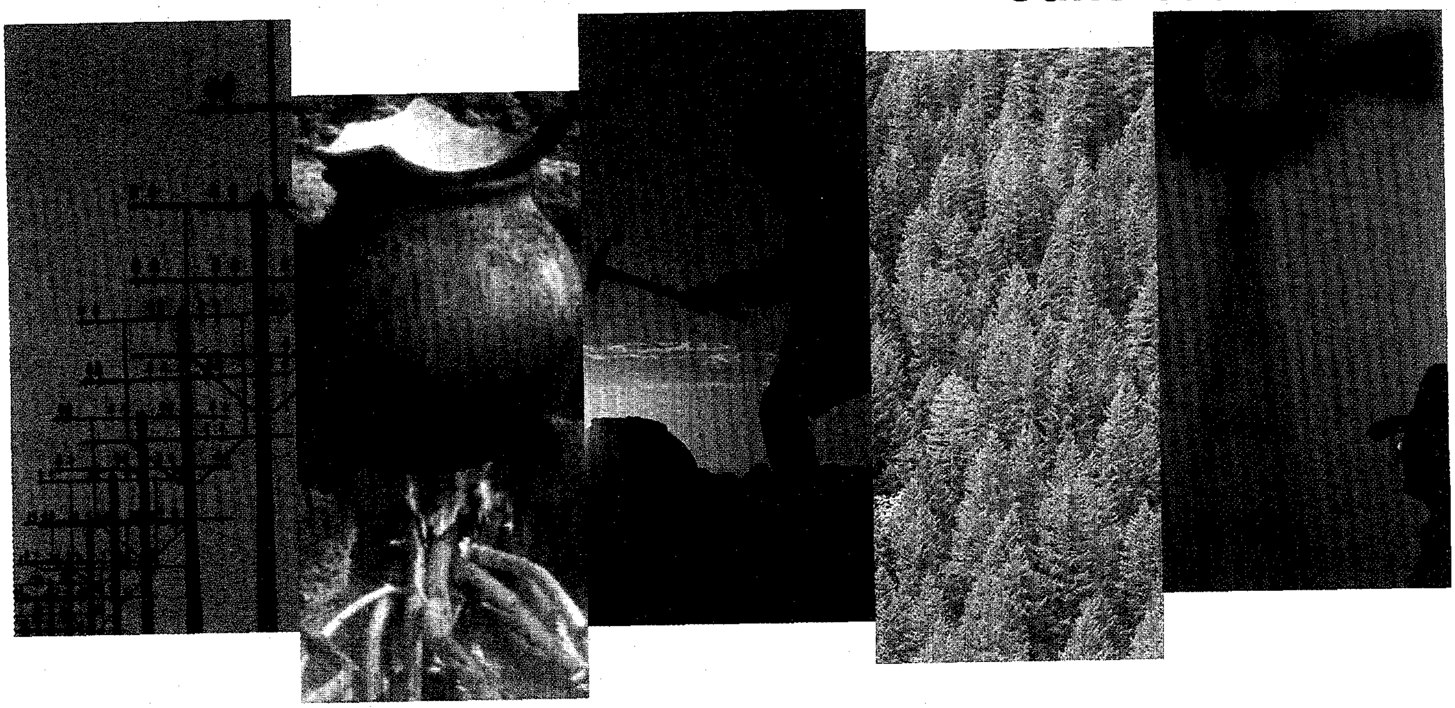
India

Environmental Issues in the Power Sector

Manual for Environmental Decision Making

ESM213
June 1999



Energy

Sector

Management

Assistance

Programme

ESMAP

Report 213/99

June 1999

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, Mining and Telecommunications Department

The World Bank

1818 H Street, NW

Washington, DC 20433

U.S.A.

India

Environmental Issues in the Power Sector
Manual for Environmental Decision Making

June 1999

Energy Sector Unit
South Asia Region

Energy, Mining and
Telecommunications Department

The World Bank
1818 H Street, N.W.
Washington, D.C. 20433
U.S.A.

First printing June 1999

ESMAP Reports are published to communicate the results of the ESMAP's work to the development community with the least possible delay. The typescript of the paper therefore has not been prepared in accordance with the procedures appropriate to formal documents. Some sources cited in this paper may be informal documents that are not readily available.

The findings, interpretations, and conclusions expressed in this paper are entirely those of the author(s) and should not be attributed in any manner to the World Bank, or its affiliated organizations, or to members of its Board of Executive Directors or the countries they represent. The World Bank does not guarantee the accuracy of the data included in this publication and accepts no responsibility whatsoever for any consequence of their use. The Boundaries, colors, denominations, other information shown on any map in this volume do not imply on the part of the World Bank Group any judgement on the legal status of any territory or the endorsement or acceptance of such boundaries.

Contents

Preface and Acknowledgements

Purpose

This Manual for Environmental Decision-Making (MEDM) is being published to help decision-makers, in India and elsewhere, analyse and weigh different options for power system development, recognising explicitly their environmental impacts. The MEDM describes a set of analytical tools and a decision-making process (the "tools and process") that have been developed in two states in India. The tools and process addressed successfully most of the key questions that were asked by the stakeholders in those states; and gave clear pointers about the implications of the different policy options. Also, it was concluded that the tools and process have wider applicability, in power systems in other states in India and in other countries; and publication of the MEDM would be an effective dissemination vehicle.

Background

Environmental issues in the power sector are of major importance in India, where electric power plays a fundamental role in the economic development process. However, the most important single source of fuel for power generation has been coal, accounting for about 70% or more of electricity production; and the environmental impacts of coal-based electricity production are particularly serious, in terms of human health and well-being. The expansion of coal-based power generation affects air, land and water resources. Air pollution is a high-priority concern, because of the health consequences. The accumulation of ash at power station sites pre-empts land and endangers both ground and surface water. Furthermore, when additional coal is burned, there is an associated increase in coal production, which can degrade more land, deplete water resources and cause water pollution.

In India, as elsewhere in many developing countries, the planning and operation of power systems has been conducted without due regard to these environmental consequences. The root causes are: (i) critical shortages of supply capacity, due to inadequate financial policies, making it difficult to act against power stations not in compliance with environmental regulations; (ii) inadequate attention to demand-side management, renewables, alternative fuels such as gas, clean-coal technologies, coal washing, and ash utilisation, due to a distorted system of incentives, throwing the burden of meeting power needs heavily onto supply from conventional coal-fired power stations; (iii) the absence of power-system planning at the level of the states to incorporate the environmental effects of alternative policy options; (iv) inadequate awareness and agreement among stakeholders on the magnitude of the environmental impacts of power generation; and (v) the failure by decision-makers to recognise fully the trade-offs that are being made in implementing current policies and practices in the power sector.

The EIPS Activity (First Phase)

Against this background, the Government of India (GoI), the World Bank and the UK Department for International Development (DFID) collaborated in an activity called India: Environmental Issues in the Power Sector (EIPS). The counterpart for the activity was the Ministry of Power (MoP). The World Bank managed the work, with Robin Bates (EMTEG) and Mudassar Imran (SASEG) as co-task managers; and contributed part of the funding, through the South Asia Region. Further substantial funding was provided by DFID, through ESMAP. Liaison with MoP on day-to-day matters was facilitated by MoP's Energy Management Centre (EMC).

The key developmental objective of EIPS is to reduce the adverse impact on the environment of power generation in India. The principal outputs of the work so far (the first phase) have been: the development of the tools and process to help plan power systems, taking into account financial, economic and environmental considerations; and the preparation of seven Special Studies, two Case Studies (for the states of Andhra Pradesh (AP) and Bihar), and a Synthesis Report. The tools and process have been successfully tested in the context of the power systems in these two states. The Case Studies were carried out by teams of local consultants in both states, i.e. the Administrative Staff College of India (ASCI) in AP and the Sone Command Area Development Agency (SCADA) in Bihar, with the technical support of the local engineering consulting firm of Metallurgical and Engineering Consultants (MECON). ASCI and SCADA/MECON worked closely with the appropriate decision-makers in their states, to maximise the acceptability and relevance of the work. Local consultants also prepared most of the Special Studies. An international consulting firm, Environmental Resources Management (ERM), was responsible for the Synthesis Report and served as the Co-ordinating Consultants. The Synthesis Report was published as ESMAP Report No. 205/98, in June 1998 ("India: Environmental Issues in the Power Sector").

Following publication of the Synthesis Report, as an extension to the first phase, ASCI and SCADA/MECON conducted Global Overlays for the states of AP and Bihar respectively, by looking in more detail at a wider range of greenhouse gases (GHG) and estimating the incremental costs of GHG mitigation for several GHG mitigation options. The Global Overlays were based on the World Bank's "Guidelines for Climate Change Overlays" (Environment Department Paper No. 047, Climate Change Series, Global Environment Division, February 1997). They were funded by the World Bank's Global Overlay Program (partially funded by the Government of Denmark), ESMAP (as part of the Environmental Manual Activity for Power) and the South Asia Region.

The EIPS Activity (Second Phase)

The EIPS activity has now entered the second or dissemination phase in India, again managed and partially funded by the World Bank (co-task managers: Robin Bates and Mudassar Imran); with further significant funding from DFID, through ESMAP. The second phase is designed to: publicise the main findings of EIPS; raise awareness about the environmental impacts of power generation; address the need to implement the options identified in EIPS to mitigate those impacts; and facilitate the actual transfer of the analytical tools and decision-making process that were developed under EIPS. The MEDM is a key component of the second phase, along with a series of workshops in selected states that have started to reform their power sectors.

The MEDM is a self-contained document, describing the objectives, methodology, outputs and interpretation of the outputs of the analytical tools and the decision-making process of EIPS. It is available for distribution to other organisations involved in the preparation of similar studies and can serve as a standard reference for future work. The substance was prepared in India by ASCI, SCADA/MECON and ERM. The MEDM has been finalised and produced by ERM.

The EIPS decision-making process involved the participation by a wide range of stakeholders, including NGOs, large power consumers, academic and research institutions, etc. The EIPS work demonstrated that the process was effective in identifying relevant policy options, finding some common ground for approaching the difficult trade-offs involved (or at least raising awareness about them), and informing decision-makers about the need for policy changes.

The analytical tools of EIPS comprised a set of linked modules to analyse different policy scenarios. The main components of the modules handled decisions about each of the following elements required for planning power systems: generating plant mix (determining investment in different types of generation), demand forecasting, power-plant dispatching and operations, fuel choice, the economic costs of fuels (including the environmental costs), the financial results, and environmental impacts (notably emissions, air quality and land use). The testing of the tools in AP and Bihar demonstrated that they were able to address successfully most of the key questions that were being asked by the stakeholders and give clear pointers about the implications of the different policy options. In practice, the manipulation of the modules and their linkages had to be performed by the analysts directly. Although some training and experience is necessary to do this, it results in a fully transparent decision-making process (rather than a black box), which is conducive to interactions between the stakeholders.

ESMAP and the South Asia Region are indebted to a large number of individuals and organisations involved in EIPS. However, a special acknowledgement is necessary to DFID and to many government officials at the state and central level, especially: the Department of Economic Affairs (DEA), the Planning Commission, MoP/EMC, the Ministry of Coal (MoC), the Ministry of Environment and Forests (MoEF), the Ministry of Non-conventional Energy Sources (MNES), the Central Electricity Authority (CEA), the National Thermal Power Corporation (NTPC), the Central Pollution Control Board (CPCB), the State Secretaries of Energy for Andhra Pradesh and Bihar, the State Secretary of Environment, Forests, Science and Technology for Andhra Pradesh, the State Secretary of Forests and Environment for Bihar, the Bihar State Electricity Board, Tenughat Vidhut Nigam Ltd. in Bihar, the Bihar State Hydroelectric Power Corporation, the Andhra Pradesh State Electricity Board, the Bihar State Pollution Control Board, the Andhra Pradesh State Pollution Control Board, and the Environment Protection, Training and Research Institute (EPTRI) in Andhra Pradesh. Acknowledgements are also due to ASCI and SCADA/MECON, who made substantial contributions to MEDM; and to ERM, who prepared MEDM. Finally, we thank the many staff at the World Bank who have commented on the work and provided sound advice and support. All of these parties played a critical role in contributing to the success of the endeavour.

Abbreviations and Acronyms

ADB	Asian Development Bank
AP	Andhra Pradesh
APPCB	Andhra Pradesh Pollution Control Board
ASCI	Administrative Staff College of India
AUD	Ash Utilisation Division
BAT	Best Available Technology
BAU	Business as Usual
BHPC	Bihar State Hydroelectric Power Corporation
BSEB	Bihar State Electricity Board
Btu	British Thermal Units
CAC	Command and Control
CCGT	Combined Cycle Gas Turbine
CEA	Central Electricity Authority
CERI	Canadian Energy Research Institute
CII	Confederation of Indian Industry
CO2	Carbon Dioxide
COI	Cost of Illness
CPCB	Central Pollution Control Board
DFID	Department for International Development
DG	Directorate General
DRF	Dose Response Function
DSM	Demand Side Management
DVC	Damodar Valley Corporation
EBRD	European Bank for Reconstruction and Development
EGAT	Electricity Generating Authority of Thailand
EIA	Environmental Impact Assessment
EIPS	Environmental Issues in the Power Sector
EM	Environmental Manual for Power Development
ERM	Environmental Resources Management (London)
ES	Environmental Statement
ESCO	Energy Service Company
ESMAP	Energy Sector Management Assistance Programme
FGD	Flue Gas Desulphurisation
FO	Fuel Oil
GAIL	Gas Authority of India Ltd.
GDP	Gross Domestic Product
GNP	Gross National Product
GTZ	German Agency for Technical Cooperation
GWh	Giga Watt hours
HE	Hydroelectric
HP	Hydro Power
HT	High Tension
IFS	Inter-Fuel Substitution
IGCC	Integrated Gasification Combined Cycle Plant.
IGIDR	Indira Gandhi Institute of Development Research
IIED	International Institute for Environment and Development
IPP	Independent Power Producer
kcal	kilo calorie

kWh	kilowatt-hour
LC	Least Cost
LNG	Liquefied Natural Gas
LOLP	Loss of load Probability
LRMC	Long Run Marginal Cost
LT	Low Tension
MATA	Multi-Attribute Trade-Off Analysis
MBI	Market Based Instruments
MMBTU	Million British Thermal Units
MNES	Ministry of Non-conventional Energy Sources
MoEF	Ministry of Environment and Forestry
MOU	Memorandum of Understanding
mt	Million Tonnes
MW	Mega Watts
NCAER	National Council of Applied Economic Research
NCV	Net Calorific Value
NGO	Non Governmental Organisation
NHPC	National Hydro Power Corporation
NOx	Nitrogen Oxides
NTPC	National Thermal Power Corporation
PFBC	Pressurised Fluidised Bed Combustion
PM	Particulate Matter
pv	Present Value
R&R	Resettlement and Rehabilitation
RET	Renewable Energy Technology
Rs	Rupees
SCADA	Sone Command Area Development Agency
SDP	State Domestic Product
SEB	State Electricity Boards
SHP	Small Hydro Power
SME	Small and Medium Enterprises
SOx	Sulphur Oxides
SPBC	State Pollution Control Board
T&D	Transmission and Distribution
TEDDY	Teri Energy Data Directory & Yearbook
TERI	Tata Energy Research Institute
TOD	Time of Day
TSP	Total Suspended Particulates
TVNL	Tenughat Vidyut Nigam Ltd
TWh	Terra Watt Hours
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation
USAID	United States Agency for International Development
VSL	Value of a Statistical Life
WB	World Bank
WTP	Willingness To Pay

Executive Summary

To address the serious environmental impacts from power generation in India…

Environmental impacts of power generation in India can be serious. For example, the single most important source of fuel for power generation has been coal (accounting for about 70% or more) and the environmental impacts of coal-based electricity production can be particularly serious in terms of human health.

… the Government, World Bank, and DFID joined forces and developed analytical tools and a decision making process to assist decision makers in India's power sector.

Recognising these problems, the Government of India, the World Bank and the UK Department of International Development (DFID) have collaborated in an activity entitled *India: Environmental Issues in the Power Sector* (EIPS). The counterpart for the activity was the Ministry of Power.

The tools were applied to only two states…

One of the main outputs of the EIPS work was the development and application of a set of analytical tools and a framework to provide quantitative analysis, all designed to assist decision makers in the power sector. The tools were applied to two states, Andhra Pradesh and Bihar, where Case Studies were carried out by state-level 'nodal' institutions; the Administrative Staff College of India (ASCI) in Andhra Pradesh and the Sone Command Area Development Agency (SCADA), assisted by Metallurgical & Engineering Consultants (India) Ltd. (MECON). In both states there was ample scope for an analysis of a whole range of policy options, including DSM and restructuring.

Nevertheless, the intention is to use the framework further in other states.

… but this 'Manual for Environmental Decision Making' was prepared to help other states to use the tools and the decision making process.

In light of this a *Manual for Environmental Decision Making* has been prepared to ensure that the lessons learned throughout the EIPS work are not lost and to help future users of the analytical tools and decision making process. The purpose of the Manual is to provide:

- a record of institutional memory of ASCI, SCADA/MECON and the international consultant - Environmental Resources Management (ERM);

- a record of problems encountered and lessons learned by the state nodal institutions ASCI, SCADA/MECON and ERM;
- a basis for future similar studies in other states of India and elsewhere.

Within the EIPS framework, a *Decision Making Tool* was used to conduct the Case Studies, consisting of a set of linked modules - power system planning software, methodologies for demand forecasting, financial analysis, etc. However, other analytical tools (with equal credibility and scientific rigour) might also be used in other states.

The Manual is aimed to assist teams in other States to undertake similar exercises ...

The Manual is aimed primarily at the counterparts of ASCI, SCADA and MECON in other states who will undertake similar exercises. This work could, in future, be carried out by state nodal institutions, consultants, public and private electric power utilities, State Electricity Boards (SEBs), academic institutions or central power agencies.

...will need to first define the problem(s) concerned ...

The first task in repeating the EIPS work in other states will be to define the problem or problems which concern decision makers, NGOs or other organisations. *Section 2* of the Manual describes the issues addressed in the EIPS work that relate to key energy policy questions and broadly include environmental and social problems of interest to decision makers. It sets out the several questions that were asked in the EIPS work. States wishing to develop a similar project will need to define a general set of concerns. These will need to be turned into specific questions which can be tackled using the quantitative analysis of the *Decision Making Tool.*

... and turn these into specific questions which can be tackled using the quantitative analysis of the Decision Making Tool.

The problem definition process is best structured around a set of questions, all designed to allow a quantitative answer to be given. The questions asked in the EIPS work include for example:

- (on the environmental impact of reform) what would be the consequences of choosing plants on the basis of economic costs including internalisation of environmental costs;

- (on technical options) how much would it cost to use new clean coal technologies and to wash coal and how much would this achieve.

The EIPS framework is designed to answer the questions posed in the EIPS work and other similar questions which require a quantitative answer. It should be kept in mind, however, that the framework is devised to be fully flexible and allows the use to employ a range of alternative software.

Section 3 outlines the overall design of the 'analytical tool'. It further describes the structure of the Decision Making Tool as applied in the EIPS work; in brief, the Decision Making Tool is comprised of a power system planning module, demand forecasting modules, environmental and financial modules. These modules, individually or as a set, could be use in other States, but more important is the framework itself.

The team will then define the primary and derived scenarios for further analysis ...

Section 3 also considers the definition of the 'scenarios', which play a central role in the analysis. The term 'scenarios' may be used in various ways. In the EIPS work, it was used to describe a loose collection of general economic policies, energy sector policies, policy instruments and power sector options.

The typical scenario analysis in a study of this type involves three steps:

1. identifying the critical variables for scenario definition;
2. developing primary scenarios;
3. developing derived scenarios.

In the EIPS three primary scenarios set the basis for further analysis: the Base scenario, or the Business-As-Usual scenario; the Reform scenario, describing the changes that would occur in the power sector if the distortions in policy and pricing were to be corrected and the market is introduced to encourage efficiency; and the Reference scenario, against which specific measures and investments could be compared. In the EIPS project this comprised a traditional supply side planning using input prices based on economic costs. In addition, a number of derived scenarios were identified to analyse the impacts of combinations of policies or options. All of these are addressed in *Section 3* (and summarised in *Tables 3.2* and *3.3*)

...as well as decide the basic parameters, such as study boundary, period, prices, shadow prices and tariff assumptions ...

Section 4 describes some basic parameters which need to be decided at the start of the work. These may include:

- the study boundary, concerning the definition of the consumers and the power plants which are the subject of the study;
- the study period;
- basic parameters including: (a) prices; (b) shadow prices - capital costs of power plants should include the cost of necessary environmental mitigation measures including Rehabilitation and Resettlement (R&R) costs or compensation. Typically, the cost of these mitigation measures in a conventional pulverised coal plant in India works our at about 7% of the project costs (this does not include R&R costs that are site-specific); and (c) discount rates.
- tariff assumptions - generally, Long-Run Marginal Cost (LRMC) principles are used to establish the target economic prices for different tariff groups.

The next step requires the team to design a demand model for use in the analysis ...

Section 5 describes the demand model, which is one of the primary inputs to the power development planning work and the financial analysis. It aims to present the fundamental requirements of the demand model for use in the analysis, and to describe the experience in Bihar and AP which may be relevant to other states. The approach involves, inter alia., a forecast of unconstrained kWh electricity sales by consumer category and in total (*Section 5.2*), an estimate of price and income elasticities (as principle drivers of demand) (*Section 5.6*) and an estimate of non-technical losses and technical losses on the T&D system (*Section 5.7*). *Section 5.8* further discusses Demand Side Management (DSM) in relation to the demand model.

...and undertake the exercise of converting financial costs of fuels into economic costs ...

In *Section 6*, the Manual describes how financial costs for fuels are converted to economic prices, including the cost of transport to the power plants. It explains how generic cost estimates, derived from the Special Study entitled *Inter-Fuel Substitution Study*, were used to derive economic cost estimates in Bihar and Andhra Pradesh and how they, or updated estimates, could be used similarly in other states in India. *Section 6* addresses the internalisation of environmental costs, and subsequently presents the results of the Special Study in relation to the economic value of coal for both AP and Bihar. The construction costs of a power plant in AP burning grade G coal are estimated to be 24% higher per kW than a similar plant burning grade D. The higher cost is the result of larger pipework to allow for higher ash content more robust coals crushing etc. Additionally the availability of a plant burning grade G coal is estimated to be lower (55%) than a similar plant burning grade D (61%).

Section 6 further discusses the (limited) availability of natural gas as well as the necessary assessment of constraints on the availability of sources of conventional fuels for power generation.

India
Environmental Issues in the Power Sector
Manual for Environmental Decision Making

June 1999

Main Report

The main report (Chapters 1 to 10) and Annexes B-E have been prepared by Environmental Resources Management (ERM) of London, UK, under consultant contract for ESMAP in cooperation with the Administrative Staff College of India (ASCI), from Hyderabad, India, the Sone Command Area Development Agency (SCADA) from Patna, India and Metallurgical and Engineering Consultants (India) Ltd., from Ranchi, India.

1

Introduction

Background

1.1 The activity entitled *India: Environmental Issues in the Power Sector* (EIPS) was undertaken between 1996 and 1998 on behalf of the Government of India, through the Ministry of Power. This was managed by the World Bank, and supported by funding from the UK Department for International Development (DFID).

1.2 One of the main outputs of the EIPS work was the development and application of a set of analytical tools and a framework to provide quantitative analysis, all designed to assist decision makers in the power sector. These were then applied to two Case-Study states, Andhra Pradesh (AP) and Bihar.

1.3 Although no two states can adequately represent the complexity of the Indian power sector, AP and Bihar offer a good cross-section of the issues and options. In both states there is ample scope for an analysis of a whole range of policy options, including DSM and restructuring. Nevertheless, the intention was to use the framework further in other states.

1.4 The Case Studies were carried out by state-level 'nodal' institutions; the Administrative Staff College of India (ASCI) in AP and the Sone Command Area Development Agency (SCADA), assisted by Metallurgical & Engineering Consultants (India) Ltd. (MECON), in Bihar.

1.5 A summary of the organisation of the overall EIPS work is contained in *Section 10* and in the reports produced as part of the EIPS work (*Refs: 1 to 3*). The Terms of Reference for EIPS are included as *Annex A* of this Manual.

The Purpose of the Manual for Environmental Decision Making

1.5 To ensure that the lessons learned throughout the EIPS work are not lost and to help future users of the analytical tools and decision-making process it was decided to prepare this *Manual for Environmental Decision Making* (Manual). The purpose of the Manual is to provide:

- a record of the institutional memory of ASCI, SCADA/MECON and the international consultant - Environmental Resources Management (ERM);
- a record of problems encountered and lessons learned by ASCI, SCADA/MECON and ERM;
- a basis for future similar studies in other states in India and elsewhere.

1.6 The Manual is aimed primarily at the counterparts of ASCI, SCADA and MECON in other states who will undertake similar exercises. This work could, in future, be undertaken by state nodal institutions, consultants, State Electrcity Boards (SEBs), academic institutions or central power agencies.

1.7 *Section 2* and *3* of the Manual, which relate to problem definition and to the design of the decision making process, will also be of interest to decision makers. *Section 10* provides some information on the organisation of the project and the resources required. This may be particularly valuable for states wishing to develop a similar project.

1.8 *Sections 4* to *9* describe some details of the work itself. These Sections will be of most interest to the teams which will undertake the analysis itself.

What is the Decision Making Tool?

1.9 The structure of the Decision Making Tool used to conduct the Case Studies consisted of a set of linked modules. The power system planning module calculated an investment programme for power plant and a corresponding operating schedule that will meet forecast demand at least cost. The demand forecasting module was driven by a detailed examination of the historic electricity demand and assumptions about factors that may affect that demand, such as system losses and tariff and income changes. The results of the power system expansion plan were linked to environmental and financial modules that produce environmental balances and financial accounts. The local environmental aspects (ambient conditions and plant siting) were examined using an air quality model. The Case Studies demonstrated the general validity of the analytical tools and decision-making process.

1.10 It must be emphasised that the Decision Making Tool is not a black box. Rather, it is a decision making process combined with a set of analytical tools. The EIPS work used one set of analytical tools - power system planning software, methodologies for demand forecasting, financial analysis, etc. But other analytical tools, with equal credibility and scientific rigour, might also be used in other states.

1.11 The emphasis of the EIPS approach is on providing rigorous quantitative analysis, based as much as possible on reliable and verifiable data, as an input to the decision making process. A second core philosophy of the EIPS approach is the process of early consultation to obtain views and advice from a wide cross-section of organisations.

2

Problem Definition

Introduction

2.1 The first task in repeating the EIPS work in other states will be to define the problem or problems which concern decision makers, NGOs or other organisations.

2.2 In the EIPS work, the problem definition stage involved extensive discussions between the Ministry of Economic Affairs, Ministry of Power, Ministry of Coal, Ministry of Environment and Forests, the World Bank, DFID (then the Overseas Development Administration), other donor agencies and NGOs. Following agreement for EIPS to go ahead, the Terms of Reference were agreed, state nodal institutions were identified and consultants contracted. EIPS formally began in June 1996 and the first stage of the work was to further refine the definition of environmental problems in the power sector.

Identifying Problems and Issues

The Questionnaire

2.3 The early stages of the EIPS project began with a survey of decision-makers, NGOs and experts in the areas of energy and environment. The questionnaire sought to obtain the views of decision makers and interest groups on the main issues relating to the environment in the power sector. This was used for identifying issues and problems considered to be most pressing in India. The questionnaire is included as *Annex B* to this document.

2.4 The questionnaire in the EIPS project was targeted at officials and interest groups both at the central level and in the two case study states of Bihar and AP.

Lessons Learned for Future Work

2.5 The questionnaire presented particular difficulty in obtaining a reasonable response rate. The questionnaire was, in most cases, directed to high level officials. To achieve a response of over 60%, it was necessary to devote considerable resources of the team at a senior level for making personal requests to complete the questionnaire or to delegate other officials to complete it.

2.6 The EIPS work was the first of its kind in India and covered a very wide range of issues. The proposed all-embracing nature of the work may have been, in part, responsible for the difficulties in obtaining responses to the questionnaire. Future work in other states may address a smaller subset of issues and the 'survey' could be directed at individuals with strong official, or personal, interests in the topic and who do not require prompting to respond.

2.7 Another difficulty concerned the period allocated for undertaking the survey. EIPS began in the middle of June and the questionnaire was completed in preparation for an *Inception Seminar* at the end of July. Given the difficulties mentioned above, in the short time-frame available it was difficult to achieve a high response rate (although subsequent to the Inception Seminar, more completed questionnaires were received). Additionally, it made it difficult to undertake anything more than a simple, pilot testing of the questionnaire using members of our own team, prior to issuing the full questionnaire.

2.8 The questionnaire survey with appropriate follow-ups may usefully be undertaken when similar work is repeated in other states. However, a questionnaire is not necessarily the only method of defining problems which should be addressed. Consideration might be given to:

- telephone surveys conducted by senior members of the team undertaking the work but structured around an interview guide; or
- semi-structured face-to-face interviews.

2.9 Alternatively, issues could be identified by reference to published reports, policy and status reports, discussions with officials and NGOs, etc.

2.10 Whichever approach is adopted, it will be crucial that a wide cross-section of parties are consulted, including NGOs, Ministry officials, regulatory agencies and the power companies. It is therefore important that the body conducting the work should have a network of contacts in these types of bodies or should engage the services of people who have such a network.

Inception Seminar

2.11 In the EIPS work, following the completion of the survey, the results were collated and discussed at an Inception Seminar. The Seminar was attended by a cross-section of officials, NGOs and experts. The Programme for the Seminar is reproduced as *Annex C*.

2.12 The purpose of the Seminar was to provide guidance to ERM and the Case Study teams in shaping the project and, in particular, on:

- the issues in the energy & environmental sectors which are of greatest concern in India;

- how those issues might be examined most usefully to provide guidance for decision-makers.

2.13 The Seminar was particularly valuable in launching the work and alerting a wide audience that the work was about to commence.

2.14 One of the difficulties faced in using the Seminar to identify problems and issues was that the Terms of Reference for the Consultants had at that date been finalised, agreed with the Government of India and the Consultants had been contracted. New issues arising from the Seminar could then only be incorporated in the work by changing the Consultant's Terms of Reference through contract amendments. In future work, it would be appropriate either:

- to hold the survey and Inception Seminar preparatory to the drafting of the Terms of References for the work; or
- to draft the Terms of Reference for the work before the Inception Seminar and use the Inception Seminar to describe some of the details of the quantitative work about to be undertaken (but not to seek the views of the audience about the problems themselves).

The Issues Addressed in the EIPS Work

2.15 The issues which lay behind the EIPS work relate to key energy policy questions and to fundamental operational aspects such as DSM, power system loss reduction, siting of power plants or optimal technology. The issues broadly include:

Environmental Problems

2.16 The environmental problems of interest to decision makers could be:

- India has large reserves of coal that are a major asset. They mostly have a high ash content, up to 40% or more. Disposing of the ash by-product is troublesome; the requirement for land is huge and leaching can contaminate ground water. Most forecasts of energy use in India show rapidly rising use of local coal, so the problem will get worse if nothing is done. Coal ash can be used in many ways and it may be appropriate to encourage this practice so as to minimise the environmental impacts.
- Sites for hydro and thermal power stations and for ash disposal require large areas of land. Hydro power stations are inevitably on rivers and thermal power stations also require cooling water, often taken from lakes or rivers. The inevitable location of these plants therefore usually means that the land generally has a high economic value. The resettlement of populations, though more properly a social rather than environmental issue, is an important constraint on new development. The two issues are often practically inextricable.
- Acid gases and particulate matter produced by power stations. These are dispersed by high stacks, but eventually they reach the ground and can damage health and property. Except for a few places in India, the contribution of the power sector to ambient concentrations of acid gases is not large but the sector is frequently responsible for excessive concentrations of particulate matter.

- Acid gases can be transported long distances across frontiers and are eventually precipitated as acid rain. Oxides of nitrogen (NOx) are also precursors of tropospheric ozone, so high local concentrations of ozone can originate from remote sources. These trans-boundary problems are well documented in Europe and North America and have lead to stringent controls to reduce emissions. The problems are not yet severe in India, but the large increases in coalfired power generation that are expected could change this picture.
- Carbon dioxide (CO_2) emissions from coal-fired power plants are a major contributor to global warming. Following the agreements reached at Kyoto in 1998, the abatement of greenhouse gas emissions is becoming an increasingly high priority across the world.

2.17 Given these significant social and environmental impacts of power development it is reasonable to ask what can be done to mitigate or avoid them and what it would cost. The environmental impacts of power development may be reduced by using less electricity, by controlling the impacts of generation, by preventing waste products reaching the environment or by adopting new, intrinsically clean technologies. Energy conservation is an alternative to new power supply. Renewable energies are an alternative to fossil-fuel generation.

2.18 These measures cannot be studied in isolation. An integrated view is necessary to see how the possibilities in terms of supply, demand and control can be best combined. The objective is to find a suitable balance between the needs for power and the preservation of the environment over the long-term.

Impact of Energy Sector Reforms

2.19 The power sector in India is on the verge of fundamental and significant reforms. They will affect the demand for electricity, the financial viability of the entities involved, the capacity of the state to influence action, the viability of all market based policies and the choice of fuel and technologies. It is necessary to understand how these structural changes will affect the environment and to identify how the opportunities can be maximised and any threats averted.

Other Problems or Issues

2.20 These and other issues may be the concern of decision makers throughout India. The Decision Making 'Tool' does not confine itself to these specific issues. It can be broadened, deepened or narrowed according to the interests of the decision makers or those wishing to influence decision making. It could be broadened to include a wider set of issues such as the macroeconomic or employment consequences of power sector development. The process could, for example, be used to include a more detailed examination of the consequences on population displacement of power sector developments. Or it could be used with a very narrow focus to examine specific topics, such as the appropriate level of carbon taxes.

2.21 The process and analytical tools could also be used to help prepare power development programmes (both demand-side and supply-side) for State Electricity Board (SEBs). Or it could consider questions relating to the optimal siting of power plants.

The Questions That Were Asked in the EIPS Work

2.22 The second task in defining the problem is to turn the general set of concerns described above into specific questions which can be tackled using the quantitative analysis of the Decision Making Tool.

2.23 The work undertaken in AP and Bihar addresses the practical questions of where the power sector is going, what the consequences will be, what can be done to reduce the impacts on the environment, what it will cost and the trade-offs involved. The work was structured around the following set of questions:

The environmental impacts of reform:

- what will happen to the environment if present policies on electricity and fuel prices are maintained?
- would reform and restructuring of the power sector benefit the environment?
- what would be the consequences of choosing plants on the basis of economic costs including internalisation of environmental costs?

Green options:

- renewable energies would improve the environment, but by how much and what would it cost?
- demand side management would improve the environment, but by how much and what would it cost?
- what are the benefits of rehabilitating transmission and distribution networks for electricity and existing generating plant?

Technical options:

- how much would it cost to use new clean coal technologies and to wash coal and how much would this achieve?
- can more ash from power stations be utilised, and if so how?
- what would it cost to implement the new World Bank environmental standards?

General environmental policy issues:

- what are the environmental impacts of power plant location and concentration?
- what are the costs of environmental controls?
- what are the costs of reducing emissions of carbon dioxide?
- what are the costs of environmental damage?

2.24 In each case, the question is designed to allow a quantitative answer to be given. The quantitative answers can be expressed in terms of costs, environmental impacts (emissions, land pre-emption, population displacement, etc.), ambient air quality, benefits (which would be in terms of reduced costs or reduced environmental impacts), investment requirements or the financial condition of the power companies.

2.25 Other questions which might be asked by decision makers might include:

- what is the optimal power sector investment programme, taking account of both cost and environmental factors?
- what is the optimal location of power plants within the state or outside, taking account of environmental impacts, fuel transport and power system costs?

3

The Overall Design of the 'Analytical Tool'

Introduction

3.1 The EIPS framework is designed to answer the types of questions posed in *Section 2* and other similar questions which require a quantitative answer. The framework is, however, devised to be fully flexible and allows the user to employ a range of alternative software. It also allows the user to exclude some modules where the inputs can be obtained from an external source (where, for example, a reliable demand forecast has recently been prepared this forecast might be used as an input to the power system planning and financial analysis models); and to restrict the amount of feedback between models.

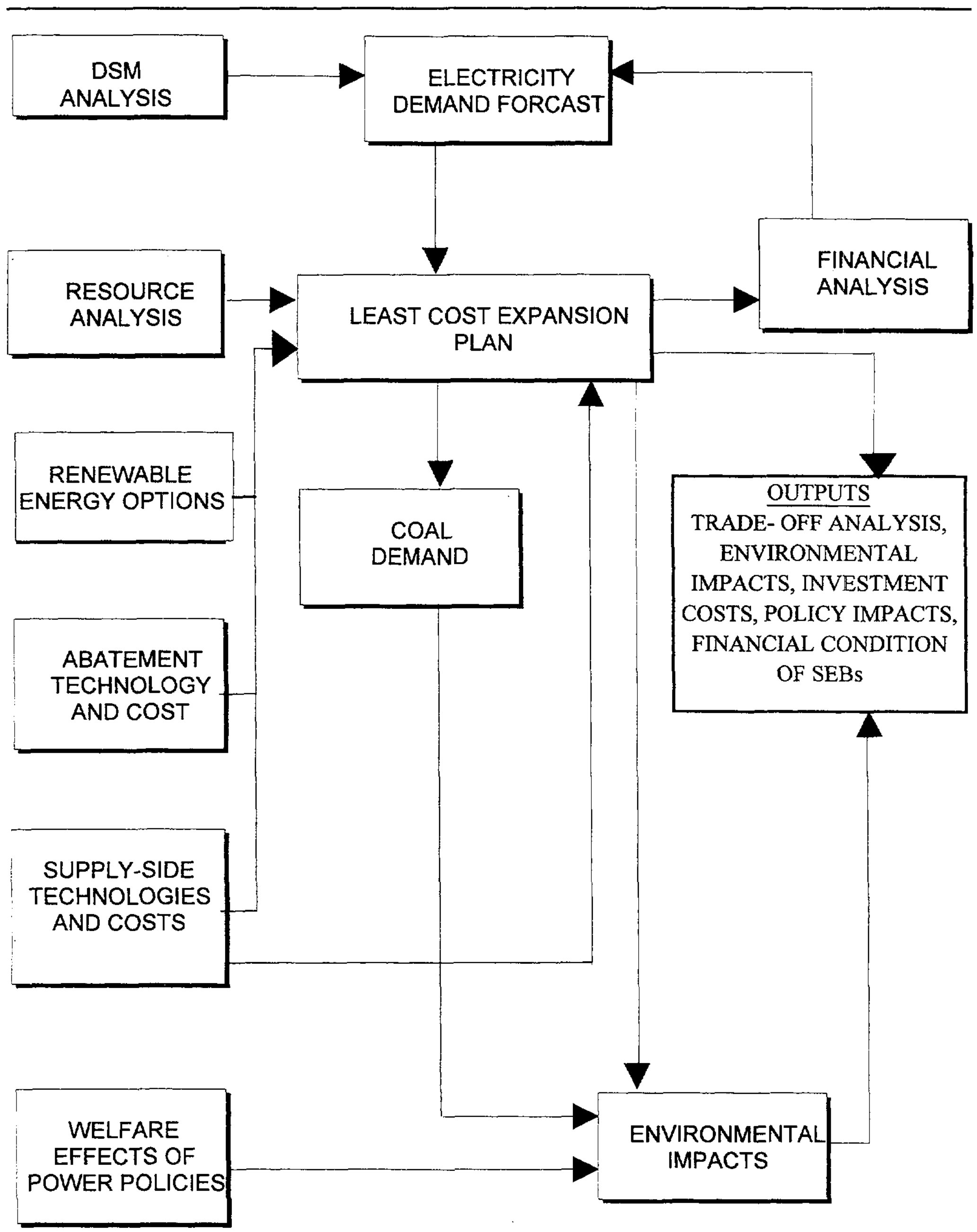
The Structure of the Decision Making Tool

3.2 The structure of the Decision Making Tool used in Bihar and AP, is shown in *Figure 3.1.* The power system planning module calculates the schedule of investment in power plant that will meet forecast demand at least cost. In this study it uses a least-cost power system expansion planning software, AS-PLAN, which is described in *Section 7.*

3.3 The demand forecasting module in the EIPS work was driven by a detailed examination of the historic demand and assumptions about factors that may affect the future demand for electricity at the power plant, such as price rises and growth in income under Reforms, DSM programmes and rehabilitation of T&D networks.

3.4 The output from the power system expansion plan was linked to environmental and financial modules that produce environmental balances and financial accounts. The local environmental aspects were examined using an Air Quality Model.

Figure 3.1 Structure of the Decision-Making Tool



3.5 The work undertaken for the Case Studies adopted certain common modules, but some divergence developed in the approach to load forecasting and the financial analysis. Both Case Studies used the same power system planning module, but in future applications in other states it is possible that a different power system module would be chosen.

3.6 Rather than defining appropriate models as analytical tools, the work of the EIPS demonstrated the general validity of the analytical structure used to answer the particular questions described in *Section 2* and illustrated the use of a particular set of analytical tools. The work has also demonstrated a decision making framework comprising a particular set of modules that works well. These modules, individually or as a set, could be used in other states, but more important is the framework itself.

Scenario Definition

Introduction

3.7 The 'scenarios' play a central role in the analysis. The term 'scenario' may be used in various ways but in the EIPS work, it was used to describe a loose collection of general economic policies, energy sector policies, policy instruments and power sector options. The 'scenarios' are crucial in answering the questions which are developed as described in *Section 2* above. The typical scenario analysis in a study of this type involves three steps:

1. identifying the critical variables for scenario definition;
2. developing primary scenarios;
3. developing derived scenarios.

These are discussed in turn below.

Identifying Critical Variables

3.8 In developing a scenario the first task should be to identify the critical variables that will best describe the current status as well as the expected changes in the power system under study. This stage is critical as the identified variables form the building blocks of the corresponding scenarios and ultimate results will be strongly influenced by the assumptions made regarding these variable. An indicative list of variables and issues relating to those variables are detailed in *Table 3.1* below.

Table 3.1 Critical Variables, Inputs, Outputs and Issues

Variable	Issues
Electricity Tariffs	What are the current tariff polices? How are these likely to change? What are the LRMC based tariffs?
SDP Growth	What SDP growth rate is expected without reforms? What SDP growth rate is expected with reforms?
Fuel Costs	What are the financial costs of fuels? What are the economic costs of fuels? What are the expected changes in real terms?
T&D Losses	What are the current T&D Losses? What loss reductions are expected with reforms? What are the administrative & technical costs of implementing T&D loss reduction measures?
Purchased Power	What is the cost of purchased power?
DSM Measures	What is the potential for alternative DSM measures? What are the administrative & technical costs of implementing DSM?
Renewable Energy Technology (RET)	What is the potential for introducing RETs? What are the associated administrative & technical costs?
Captive Generation	What is the installed capacity of captive generation? How is this expected to change under alternative scenarios?
Other Supply Constraints	Are there any other supply constraints or special conditions that need to be considered while defining the scenario?

Developing Primary Scenarios

3.9 Primary scenarios set the basis for further analysis. In the EIPS project, these were the situations of a) status quo, b) reforms, and c) economic pricing within the power sector, as described below:

- *Base Scenario*: This scenario is a detailed description of the existing economic and energy sector policies and an extrapolation of these for the period under consideration. This is the 'Business As Usual or BAU Scenario". The Business-As-Usual scenario describes what would take place in the absence of any policy changes within the power sector. Where policy changes have been agreed in principle but not yet implemented, judgement must be used to decide whether implementation is *likely* to take place.

- *Reform Scenario*: The second main scenario in the EIPS project described the changes that would occur in the power sector if the distortions in policy and pricing were to be corrected and the market is introduced to encourage efficiency. The description of reform is determined in consultation with policy makers. The changes in policies as well as their impacts may then be incorporated into parameters which drive the analysis, such as: SDP projections, electricity price projections, electricity demand forecasts, prices and availability of fuels, compliance with environmental standards and the availability of investment funds. The purpose of the Reform scenario is to identify some quantifiable effects of reform, compare them with the business-as-usual scenario and evaluate whether reform was good or bad for the environment. In the EIPS project, the comparison could not be used by itself to show whether reform was good or bad - but it did allow some evidence to be presented showing some of the impacts of reforms.
- *Reference Scenario:* The third main scenario in the EIPS project was used as the reference against which specific measures and investments could be compared. In the EIPS project, this represented a traditional supply side planning using input prices based on economic costs. Other scenarios were perturbations of this scenario.

Derived Scenarios

3.10 As noted earlier, the term scenario was used in the EIPS work, to describe a combination of economic projections, energy policies and options. A number of scenarios were identified to analyse the impacts of combinations of policies or options. These combinations were labelled, for example, the 'green' scenario comprising DSM and RET measures or the 'technical' scenario comprising clean coal technologies and coal beneficiation.

3.11 The decision-maker may also be interested in the impact of individual policies, programmes (eg an RET programme) or options (eg coal beneficiation) or in a small mix of policy measures to 'mimic' real life situations. More detailed, individual policy-programme-option analysis may be carried out in the final stages by perturbing critical variables in the Reference scenario and studying the impacts of the same. Notably, at this stage one can analyse the impact of pure policy measures (such as introduction of tariff reforms) or a combination of supply and demand side measures tempered by practical considerations (such as tariff reforms followed by greater use of renewables and T&D loss reduction.)

The Scenarios in the EIPS Work

3.12 The 'scenarios' used in the work in AP and Bihar are summarised in *Table 3.2* and *3.3*. *Table 3.2* shows the primary scenarios (BAU, Reform and the Reference scenario) while *Table 3.3* shows the derived scenarios which are compared with the Reference scenario.

Table 3.2 EIPS: Primary Scenarios

Scenario	Critical Variables: Assumptions					
	Electricity Tariffs	**SDP Growth**	**Fuel Costs and Purchased Power (1)**	**T & D Losses**	**DSM, RET**	**Captive Plants & Supply Constraints**
BAU	Current policies and those currently approved and expected to be implemented	SDP projections based on current economic policies and expected to be implemented	Fuel choices based on existing real prices (financial). Price increases based on policies currently approved and expected to be implemented (2)	Loss projections based on current investment and management policies and those currently approved and expected to be implemented (3)	Current policies and those currently approved and expected to be implemented	Captive capacity increases steadily through reference year and then held constant. Supply constraints increase
Economic Reform	LRMC based tariffs or approximation to these	SDP projections assuming economic reform takes full effect by 2002 (4)	Price levels and price structures assumed to be based on economic costs and expressed in real terms (5)	Losses fall as commercial incentives come into play	Conservative estimates of RET costs in least cost analysis. DSM driven only by tariff reform	Captive power plant and supply constraints estimated by a reference year (6)
Reference Case (IFS)	As for BAU	As for BAU	As for Economic Reforms	As for BAU	As for Economic Reforms	As for Economic Reforms

Notes:

1 Shadow pricing is unnecessary in any scenario. In the BAU scenario, all prices and costs are financial and no attempts are made at shadow pricing in the Non-BAU scenario, cost of fuel and purchased power are priced at economic cost, therefore shadow pricing is unnecessary

2. In constant Base Year prices
   Imported fuel prices should take account of any expected 'real' changes in prices of constant base year price levels
   Purchased power tariffs should mirror, to the extent possible the fixed and variable structure of the actual tariffs
   Purchased power tariffs should reflect any future "real" increases or decreases in prices. If, for example, the price is fixed in nominal terms then the price will fall over time in 'real' terms.

3. Losses would be expected to increase over time if current policies and practices are pursued and the transmission and distribution systems become increasingly overloaded.

4. SDP growth may quicken as the result of improved availability and quality of electricity supply

5. Environmental costs assumed to be internalized. Current environmental standards assumed to be met

6. Financial constraints on investment are not considered in this scenario

Table 3.3 Derived Scenarios

Scenario	Purpose of Analysis	Critical Variables: Assumptions					
		Electricity Tariffs	**SDP Growth**	**Fuel Costs and Purchased Power**	**T & D Losses**	**DSM, RET**	**Captive Plants & Supply Constraints**
Reference Case (IFS)	To examine the impacts of using economic costs of inputs rather than financial prices	As for BAU Current Policies and those currently approved and expected to be implemented	As for BAU SDP projections based on current economic policies and expected to be implemented	As in BAU Fuel choices based on existing real prices (financial). Price increases based on policies currently approved and expected to be implemented	As in BAU Loss projections based on current investment and management policies and those currently approved and expected to be implemented	As for Economic Reforms DSM driven by tariff reforms, if any	As for Economic Reforms Captive power plant and supply constraints estimated by a reference year
Green (1)	To examine the environmental benefits and costs of 'green' options (2)	As for IFS	As for IFS	As for IFS	As for IFS	Make optimistic assumptions about RET, DSM, coal beneficiation etc.	As for IFS
Technological	To analyze costs and associated environmental impacts of clean coal technologies	As for IFS	As for IFS	As for IFS	As for IFS	As for IPS	As for IFS
Alternative Standards	To analyze the costs and environmental consequences of applying World Bank's emission standards	As for IFS	As for IFS	As for IFS	As for IFS	As for IPS	As for IFS
CO2 Reduction	To analyze the implications of reducing CO_2 below IFS levels and derive cost curve for CO_2 reduction.	As for IFS	As for IFS	As for IFS	Additional T & D loss reduction to be considered an option for CO_2 abatement	Aggressive DSM/RET policies to be considered an option for CO_2 abatement	As for IFS

Notes:

1. Environmental costs assumed to be internalised. Current environmental standards assumed to be met
2. The benefits and costs should be based on broad considerations of all alternatives to traditional supply side options. These have loosely been labelled "green".

The Attributes

Definition of an Attribute

3.13 People are affected in numerous and complex ways by the activities in the power sector. 'Attributes' is the term used in this Manual to describe the quantitative impacts of power sector development. An obvious attribute is that of cost while environmental attributes are less easy to identify.

3.14 The affect of pollution on people is less straightforward and is currently subject to considerable uncertainty. Air pollution, for example, leads to respiratory diseases and can contribute to increased incidence of respiratory failure and mortality. The response to increased emissions depends on a large number of factors which vary significantly from place to place. Empirical studies quantifying the mortality and morbidity impacts are not well developed.

3.15 It is therefore helpful to adopt a set of measurable 'attributes' that can be accepted as proxies for the complex and extensive set of environmental impacts on people. The choice of attributes underlies the design of any instruments for pollution control. For that purpose it is essential that the attributes be measurable. For the purpose of anticipating the future it is also necessary that the attributes can be predicted from the modelling process.

Internalisation of Environmental Costs

3.16 The Indian government, the Central Pollution Control Board (CPCB) and the State Pollution Control Boards (SPCB) set rules for the use of the environment that affect the costs incurred by the business. Technical standards are a common instrument; in this case business must change its operations or introduce controls that reduce some environmental attribute to a prescribed level; these controls increase the costs of the business.

3.17 Market based instruments may also be used; in this case a tax may be imposed on an environmental attribute (for example the carbon tax) or a licence is purchased to allow a certain level of discharge (for example the systems of tradable permits used in some cases in the US).

3.18 Emissions to the environment which affect other people or business but for which no payment is made by the polluter is an example of an 'externality' - in economic jargon. If the polluter could be charged for the pollution then he is more likely to eliminate that pollution or, at least, to cut back. The existence of externalities means that the level of pollution is not optimal from an environmental/economic perspective. Charging for pollution according to the damage caused by the pollution through market based instruments is known as the 'internalisation' of externalities. However, market based instruments face practical difficulties in implementation and in the valuation of pollution damage.

3.19 An alternative to full internalisation is to impose minimum environmental standards - mandatory abatement technology, emission limits or standards for ambient concentrations. If the appropriate standards could be estimated perfectly and could be enforced, then a proper balance between economic activity and the environment would automatically be achieved. Pollution levels would then be equivalent to the pollution levels which would occur if externalities were fully internalised.

3.20 The approach adopted in the EIPS work was to assume that environmental standards in India are acceptable and that proper enforcement of these standards would be equivalent to the internalisation of externalities. Therefore considerable attention was given to ascertaining the control costs of power generation and the costs of mitigating the environmental impacts of coal mining. However, a scenario was incorporated to analyse the effect of bringing standards in line with guidelines recently issued by the World Bank (see *Table 3.3*).

3.21 Emissions to air and water were assumed to be optimised through the imposition of discharge, emission and ambient air quality standards; the land use aspects are contained in the economic cost of acquiring land; and the impact of resettlement and rehabilitation is internalised through the economic costs to compensate the land-owners or users.

3.22 However, certain features of the methodology used in the EIPS work need to be underlined:

- First, the environmental costs included as part of economic costs are not necessarily equal to the financial costs or compensation actually paid.
- Second, the methodology provides valuable information to decision-makers about the costs of alternative ways to meet their own environmental objectives, but does not evaluate the merits of those objectives. Information on the relationship between damage costs (including the external costs of pollution and the social impacts of resettlement and rehabilitation) and control costs, essential for such an evaluation, were not available or could not be collected to a satisfactory level of reliability under this activity.

3.23 Within the EIPS work, only two limited attempts were made to go beyond existing environmental standards:

- to analyse the cost impact of alternative (World Bank) standards and the resulting emission reductions, and
- to assess the costs of CO_2 reduction.

3.24 No attempt was made to introduce a normative assessment of those cost impacts relative to possible benefits.

3.25 In recognition of the above features, a small subset of environmental attributes was monitored explicitly at critical points in the analysis:

- Total suspended particulates (TSP), oxides of sulphur (SO_2) and NO_x are tracked because of their importance to air quality and human health, and the need to highlight, for decision-makers, the possibly serious implications of substantial increases in these attributes, which may not be addressed adequately in the long term by existing standards;

- CO_2 is tracked, because India has no environmental objectives regarding green house gas reduction, so CO_2 (which has an important global impact) is not subject to standards; and
- Land use and ash are treated explicitly, because the sheer scale of the problem in India in the future is a cause for concern, which again needs to be highlighted for decision makers.

Choice of Attributes

3.26 The attributes chosen for the EIPS study were of two types - discounted and not-discounted:

- In some cases the present value of emissions is calculated over the study period. This attribute is appropriate for emissions that do not accumulate, but cause acute damage; an example is the effect of TSP or SOx on human health. The present value of the investments required to reduce emissions can be compared to the present value of the reduction in emissions to give an estimate of the unit cost of emission reduction.
- A second type of attribute is the cumulative emission of materials that are not destroyed or have longer residence times. An attribute like this is appropriate when the impact is a consequence of a "stock" rather than a "flow". Examples are the radiative forcing properties of CO_2 which depends on the total amount in the atmosphere or the management of coal ash where the problems depend on the amount accumulated.

Specifically the set of attributes used were:

- the present value of emissions of particulates and oxides of sulphur and nitrogen from specified sets of plant (tonnes);
- cumulative emissions of CO_2 (tonnes);
- cumulative production of ash (tonnes);
- cumulative land pre-emption (m^2).

4

Basic Parameters and Input Assumptions

Introduction

4.1 The following Section describes some of the fundamental parameters which need to be decided at the start of the work.

The Study Boundary

The Issue

4.2 The 'study boundary' concerns the definition of the consumers and the power plants which are the subject of the study. In some instances, the study boundary will be obvious but in other instances it will become a major issue and it will be necessary to consider this very carefully.

4.3 The problem arises because power can be produced in one geographical area, supplied to consumers in another area and the emissions can affect people in a third area. In some instances, the three areas coincide - but this will be rare. Most SEBs in India take some power from central organisations (NTPC, NHPC, etc.) or other organisations and some plan to take power from Independent Power Plants (IPPs). This gives rise to environmental impacts in one state or territory where this power is for the benefit of consumers in other states or territories.

4.4 Additionally, a number of consumers are supplied with power supplied by their own 'captive' plant. Consumption by these consumers does not form part of the sales of the SEB but the environmental impacts are felt within the state and the state-level decision makers may wish to consider the advantages and disadvantages of these captive plants.

Boundaries Adopted in Bihar and AP

4.5 In Bihar, the boundary was drawn around the consumers of Bihar State Electricity Board (BSEB). Consumers of Damodar Valley Corporation (DVC) were excluded. The power system supplying the BSEB consumers included Tenughat Vidyut Nigam Ltd (TVNL) and Bihar

State Hydroelectric Power Corporation (BHPC) plants. DVC's plants were excluded from the study, but BSEBs purchased power from DVC was included in the electricity balance. The capacity of NTPC and NHPC plants supplying BSEB were assigned to BSEB according to BSEB's share of those plants.

4.6 The electricity consumption of industries in the BSEB territory with captive power plants was included in the boundary of the study while the captive plants in the DVC territory was excluded.

4.7 Environmental impacts from plants were allocated in proportion to the amount of electricity that they supply to BSEB - whether they are located within or outside the state. The environmental impacts from captive plants were included fully in the analysis.

4.8 In AP, the boundary was similarly drawn around the consumers of APSEB and captive power plants. However, the analysis was much simpler because this boundary also coincided with all consumers within AP since there are no organisations similar to DVC in AP.

The Study Period

4.9 A study period must be selected. For the AP and Bihar studies, a study period of 20 years was adopted (1996 to 2015).

4.10 Because power sector investments have a long life, often extending beyond 30 years, a short study period cannot be considered. However, because of discounting, the long term impacts will become increasingly unimportant while uncertainties will increase. Developing a very long study period could therefore be wasteful of resources without adding much to the robustness of the answers. A study period between 20 and 30 years would normally be adequate.

Some Basic Parameters

Prices

4.11 Prices should be 'real' and fixed at a given date. Beyond that date, only real escalation in prices was considered (ie price increases above the general level of inflation).

4.12 In the case studies in AP and Bihar, the prices and exchange rates were fixed at mid-1996 levels.

4.13 The exception to this was the financial analysis, where general inflation was introduced.

Shadow Prices

4.14 'Shadow Pricing' refers to the conversion of financial prices to economic values.

4.15 Financial prices were used in the case studies for the BAU scenarios but economic values were used in all other scenarios. Financial prices are also used in the financial analyses.

4.16 Conversion from financial to economic prices is particularly important for the costs of fuels, for instance including environmental costs, and the transport of those fuels - these are discussed in *Section 6.*

4.17 Costs of capital equipment should exclude taxes or subsidies. Taxes on Indian equipment were found in the AP and Bihar studies to be predominantly excise duties and sales taxes which, on average, amounted to 20% of the capital costs. For some foreign equipment, import duties could comprise up to 60% of the cost.

4.18 Some renewable energy technology in India is supported with grants and tax exemptions. Where the equipment is exempt from tax, no further adjustment needs to be made to convert to economic prices. Where grants are given, the grant needs to be added back to the cost to obtain the economic cost.

4.19 Capital costs of power plants should include the cost of necessary environmental mitigation measures including Rehabilitation and Resettlement (R&R) costs or compensation. The normal pollution control systems that are required for a coal-fired power plant in India are:

- air pollution control

    tall stack to disperse flue gases
    low NOx burners
    space provision for retro-fitting FGD
    high efficiency ESP
    dust suppression and extraction systems at coal handling plant
    green belt development and afforestation

- water pollution control

    pit for pH adjustment of the DM plant regeneration-waste
    central effluent treatment plant
    sewage treatment plant in the colonies

- solid waste disposal

    disposal of fly ash and bottom ash

4.20 Typically, the cost of these mitigation measures in a conventional pulverised coal plant in India works out at about 7% of the project cost. This does not include R&R costs that are site-specific. The absolute and percentage costs for the various environmental components on a 500 MW coal fired plant are given in the *Synthesis Report.*

4.21 The R&R costs for a hydel (hydroelectric) power station can be very significant. For example, in Bihar the Koel-Karo hydel plant has an estimated R&R cost which represents 15%-16% of the total project cost (*Synthesis Report*).

Discounting and the Discount Rate

4.22 Where costs are discounted, they will be discounted to the base year. The base year in the AP and Bihar case studies was chosen to be 1996. This date is normally chosen to be the year before the study period begins.

4.23 A base discount rate of 12% in real terms was used in the case studies in AP and Bihar. This represents the opportunity cost of capital which conforms to the approach to discount rates described in (ref: 1) and routinely adopted for project appraisal by the World Bank. It is worth noting, however, that the choice of discount rates for environmental impacts is currently controversial (ref: 2).

Tariff Assumptions

Marginal Cost Based Tariffs

4.24 Marginal cost based tariffs had not been estimated for AP or Bihar but some indication on possible levels was available from a tariff study for UP and Orissa prepared for the World Bank. The prices from these studies are given in *Table 4.1.*

Table 4.1 LRMC Based Tariffs, Uttar Pradesh and Orissa (1996 prices)

Tariff Group	UP	Orissa
Residential	Rs. 4.1/kWh	Rs. 4.35/kWh
Commercial	Rs. 2.5/kWh	Rs. 4.02/kWh
Agricultural	Rs. 2.6/kWh	Rs. 2.28/kWh
HT industry	Rs. 1.5/kWh	Rs. 1.54/kWh
LT industry	Rs. 3.0/kWh	Rs. 1.90/kWh

4.25 The agricultural tariffs for both UP and Orissa are very low which appears to suggest a continuation of the current practice of using pumpsets only at off-peak times (the UP tariff is for LT agriculture while the Orissa tariff does not specify whether it is LT or MT). The use of pumpsets only at off-peak times was introduced because of generating capacity shortages but this practice could also be the result of time-of-day pricing which could (should) be introduced in the reform scenario. Thus, agricultural consumers could face a relatively low tariff.

4.26 The financial model can calculate the appropriate *level* of average revenues to meet a target financial rate of return. LRMC principles are generally used to establish the relative prices between different tariff groups. In AP, based on the UP and Orissa studies, relative prices were established as shown in *Table 4.2.*

Table 4.2 LRMC Based Relative Prices in AP

Customer Group	Tariff (as % of industrial)
Industrial	100
Residential	170
Commercial	145
Agriculture & irrigation	109

Note: All relative to the industrial tariff, which equals 100.

The financial model will then identify the levels of tariffs necessary to keep APSEB financially viable while keeping the relative prices unchanged.

Prices need to be increased year-on-year by assuming an automatic *fuel cost adjustment* factor in a tariff schedule.

5

The Demand Model

General

5.1 The demand model is one of the primary inputs to the power development planning work and the financial analysis.

5.2 There are a number of different approaches, each with some advantages and disadvantages. Additionally, some of the econometric techniques used to derive the parameters for the forecasting cannot be explained in a Manual such as this. We do not recommend one forecasting technique over another. Our purpose here is:

- to describe the fundamental requirements of the demand model for use in the analysis; and
- to describe the experiences in Bihar and AP which may be relevant to other states.

5.3 The demand models used in AP and Bihar adopted similar approaches. While an identical approach need not be used in other states, it is useful to describe this approach in order to describe the building blocks of a demand forecast. In summary, the approach involves:

- a forecast of unconstrained kWh electricity sales by consumer category and in total;
- an estimate of non-technical losses and technical losses on the transmission and distribution system. The addition of technical and non-technical losses to sales gives the demand at the power station busbar or the sent-out demand;
- a forecast of system peak demand, built up from the coincident demands of the different consumer groups or from the total aggregate sent-out kWh demand.

5.4 An example of such a forecast is given in *Table 5.1*.

Table 5.1 Example of the Build-Up of a Load Forecast

		1996	....	....	2015
a	**Sales (GWh)**				
b	Residential	750			2,300
c	Commercial	450			1,500
d	etc.				
e	*Total Sales (b to d)*	5,500			20,000
f	**Losses (technical and non-technical (GWh)**				
g	Residential	310			575
h	Commercial	150			300
i	etc.				
j	*Total losses (g to i)*	2,000			4,400
k	*Total Sent Out (GWh) (e+j)*	7,500			24,400
l	**Coincidence Factors**				
m	Residential	0.8			0.8
n	Commercial	0.8			0.8
o	etc.				
p	**Load Factors (%)**				
q	Residential	35%			35%
r	Commercial	40%			40%
s	etc.				
t	**Demand (MW)**				
u	Residential (b/8760/1000/q*m + g/8.76/LLF*m)	233			715
v	Commercial (c/8760/1000/r*n + h/8.76/LLF*n)	127			422
w	etc.				
x	*Total Sent Out Demand (MW) (u to w)*	1,300			22,000

Note: LLF is the loss-load factor, calculated as: loss rate/(.3+.7 x load factor) 8760 is the number of hours in a year.

Other Demand Forecasts

5.5 An important demand forecast prepared annually by the CEA (Ref: 11) should not be overlooked. The forecast is based on a comprehensive survey conducted through the SEBs and contains valuable information. Its drawbacks from the point of view of the EIPS work are:

- that it is outside the control of the state teams and they cannot investigate the impact on demand of changes in price or income or other parameters; and
- it is not an estimate of unconstrained demand (see below).

5.6 The CEA forecast nevertheless provides a good basis for comparing the forecasts made by the study teams.

Constrained and Unconstrained Demand

General

5.7 Electricity supplied in India is constrained by shortages of generating, transmission and distribution capacity. The electricity supplied is generally below the level of demand. In other words, demand is constrained by the availability of supply. The demand forecast should be a forecast of *unconstrained* demand. It should not, at this stage, consider whether demand can or cannot be met - the latter is examined during the power system analysis work.

Estimate of Unconstrained Demand

5.8 Among the initial problems to be encountered in the analysis will be the need to estimate unconstrained demand. Data on electricity generated is generally readily available. Data on electricity sold is also available (but, as discussed below, this data may not be accurate). But data on the demand which would have been supplied had there been no constraints, must be estimated. This is very difficult to do.

5.9 Demand can be constrained in several ways:

- through power cuts;
- by supplying some consumers at fixed times (eg agricultural consumers supplied on a rotational basis or industrial consumers supplied off-peak);
- by increasing the waiting lists for new consumer connections; and
- by insisting that industrial consumers use their own power supplies.

5.10 Unconstrained demand was estimated in both AP and Bihar by focusing on power cuts and attempting to derive the energy which would have been supplied if those power cuts had not taken place.

5.11 In Bihar, the team obtained information on the frequency and duration of power cuts and which consumer groups suffered from the power cuts. Using assumptions about the electricity which would have been consumed by those groups, the team assessed the electricity not supplied. This was estimated, for example, to be 25% of (un-suppressed) sales in 1994/95 for commercial consumers.

5.12 In AP, the APSEB introduced a Restriction & Curtailment Policy in the late 1980s and established a formula to estimate the electricity lost through these policies. The formula uses data on the incidence of power cuts - which are routinely collected and collated by APSEB. The formula is described in *Box 5.1.*

Box 5.1 ASCI Formula for Estimating Load Shedding

In AP there have been statutory restrictions on HT energy supplied with the actual restriction varying from month to month. In respect of LT energy consumption there were no statutory restrictions but scheduled and unscheduled load relief were availed to match the supply to the generation from time to time. However, sales to the agricultural sector were fully met. The daily data on the load relief availed in different areas were not available, hence estimation was made heuristically.

HT Consumption: The HT consumers were subject to varying statutory cuts, for different periods, the cut varying with contracted demand. Essential services like railways, hospitals, coal mines were not subjected to any cut. Hence the energy sales for HT consumers can be divided into the parts, one subjected to power cuts and others exempted from power cuts. The energy sales under each part for different demand slabs were obtained from customer data. The effective power cut to HT consumers was computed considering the percentage of power cut and the period of power cut. Mathematically expressed, the effective power cut is:

$$\sum_{K=1}^{NP} \sum_{J=1}^{NS} \frac{ES_j}{TE_j} \times \frac{PC_{j,k} \times ND_{j,k}}{365}$$

$ND_{J,K}$	=	No. of days the demand slab J is subjected to power cut in the period K
$PC_{J,K}$	=	Percentage of power cut on demand slab J during the period K
NS	=	No. of demand slabs
NP	=	No. of periods the power cut is imposed in the year
ES_J	=	Energy sales of demand slab J in the year
TE_j	=	Total energy sales of all slabs in the year

The unrestricted energy sales of the HT consumers subjected to restrictions is computed considering the effective power cut as calculated.

LT Sales other than Agricultural: For these consumers there are no cuts but varying hours of load relief (LR) are imposed on these consumers during different periods in a year. The complete data of LR was not available. The effect of LR was estimated in two ways. The first method assumes that the LR is availed only during the days of statutory power cuts and the effect of LR on energy sales as a 20% reduction of sales. Then the effect of LR is 20% and:

$$\sum_{K=1}^{NP} ND_K /365$$

The second method assumes the effect of load relief on energy sales as 50% of HT power cuts. The year wise effect of load relief estimated by the two methods was compared and found to be approximately the same. The AP study took the effect of LR as the average of the two methods.

5.13 Using this formula, the AP team estimated that the unconstrained demand was 12.5% higher than the kWh actually supplied in 1995/96 and the MW demand was 23% above the MW actually supplied. Strictly speaking, the formula will only be valid under certain conditions (the conditions which held when the formula was estimated) but it nevertheless gives a useful idea of the likely scale of load shedding.

5.14 It should be noted that the estimate of constrained demand in both AP and Bihar represents only a limited part of the constraint. Industrial consumers often respond to supply constraints by switching to captive generation (this is illustrated by the fall in growth in demand of industrial consumers from 12% per year in the late 1980s to 2.5% during the mid-1990s.

Captive generation, where the consumer operates largely in isolation from the grid, is covered as a separate item in the forecast. However, when supply constraints are eased and then eliminated and confidence in grid supply returns, it is likely that many of those consumers with captive diesel gensets will wish to return to grid supplies and that growth in the demand for grid supplies will accelerate.

5.15 Lengthening waiting lists, particularly for residential consumers, is one aspect of demand constraint which is not captured in this estimate.

5.16 Another possible approach which might be investigated to estimate unconstrained demand would be to prepare a demand model over a period when supply constraints were unknown or were moderate. The demand projections would then begin at the point when supply constraints emerge. The projection of demand in the current year in comparison with the actual demand in the current year would show the level of constrained demand. Such an approach would only be fruitful in states where there was a period in the recent past when supply constraints were moderate.

5.17 It should be noted that unconstrained demand is always associated with a given price level. At current (low) prices for electricity the level of unconstrained demand may exceed supply but if prices were raised then demand may match supply more closely. Nevertheless, there is a constraint on demand at current prices.

Captive Supply

5.18 That share of the market supplied by captive power plants may, or may not, be included in the boundary of the analysis (see *Section 4.2*). In the two case studies in AP and Bihar, the consumption from industries with captive power plants in the territories of the two SEBs was included. The consumers with captive power plants have considerably lower losses than consumers taking supply from the grid. This needs to be taken into account in the demand forecast. The inclusion of captive plant in the forecast is illustrated in *Section 9.*

5.19 With a relaxation of supply constraints under reform or IFS scenarios, the consumption from captive power plants would be expected to fall.

Sales Data

5.20 In many states, the data on electricity sales in MWh supplied by the SEBs is known to be unreliable. This arises because losses attributed to the consumers, particularly agricultural consumers, is under-reported. The true losses are unknown because the supply to agricultural consumers is often un-metered; the sales are therefore estimated but these sales figures are usually inflated by the SEB to suggest lower losses than actually occur. The result of this can be seen in the accounts of the SEBs where the revenue per kWh nominally supplied to agricultural consumers is much lower than the tariff.

5.21 An approach to reconciling SEB data with realistic levels of losses is contained in *Annex D*.

5.22 In AP, the losses were under-reported by APSEB at 20% but the true losses were known to occur in the agricultural sector. The true losses were estimated by the AP team by examination of data on the number and size of agricultural pumpsets and making assumptions about the hours of operation. This gave an estimate of true electricity consumption by agricultural consumers.

Structure of the Demand Model

5.23 Early in the EIPS work, it was agreed that the demand forecast should include as a minimum:

- demand by the major sub-sectors and tariff classes;
- demand by season in sectors showing high seasonal variability;
- forecasts of peak power demand and energy.

5.24 Demand projections need to be prepared for each tariff class and broken down into high tension, medium tension and low tension. This is a necessary input to the financial model. It is also important because the sectoral demand growth will be sensitive to economic growth assumptions.

5.25 Seasonal demand is an important input to the power system planning model. Three seasons were found to be appropriate for both Bihar and AP - Rainy, Dry and Winter.

5.26 System peak demand is essential as an input to the power system planning model while system energy demand is essential both for the power system planning model and to the financial model. The structure of a demand forecast (but not including seasonal demands) was illustrated in *Table 5.1*.

Drivers of Demand (Sales)

5.27 There are numerous drivers of electricity sales. Principal among these are income and electricity price. The income and price variables can be specified in a number of ways and they can enter the demand forecast in a number of ways. But whichever demand model is used and in whatever way these variables are introduced, the two will play a central role in any projection of demand.

5.28 The relationship between price and electricity sales is the (own) price elasticity of demand; and the relationship between income and electricity sales is known as the income elasticity. An income 'elasticity' of, for example, 0.8 shows that a 10% increase in the income variable would lead to an 8% increase in electricity sales. A price 'elasticity' should be negative because an increase in price should lead to a reduction in demand. So a price elasticity of -0.2 would show that a 10% increase in electricity price would lead to a 2% fall in electricity demand.

5.29 Attempts were made to estimate price and income elasticities for India in one special study (Ref: 1). However, since consumption is constrained by supply (partly due to limits on investments) it is difficult to estimate from Indian data the income and price effects. The study did, nonetheless, list a range of long-run elasticities from studies in other countries. These are listed in *Figure 5.1* below.

Figure 5.1 Comparison of TERI Estimates

	TERI India (1997)	Ramacharran Jamaica (1990)	Glakpe & Fazzolare W. Africa (1995)	Kadekodi India (1987)	Kar & Chakrobarty India (1986)	Westley Costa Rica (1984)	Westley Paraguay (1984)	Westley Dominican Republic (1984)	Berndt & Samaniego Mexico (1984)
Residential									
Income elasticity	0.33	1.21 4.17	0.28 1.24	3.08		-0.5	-0.5	-0.5	-0.47
Price elasticity	-0.45		-0.2 -1.24						
Commercial									
Income elasticity	1.01								
Price elasticity	-0.49					-0.5	-0.5	-0.45	
Agriculture									
Income elasticity	1.58								
Price elasticity	-1.23								
Small/Medium Industry									
Income elasticity	0.49		0.34 0.89	1.64					
Price elasticity	Ns	-0.26. -0.43	0.46 -0.85		-0.3 -1.27			-0.65	
HV Industry									
Income elasticity	1.06								
Price elasticity	-0.45								

Note: See TERI Report for references, except Westley and Berndt & Samaniego which were taken from Commercial Energy Efficiency and the Environment, World Bank Background paper for World Development Report, 1992.

5.30 Elasticities used by the two study teams in the EIPS project are shown in *Table 5.2*.

Table 5.2 Long-Run Elasticities Used in Demand Models in EIPS (Reform Scenario)

Sector	Own-Price Elasticity	Income Elasticity
Domestic	-0.30	1.75
Commercial	-0.26	1.27
Industrial	-0.20	1.50
Agriculture	-0.10 to -0.50	1.50

5.31 It should be noted that the elasticities may differ between the BAU and other Scenarios. This is because behaviour may change as a result of general economic or energy reforms. This is particularly important for the residential, industrial and agricultural sectors. Without reforms, agricultural and residential consumers often do not pay for their electricity - the impact of price changes will therefore be muted. Similarly, with wide-scale state ownership or state regulation of prices, many industries will be indifferent to electricity prices since losses (or loss of profit) will be compensated from the state or the prices for the end-product will be adjusted to compensate for electricity price changes. After wide-scale reforms, industry would be more concerned about increased costs.

5.32 The elasticity for the agricultural sector in the reform scenario is assumed to increase over time. This change in elasticity partly reflects a greater responsiveness to prices. Additionally, because any elasticity is normally correct only for a limited range of variations (in price or income) and because the price increases for the agricultural sector are large, the price elasticity is likely to change over time independent of any other reforms taking place.

5.33 An example of the spreadsheet formulae to make this forecast is provided in *Table 5.3.*

Table 5.3 Example of Use of Price and Income Elasticities for Residential Sales

	1998	1999	2000
Real Price Index (1998=1)	1.00	1.03	1.05
% change in price, year on year	-	3.0%	1.9%
Real Income Index	1.00	1.05	1.04
% change in income, year on year	-	5.0%	1.0%
GWh Sales to Residential Class	500	539 (1)	545 (2)
% change in sales, year on year	-	7.9%	1.2%

Notes:
(1) With an income elasticity of 1.75 and a price elasticity of -0.3, the formula to give 539GWh is: 500*(1-(3% x 0.3)+(5%x1.75)).
(2) The resulting 545GWh is calculated as: 539*(1- (1.9% x 0.3) +(1%x1.75)).

5.34 Additionally, the forecast could be related to parameters such as:

- system reliability (eg consumers whose refrigerators burn out will be reluctant to buy or use new ones);
- technological change;
- price of competing energy.

Losses in the Demand Forecast

Technical and Non-Technical Losses

5.35 Losses arise for technical reasons when electricity is transmitted through electricity lines or transformers. Losses also occur through theft - through by-passing of meters, tampering with meters or illegal connections. Additionally losses may occur where the consumption is estimated by the SEB instead of being metered and the true consumption exceeds the estimated consumption. These last two are known as non-technical losses.

5.36 The electricity supplied to the electricity grid is generally carefully metered and data tends to be accurate. Billings of consumers by the SEBs also tends to be accurate. As described above, the kWh sales figures are often over-reported but the true level of kWh sales can be estimated from the billing data. The difference between the electricity supplied to the grid and sales is then the total losses, both technical and non-technical.

5.37 In order to make demand projections it is necessary to make predictions about how technical and non-technical losses will change in the future. Additionally, changes in non-technical losses are particularly important for the projections of sales used in the financial analysis. It is therefore necessary to attempt to distinguish between the two types of losses.

5.38 Technical losses obey well known physical laws and are predictable from load flow studies if information is available on the loading of lines and transformers. The line and transformer loading can be estimated through feeder monitoring. This exercise would not normally be considered to be part of the EIPS work and reliance would need to be placed on estimates established during other loss reduction studies.

5.39 For the case study in AP, the team used estimates which were given in the IRP study (Ref: 5). For Bihar, estimates were obtained from the IRG study (Ref: 3). An example of the types of numbers provided from these reports is given in *Box 5.2.*

Box 5.2 Technical Losses in One Area Board in the BSEB Area

Due to lack of measured data, the technical losses for the BSEB distribution network can only be estimated based on the data for the one Area Board in the BSEB territory. This data was obtained by power flow analysis carried out in 1988 by TATA Consulting Engineers on a basis of 112 MW power demand in this area.

Voltage level [kV]	Losses (1988) [MW]	Losses (1988) [%]	Losses (1996) [%]
33	4.98	4.44	5.3
11	4.28	3.81	4.6
0.415	13.46	12.0	14.4
Total	22.72	20.25	24.3

Note: The above was analysed by TATA in 1988 and estimation for 1996

The peak power demand of the Area Board was reported as reaching 160MW in 1996. This means that the average power has some 136MW and the demand increase since 1988 was roughly 20 percent. Assuming that with growing power demand the distribution network is partially enlarged and locally strengthened, the percentage power losses might increase linearly with the demand growth (and not with the square of this). The above Table shows technical losses for the Area Board in 1996 estimated to be nearly 25 percent of the total energy demand. The actual total loss rate for the Area Board is 45 percent. Subtraction of 25 percent technical losses from 45 percent total losses results in 20 percent non-technical losses for the Area Board.

Accordingly, the technical losses in the Area Board represent 56 percent of the total losses.

The data from the one Area Board was extrapolated to all other area boards. The actual average total losses value of all area boards was 40 percent in 1996. This can be divided into a 22 percent share for technical and a 18 percent share for non-technical losses. During periods of peak power demand, the technical losses might increase to roughly 25 percent.

Projections of Losses

5.40 Projections of losses must be made for the different scenarios. The assumptions for losses were mentioned in *Section 3* when the scenario definitions were being described.

5.41 Non-technical losses are reduced when the SEBs implement procedures to ensure that all consumption is metered and that meters are not tampered or by-passed. In Bihar it was assumed, for example, under the reform scenario that overall non-technical losses would fall to 4% of sent-out electricity by 2015 while in the BAU scenario they would increase from present levels.

5.42 Technical losses depend on the size of the lines, the voltage and the load. Moreover, losses increase with the square of the increase in the load (ie a 2% increase in load, all else being equal, leads to a 4% increase in losses). Thus, if load increases but no investment takes place in the transmission and distribution system, the losses will increase at an ever faster rate. Normally, however, it would be expected that even under a pessimistic scenario, investment would take place so that technical losses do not reach ridiculous levels.

Demand-Side Management and the Demand Model

Tariffs as a Tool of DSM?

5.43 The term 'demand-side management (DSM)' is used widely to refer to mechanisms which promote the take-up of energy efficient practices. This term encompasses several different approaches that would be better distinguished. Some commonly occurring examples are:

- cost reflective electricity tariffs, including peak-load pricing;
- measures that are directly funded and implemented by utilities, (mandatory or voluntary);
- measures that are directly funded and implemented by third parties;
- funding of energy conservation programmes through a levy on utilities and implemented by third parties;
- energy conservation programmes funded out of state budgets;
- introduction of mandatory efficiency standards and labelling for appliances.

DSM in the EIPS Work

5.44 DSM in the EIPS project was analysed in terms of direct intervention to encourage the use of specific energy efficient equipment such as metering of agricultural pumpsets, high efficiency pumpsets and high efficiency refridgerators. The analysis of the cost of these measures and the affect on demand and on the load pattern is discussed in *Section 7*. However, the impact of *tariff* changes on demand was considered in the EIPS project in the demand model. The consequences of tariff increases in the agricultural sector in Bihar is illustrated in *Table 5.4.*

Table 5.4 Impact on Agricultural Demand of Tariff Increases in Bihar (1996-2001)

% increase in tariff	% fall in demand
68% p.a	6.8% to 34% p.a

Note: Reform Scenario.

5.45 Agricultural tariffs are assumed to increase from Rs. 0.25/kWh in 1996 to Rs. 3.33/kWh in 2001 leading to sales falling by more than half (including some compensation from an increase in income).

Autonomous Energy Efficiency Improvements

5.46 The demand projections should include, either implicitly or explicitly, any improvements in energy efficiency which will take place over time without intervention. This form of technological change should be captured in the structure of the demand forecast equations.

Double-Counting and Under-Counting

5.47 In particular, tariff increases should lead to demand reductions. This demand reduction will be a combination of:

- simple conservation (ie using less energy and tolerating more uncomfortable living conditions);
- increased energy efficiency (eg better insulation, better matching of motor size to load);
- energy substitution (eg using other energy for water heating);
- load management (eg energy storage to switch demand away from peak periods).

5.48 Using the (long-term) demand elasticities approach in the demand forecast, only the overall demand response to the tariff increase is shown. However, part of the response will be to introduce energy efficient technologies and this is identical to the measures which could be introduced under an interventionist DSM programme. Therefore care must be taken to ensure that the assumed impacts of interventionist DSM measures (ie high efficiency pumpsets, high efficiency refrigerators, etc) does not duplicate some of the impacts of the tariff increase.

5.49 An example of this would be in Bihar work where one of the DSM programmes related to the free provision of more efficient pumpsets to farmers. A move to LRMC based tariffs for agricultural consumers in Bihar would, however, lead to a halving in agricultural demand which would, undoubtedly, include a move to more efficient pumpsets. If the work had included a scenario with combined interventionist DSM measures and tariff increases, then the demand reduction would be less than the sum of the two responses individually.

5.50 In the EIPS work, however, there were no scenarios which combined DSM with tariff increases so that this situation did not arise.

Peak Load Pricing

5.51 One of the important benefits of a move to economic prices for electricity will be through the introduction of peak load pricing. This helps to move demand away from the system peak and reduces the need for peaking capacity.

5.52 The response of peak demand to peak load pricing is difficult to estimate and depends on numerous factors. In the EIPS work, peak load pricing was assumed to have been reflected in the demand model, with impacts on the system load factor.

Alternative Approaches

5.53 *Section 7* discusses the Integrated Resource Planning (IRP) models which attempt to optimise DSM measures side-by-side with supply options.

5.54 In the EIPS project, tariff changes, including the impact of peak load pricing, have been estimated through the demand model while specific energy conservation technologies have been considered separately (see *Section 7*). This, however, is not the only way in which it can be done. It would also be possible to consider peak load pricing as a DSM measure as part of the power system planning exercise or it would be possible to introduce the impact of energy conservation technologies as part of the demand model.

Load Shape

5.55 The load data which is input to the power system planning model is discussed in *Section 7*. A minimum requirement for the load forecast is that it include an estimate of system peak demand (MW) as well as the total system energy (kWh) demand, both measured at the power station busbars (ie sent-out from the power station). The relationship between the two is the system load factor which is a summary measure of the load shape.

5.56 One method of deriving the system peak demand from the energy demand can be illustrated using the Bihar demand forecast model. This is summarised in *Table 5.1*.

6

Resource Analysis

Introduction

6.1 This Section describes how financial costs for fuels are converted to economic prices, including the cost of transport to the power plants.

6.2 A broad analysis of economic costs of fuels was provided in the Special Study entitled *Inter-Fuel Substitution Study* (Ref: 1). The following describes how these generic cost estimates were used to derive economic cost estimates in Bihar and AP and how they, or updated estimates, could be used similarly in other states in India.

Tradable and Non-Tradable Goods

6.3 In estimating the economic value of goods, an important distinction is made between tradables and non-tradables. For non-tradables, the economic value is usually equal to the marginal cost of production expressed in economic terms (ie all financial costs should be translated into *shadow prices* as described in *Section 4).*

6.4 For tradables, the economic value is equal to the border price with allowance for the cost of transportation to, or from, the border. This is the import price (cif) for imported goods or the export price (fob) plus transport to the border for exported goods.

6.5 Tradables can be economically imported or exported while non-tradables cannot. But the distinction between a tradable and non-tradable product often depends critically on the cost of transportation in relation to the value of the good. Coal, for example, which is traded internationally is sometimes tradable and sometimes non-tradable depending on its location and ash content. If coal fields are located at a remote location without easy access to international trade routes then the coal will be considered non-tradable and its price should be related to the marginal cost of production and transportation. Coal of an international standard with ready access to ports or railways will, however, be considered as tradable and the price should be related to the export price.

6.6 Differences in valuation method between tradables and a non-tradables can be blurred when substitute fuels are available. While a non-tradable may not itself be imported or exported, a substitute may be tradable. Indigenous natural gas in India is itself a non-tradable, because of the high costs of gas transmission. However, there are substitutes for natural gas which are tradable internationally (eg distillate oil or naptha). The cost of the tradable fuels, in equivalent terms, will set the value for the non-tradable natural gas.

Internalisation of Environmental Costs

6.7 A special study was made as a part of this work to identify the costs of various options for mitigating the environmental impacts of coal mining. Some of the major environmental impacts of open cast mining and the costs of their control are shown in *Table 6.1.*

6.8 Such costs vary from site to site but *Table 6.1* gives values for a typical open-cast mine. The costs of biotic remediation and to resettlement and rehabilitation (R&R) are especially site specific. Furthermore there are no fixed standards or guidelines for resettlement and rehabilitation across India and the procedures vary from one State to another. It is assumed that mine back-filling and land reclamation are included in the main project cost.

Table 6.1 Estimated Mitigation Costs of Coal Mining

Mitigation Option	Contribution of capital to the unit cost of coal (Rs/tonne)	Operating cost relating to environmental controls (Rs/tonne)
Levelling and grading, terracing, drawing	32.9	14.35
Preparing pits, plantation of saplings, fencing, guarding, maintaining	-	0.35
Black topping of haul roads, dust collectors in drills, dust suppression in processing plant, water spraying, green belt, maintenance of Heavy Earth Moving Machinery (HEMM).	9.1	2.8
Industrial water treatment, domestic effluent treatment, mine water sedimentation, collecting and treating surface run-off water.	3.15	1.05
Operators' cabins in equipment, maintenance of equipment, personnel protective equipment	1.05	-
Afforestation, plant nursery, habitat conservation.	3.15	1.75
Rehabilitation and resettlement of affected populace, community development work.	0.35	0.35
TOTAL	49.7	20.65

Source: Mitigation options in Coal Mining in India, Ghose, Bose & Associates, Ltd., June 1997.

6.9 The total environmental mitigation cost is about 70 Rs/ tonne of coal. It varies little among the grades of coal mined. Typical production costs, for open cast mines in the Singareni coalfields are approximately Rs500/tonne so that, of this, approximately 15% represents environmental mitigation costs.

Example of Economic Price of Indigenous Coal in AP

Coal Resources in AP

6.10 AP is home to Singareni Coalfields - the only source of coal in South India. Production levels from the Singareni Collieries Company Ltd (SCCL) reached 26 million tonnes in 1996, some 10% of the all India production.

6.11 The major portion of coal produced by SCCL is grade C, D, E and F. Taking account of quality and distance to the coast, Andhra Pradesh's coal has no international market and is classified as a *non-tradable*.

Economic Value of Fuels

6.12 The *Inter-Fuel Substitution Special Study* (Ref: 1) examines the cost savings associated with coals of different qualities and how this affects the relative economic value of these different grades of coal. The analysis takes account of the different costs incurred at power stations resulting from different coals including efficiency, availability, ash handling and disposal, coal handling and boiler costs. For example, the construction costs of a power plant burning grade G coal are estimated to be 12.4% higher, per kW, than a similar plant burning grade D. The higher cost is the result of larger pipework to allow for higher ash content, more robust coal crushing, etc. Additionally, the availability of a plant burning grade G coal is estimated to be lower (55%) than a similar plant burning grade D (61%).

6.13 Using the plant parameters described in Ref: 1, the economic values of coal, relative to imported coal, are shown in *Table 6.2.* It should be noted that these are not absolute values but relative values; if the cost of imported coal changes then the value of indigenous coal would also change.

Table 6.2 Import Parity Price for Indian Coal (1995/96 prices)

Grade:	Import	D	E	F	G
Price (Rs/te)	1,925	1,356	1,097	819	583
Avg. calorific value (kcal/kg NCV)	6,450	5,780	5,240	4,470	3,750
Ash + moisture	21.8%	31.4%	37.1%	43.6%	51.1%

Source: Inter-Fuel Substitution, EIPS Special Study, 1997.

6.14 A similar analysis could be prepared to show the economic value relative to marginal production costs of any grade of coal. The important question is then the appropriate grade of indigenous coal (or imported coal) to use as the reference from which to take the relative value of the other grades. This is considered in *Sections 6.4.3* and *6.4.4*.

Marginal Cost of Production of Coal in AP

6.15 The IFS Study provides an estimate of marginal cost for the Godavari valley coalfields (ie Singareni) - of Rs. 613/tonne. However, this marginal cost estimate is an average of both underground and opencast mines. Production costs for these two types of mining are considerably different. Underground mining costs with depths below 300m are nearly double those of opencast mining. Where the depths exceed 300m for the underground mines, the cost is nearly three times that of coal from (shallower) opencast mines (Ref: 2).

6.16 The reserves within a depth of 300 meters in AP are reported to be slightly over 50% of the total (Ref: 2). Opencast mining is expected to contribute 17.6 million tonnes (49%) in the year 2001/02 from a total of 36 million tonnes.

6.17 For the AP work in the EIPS, it was assumed that a significant share of the production of power station grade coal will be from underground mines with correspondingly higher production costs. However, these underground mines are expected to yield higher grades of coal.

6.18 Grade F coal was assumed to be produced from opencast mines. The marginal production cost for this grade has been assumed to be Rs. 470/tonne (Ref: 2, p. 29). Grade D and E coal, typically from underground mines at depths below 300 metres might then cost up to Rs. 1,300/tonne.

Economic Value of Coal by Grade in AP

6.19 From *Table 6.2* a new power station would be prepared to pay up to 24% more for grade D coal rather than grade E because this would result in lower fuel and capital costs. Similarly, the power station would pay up to 34% more for grade E coal compared with grade F.

6.20 In a competitive market, if grades D to G were all priced at the marginal cost of, say, Rs. 470/tonne, then every power station would demand grade D coal and there would soon be a shortage. The price of grade D would then rise and would continue to rise until the price reached 24% more than the price of grade E coal. At this point, power stations would demand grade E coal. When the shortages of grade E coal appear then the price would rise (together with the price of grade D) until E grade is 34% more expensive than grade F. And so on. This stops when one grade is so abundant that shortages do not appear.

6.21 In India, all grades of coal are in short supply at the present time but this reflects institutional constraints. Grade G would be most likely to remain abundant if the market were opened to full competition and its price would be driven down to marginal cost. The reference grade coal is therefore assumed to be grade G and the economic value of the other grades are taken relative to grade G, as shown in *Table 6.3*.

Table 6.3 Economic Value of Coal in AP

Grade	Calorific Value (kcal/kg, NCV)	Economic Value (relative to Grade G: (Rs/tonne)
D	5,780	1093
E	5,240	884
F	4,470	660
G	3,750	470

6.22 It should be noted that the analysis presented here is a simplification of the analysis used in the AP work for EIPS. The economic values actually used in the study were different - partly reflecting the information which was available at the time when these values were required as inputs to other parts of the overall analysis.

Example of the Economic Price of Indigenous Coal in Bihar

Coal Resources in Bihar

6.23 Bihar has abundant reserves of poor quality steam coal. Bihar is also a land-locked state where the distances from the coal fields to the nearest port at Haldia in Orissa are some 400-500km. Bihar's coal has no international market and is not tradable.

6.24 Of the 20 million tonnes of power station grade coal produced by Central Coalfields Limited (CCL) in Bihar in 1996/97 only 40% is consumed in Bihar; the remainder is linked to power stations in other states, particularly further inland, to the north in Uttar Pradesh and Haryana.

6.25 The neighbouring coal fields of Talcher and Ib Valley in the state of Orissa have significantly greater reserves of power station grade coal than those in Bihar. Talcher and Ib Valley together have one third of India's reserves of non-coking coal.

Marginal Costs of Coal Production in Bihar

6.26 The IFS Study (Ref: 1) provides estimates of marginal cost for the various coal fields in Bihar. There is some variation in marginal costs between fields, from Rs. 516/tonne for North Karanpura to Rs. 660/tonne for Raniganj (Raniganj is in West Bengal but is part of the same coal field), but in a competitive market, the price should settle at the cost of the *marginal* tonne of coal. This would normally be the coal from the most expensive mine in the region (ie Raniganj). The average production cost is Rs. 580/tonne.

6.27 The marginal cost of coal from the neighbouring Orissa fields is estimated to be lower than from the Bihar fields (Rs. 539/tonne for Ib Valley and Rs. 415/tonne for Talcher, IFS Report, Ref: 1). If the cost from these fields were very low, transport costs were low and reserves are truly plentiful then it would make coal supply from the Bihar fields redundant.

6.28 The transportation cost of coal is, however, high. The *IFS* Special Study (Ref: 1) estimates the cost of transportation at approximately Rs. 0.4 per tonne-km, (ignoring the costs of loading and unloading). Thus, to transport coal a distance of 100km would add Rs. 40 to the cost of a tonne.

6.29 Ib Valley coal therefore ceases to be competitive with Bihar coal where the difference in transportation distances exceeds 100km. Ib Valley coal would not be competitive with Bihar coal fields for power stations located in Bihar. Thus the Bihar fields can, to some extent, be considered in isolation from Ib Valley.

6.30 For coal from Talcher, the breakeven transportation distance to Bihar would be considerably higher; closer to 400km (adding Rs. 160/tonne to the cost and bringing the total cost to Rs. 575/tonne). The transport distances are actually less than this, making Talcher coal highly competitive with coal in Bihar. However, coal from the Talcher field is unlikely to be 'marginal' if, simultaneously, more expensive coal is being produced at Ib Valley. In other words, Talcher coal is likely to be fully allocated because of its low cost.

6.31 It was therefore assumed that the Bihar fields could, for simplicity, be treated as independent of the Orissa fields. The marginal cost of coal from the Bihar fields is therefore assumed to be Rs. 580/tonne.

Economic Value of Coal by Grade in Bihar

6.32 As with the AP coal resources, the economic value of coals in Bihar was estimated by reference to the demand value of different grades all relative to the grade of coal which is most abundant. Grade G coal was assumed to be abundant and the marginal production cost of Rs. 580/tonne was assumed to set the economic value of grade G coal. (It should be noted that the economic value of grade G coal (Rs. 583/tonne) in *Table 6.2* relative to imported coal, is only slightly higher than the marginal production cost (Rs. 580/tonne). However, *Table 6.2* ignores inland transport costs, which, except for coastal power stations, would mean that grade G coal would be more attractive than imported coal).

6.33 Assuming grade G coal is the reference coal, then relative demand values, based on the methodology described in *Section 6.4.2*, are shown in *Table 6.4*.

Table 6.4 Economic Value of Coal in Bihar

Grade G	Calorific Value (kcal/kg, NCV)	Economic Value (relative to Grade G) (Rs./tonne)
D	5,780	1,350
E	5,240	1,090
F	4,470	815
G	3,750	580

Natural Gas

6.34 The IFS Special Study (Ref: 1) described the limited availability of natural gas in India and discussed the demand for that gas and the substitute fuels. It suggested that the marginal use of natural gas is for fertiliser production and that the substitute for indigenous natural gas would, in general, be imported LNG. Projections of the landed cost of LNG were provided in the IFS study.

Resource Supply Constraints

6.35 An assessment of constraints on the availability of sources of conventional fuels for power generation is an essential input to the analysis. Resource constraints may arise for a number of reasons:

- techno-economic limitations on the extraction of fossil fuels (typically the cost of extraction increases as technical difficulties multiply, until it becomes uneconomic to continue production);
- constraints on transport of fuels by rail, pipeline and port facilities (again, a 'constraint' typically occurs when the investment to un-block a constraint is uneconomic) - which can be short-term (and relieved through investment) or long-term (when investment is uneconomic).

An example of constraints on the availability of coal in AP is given in *Box 6.2.*

Box 6.2 Resource Availability in AP

The availability of coal was estimated by matching coal demand with the sources of supply. Orissa coal fields (Talcher/Ib sectors) and imports were the other two preferred supplemental sources of supply and thus were included in the study. The detailed results of the study on coal demand availability indicated that:

- There would be severe supply constraints calling for radical changes in the outlook towards planning and implementation in the entire chain of coal developmental activity. The coal demand estimated under optimistic assumptions about availability indicates that the demand-supply gap could reach 160 million tons by 2010. Even assuming that the captive mining by private ventures could bridge around 60 million tons the residual unmet demand would be as high as 100 million tons.
- The requirements of coal to sustain the projected coal-based energy generation in A.P. could reach 54 million tons by the end of the tenth five year plan (2006-07). The availability of coal from SCCL in 2007 is placed at 39 million tons, of which only 25 million tons could be made available to the power sector after meeting the competing demands of other consumers. Beyond 2007 the total availability from SCCL may increase to 42.5 million tons, but by that time the incremental thermal coal demand may far outstrip the incremental availability.
- The gap between demand and supply could be well above 25 million tons by 2007, which could be met only from other sources with supply potential and production facilities. For power plants in Andhra Pradesh, the most economic outside source of coal supply is Talcher/Ib coal fields. Even in this case, despite the fields containing 40% of the open cast reserves out of the total open cast reserves in the eight principal coal fields, a production level is expected to reach only 47 million tons by 2002.

The above conclusions are based on the assumption that the current policies will continue with the present trends. The projections may vary in the event of policy changes. The coal availability projections from SCCL may not vary very widely, the availability/gaps analysed from the all-India and Talcher/Ib coal fields could undergo substantial change beyond 2006-07, depending on the scope for re-orientation of production planning from a very large number of existing and new centres of production under Coal India limited. The scenario might also change after the new Coal Policy Initiatives announced by the government lead to greater participation from the private sector in coal mining with matching investment in related infrastructure development.

Coal Imports

The analysis of the demand-supply gap for coal from Singareni Collieries in AP indicates increasing shortages due to the production constraints. This gap, which is estimated to be about 26 million tons by the end of the ninth five-year plan, will need to be met by supplies from Talcher-Ib and imports. In the short term of at least 5 years, constraints in production from Talcher-Ib coal fields indicate that import of coal would have to be considered as one of the options for bridging the demand supply gap. The actual supplies would be determined by a number of factors including quantitative and qualitative nature of supplies, major port capacities and relates facilities, rail capacities for inland transportation, small port development and the likely benefits accruing from the use of imported coals in blends or in whole, with special emphasis on environmental impacts. It is important to note that even a single factor - like non-availability of adequate port capacity can eliminate this option even assuming all other factors indicate physical feasibility and economic viability.

The coal import option was evaluated under the assumption that there is unlikely to b a severe availability constraint with appropriate advance planning. The major constraints would hinge around price of imported coal, port facilities, rail and sea-cum-rail leads and landed costs of coal at power stations, and availability of foreign exchange. The imported coals was assumed to be of a higher quality and would result in improved heat rates. The sulphur content of imported coal was also assumed to be higher when compared with indigenous coals.

Source: ASCI Case Study (Ref: 5)

6.36 Environmental constraints may also arise in relation to fuel usage (e.g extensive use of coal may breach ambient air quality standards) but these constraints are examined as part of the analysis described in *Section 7.*

6.37 Additional constraints may also arise for political reasons (e.g encouraging indigenous fuels rather than imports). However, the primary philosophy of the EIPS approach is to provide rigorous quantitative analysis of the cost and environmental impact of various options. If there are political issues which concern decision makers in relation to the share of imported fuel in the energy balance, then these concerns should be expressed explicitly in the Problem Definition (*Section 2*) and the Design of the Analytical Framework (*Section 3*).

7

Power System Planning

Introduction

7.1 The power system planning is one of the key components of the suite of analytical tools used in the overall decision making process. However, the importance of power system planning should not be over-emphasised. The model increases the rigour of the analysis and improves the credibility of the results but, however good the model, it cannot convert bad data into reliable quantitative results.

7.2 The following Section describes some of the generic model types available and the type of model used in the EIPS case studies. It further discusses the inputs to these types of model. Though different models may be used in other states, much of the discussion contained in *Section 7* will still remain relevant.

Generic Models

Types of Model

7.3 There are broadly three types of algorithms used at the heart of power system planning models:

- probabilistic simulation based on the Booth-Balleurieux method;
- linear or integer programming; and
- monte-carlo simulation.

7.4 The monte-carlo simulation method is a simple, but effective, method which uses the power of computers to repeatedly simulate the state of the power system. At one time this method was relatively slow, but with the power of modern computers results can now be generated quickly. Possibly because of its simplicity, monte-carlo simulation has not yet been adopted at the heart of any of the widely accepted power system planning models. It is not therefore discussed further.

7.5 The other two central algorithms are used in a range of models. We have divided these models into five general types:

- probabilistic simulation;
- linear or integer programming;
- integrated resource planning;
- integrated generation and transmission; and
- energy planning.

7.6 These are described briefly below.

Probabilistic Simulation Models

7.7 These models are designed specifically for power system planning to take account of the unscheduled outages of power plants. Perhaps the model of this variety used most widely internationally, is the Wien Automatic Simulation Package (WASP) which now forms part of the ENPEP suite distributed by the International Atomic Energy Authority (IAEA) in Vienna and by the Argonne National Laboratories in the US. The WASP model was first developed and used in the early 1970s but has been continuously updated since then. Examples of other models include:

- A/S Plan, developed and marketed by Analytical Solutions (US);
- WIGPLAN, developed and marketed by Westinghouse;
- EGEAS, developed by MIT/EPRI, marketed by Stone & Webster;
- GENSIM, developed and used by Acres International;
- Electric Financial (ELFIN), developed and maintained by the Environmental Defense Fund in the US.

7.8 These models have, at their core, the probabilistic simulation algorithm contained in the *simulation module*. The more sophisticated models of this variety additionally have *a dynamic programming module* or a similar method of optimisation.

7.9 The simulation module, provides a sophisticated calculation of annual power system variable production costs based on the merit order dispatch of plants but including a probabilistic assessment of the plant outages. Given the uncertainty that plants will be available, a probability distribution is developed which represents the different plant outage conditions (a capacity outage distribution). Hourly load data (or data for other time periods) is re-arranged to form another probability distribution (the load data is converted into a cumulative frequency curve which is, in effect, a probability distribution). Combining (convolving) the two probability distributions together and allows the user to estimate the expected production costs of the power system.

7.10 The *dynamic programming* or *optimisation* module attempts to select the least-cost development path from all possible configurations possible over the study period. It usually uses a representation of candidate power plants based on levelised capital and fixed costs and variable costs and chooses identifies the investment programme which minimises costs over the study period.

Linear Programming/Integer Programming

7.11 To our knowledge, there are no mainstream Linear Programming/integer programming (LP/IP) models directly comparable to the probabilistic simulation models used in power system planning. There are a number of models with wider application in the energy sector which include IP/LP at their core.

7.12 There are also some models which have been developed for specific purposes which have IP/LP at their core. The Indira Gandhi Institute of Development Research (IGIDR), for example, has developed a model named MS-PLAN. This is a non-linear mixed integer programming model, which optimises generation and transmission and which has been used to model the power system of Maharashtra. IP/LP techniques are also included in integrated transmission/generation planning models.

7.13 Here we discuss the energy models as applied to choosing optimal power generation investment programmes.

7.14 Examples of general LP/IP models which can be used in this way include:

- EFOM (Energy Flow Optimisation Model);
- MARKAL;
- LEAP (Long-range Energy Alternatives Planning).

Characteristics of these Models

7.15 The common feature of these models is the use of the standard LP or IP approach. Standard LP and IP algorithms can be purchased from a number of sources and incorporated in an optimisation package. The packages are often very flexible and can be adapted to examine a wide range of optimisation problems - not only in the electricity sector but more widely.

7.16 The load 'curve' on the electricity system is typically described by a series of blocks while the (non-)availability is taken into consideration by de-rating the capacity of the plant (for example, if the plant has a capacity of 100MW and an availability of 85%, it is assumed to have a capacity in the model of 85MW).

Integrated Resource Planning (IRP) Models

7.17 The models described above are all based on supply-side considerations which were the traditional concern of electricity utilities. With increased interest in the demand-side, these models were adapted to consider the impact of demand-side measures on the least-cost programmes. A simple, but effective, approach used in many appraisals, was to examine the impact of DSM programmes on demand and load shape. The cost of the DSM programmes was then added to the system cost outside the model. Other approaches attempt to introduce DSM measures into the traditional models as equivalent supply-side options.

7.18 In recent years a number of models have been developed which focus on the services which electricity (or energy) provides and attempts to optimise the supply of these services using a range of integrated options including power plants and demand-side measures.

7.19 A model which has IRP at its core is:

- IRP Manager, developed by EPRI and marketed by EPS of Minneapolis in the US. This was used in AP prior to the EIPS work.

Integrated Generation and Transmission Planning Models

7.20 The integrated analysis of transmission and generation development is complex. For this reason, there are few models which attempt to perform this analysis. Examples of models which do, include:

- ISPLAN;
- MS-PLAN, developed by the IGIDR for Maharashtra.

7.21 These models are designed to analyse power plant siting issues at a regional level. They will typically consider coal and gas transportation and supply and electricity transmission linkages and losses. The models are generally based on spatial linear or integer programming.

Energy Models

7.22 Energy models are most commonly used to examine environmental issues covering several energy sectors. They may also be used for indicative investment planning but rarely used for preparing specific investment plans. Examples include:

- Energy Flow Optimisation Model (EFOM), developed under the auspices of the European Commission;
- Long-range Energy Alternatives Planning (LEAP), developed and marketed by the Stockholm Environment Institute;
- Modele de demande en energies pour les pays du Sud (MEDEE-S);
- TERI Energy Economy Simulation and Evaluation (TEESE), developed by TERI and the Brookhaven Institute and marketed by TERI;
- The Environment Manual, developed by the Oko Institute with funding from a number of development agencies; and
- Energy Toolbox, marketed by ERM Energy.

7.23 The energy planning models contain a wide mix of methods and features. Perhaps the core characteristic, common to all of the models, is the use of the Reference Energy System (RES) which provides a description of the energy technologies and the paths of energy carriers from their source through different conversion technologies to the final energy use. The models all include a demand module, though the method employed for making demand projections varies widely.

7.24 Many, or most, of these models include dynamic linear or integer programming to optimise the choice of technologies for given time periods. A number of the models have add-on features, such as macro-economic models or environment models, which work together with the main energy model.

Choice of Model for the EIPS Work

7.25 The probabilistic simulation model, AS-Plan, was chosen for the EIPS work. The choice of model was made after a lengthy consultation process and taking account of a number of factors.

7.26 A choice among the available options was made through a two stage process which involved first exclusion of options which for one or more reasons were clearly not feasible and then careful consideration of the respective merits of the remaining set based on criteria which included:

- cost;
- availability;
- documentation;
- credibility;
- familiarity of the users;
- prior use for similar projects;
- risk minimisation, etc.

7.27 Some models were excluded on grounds of cost, others because availability could not be assured within the time-scale of the project, still others were rejected because they do not have international credibility for power system planning or because the documentation was inadequate. The selection process was particularly concerned to minimise risks of choosing a model which would fail under the circumstances of the project; ie teams in Bihar and AP who were unfamiliar with such models and a tight time-scale. Finally, AS-Plan was selected because of its suitability, track record, documentation and availability. Models used for subsequent work will need to be carefully considered and selected based on similar criteria.

Model Inputs - Supply Side

General

7.28 The power system modelling work in AP and Bihar used the A/S Plan software. The following describes the general supply-side inputs which were used for that model and which would be used for models of the same type.

Plant Details

7.29 Figure 7.1 illustrates the data required for the models.

Figure 7.1 Thermal Plant Data

Thermal Plant Initial Data in 19??			
Plant ID: Name:	XXX	On-line in Year:	1968
		Retired in Year:	2005
Minimum MW Loading Level	70	Heat Rate at Minimum Load	2,500. kcal/kWh
Maximum MW Capacity	70	Avg. Incremental Heat Rate	2,500. kcal/kWh
Fuel Type:	■ Nuc.	■ Coal ■ Oil	■ Gas ■ etc.
1988 Fuel Cost	$7/Gcal		
		Forced Outage Rate	7.30%
Variable O&M	3.90 $/MWh	Scheduled Maintenance	28 days/yr.
Fixed O&M	3.34 $/kW/month		
Base Block Must Run	(Y/N)	Spin Res. Contribution:	50% of MW Cap.
Load Order Penalty Factor			
100% Ownership assumed			
Report Unit as Purchased Power? (Y/N) N			
[SEASONAL Adjustments to data ... (F7)]			
[UPDATES are defined for this Plant ... (F5)]			

7.30 Capital investment costs in the power system planning model should only be used for plant which is not existing or 'committed'. A committed plant is one which has been constructed or where an 'irreversible' decision has been taken to construct it. The decision might be 'irreversible' if an order has been placed with the supplier and if cancellation of that order would result in large penalties. (Note: in the financial analysis described in *Section 9*, the capital costs of committed plants must be included).

7.31 Transmission investments directly associated with the power plant should be included in the capital cost of the power plant.

7.32 Using the study boundary described in *Section 2*, the EIPS work adopted a particular approach to power purchased by the SEB from other organisations or plant which is part-owned by the SEB. Where power will be purchased from an existing or new plant owned by another organisation, the capital and other operating costs should still be included in the power system planning analysis - as if the plant were owned by the SEB.

7.33 The capacity of the plant should be the sent-out (busbar) capacity; i.e. the total capacity less the on-site power consumption.

7.34 The A/S Plan model does not spread the capital costs over the construction period. The capital cost included as an input had to be escalated to represent the equivalent cost at the date of commissioning. For example, if the capital cost is 100 and this is phased over a three year period in the proportions 30% in the commissioning year minus 2, 65% in the year before commissioning and 5% in the commissioning year, then the cost input to the model would be:

$$30 \times (1 + r)^2 + 65 \times (1 + r) + 5$$

7.35 The fuel costs (price per unit of energy) and heat rate or efficiency should be on a consistent basis; ie if the fuel cost is based on net calorific value then the heat rate should be on the same basis.

Salvage Values

7.36 The model uses a finite study period (see *Section 4*) and at the end of the study period, some plant will have a residual life. Unless this is taken into account, the development programmes with a long residual life will be disadvantaged. Most models allow the possibility of subtracting the salvage or residual value from the cost stream at the end of the study period.

Transmission and Distribution Investment Costs

7.37 In the EIPS work, transmission investments specifically associated with power plants were added to the power plant capital costs. This omits general transmission and distribution investments which are required to supply consumers from the grid. This approach is acceptable provided that all generation options require connection to the grid. However, some renewable energy options, such as solar photovoltaics, do not require grid supply. Some, such as micro-hydel supplying remote villages, require distribution but not transmission.

7.38 One of the lessons learned in the EIPS project was that general transmission and/or distribution costs should be added to all generation options which require grid connection. Distribution costs, but not transmission costs, should be added to generation options which require only a distribution grid.

Real Plants and Generic Plants

Definitions

7.39 Plants offered as candidates to the software can be 'real' or they can be 'generic'. (Note: existing or committed plants are always 'real').

7.40 'Real' plants are those where a site, technology and fuel have been identified. The 'real' candidate plant will normally have conceptual or definite designs *(see Section 8)*, unit sizes will have been specified and a preliminary EIA should have been undertaken. Cost estimates should also have been prepared and, as a minimum, pre-feasibility studies will have been carried out. 'Real' plants are those which are most likely to be developed in the short-term.

7.41 'Generic' plants are those where the site has not been specified or details sorted out.

7.42 Examples of real and generic plants from AP are given in *Table 7.1*.

Table 7.1 Example of Candidate Plants for AP

Real Plant (Name, location, fuel)	Design Capacity (MW)	Generic Plant (Fuel/Type)	Assumed Capacity (MW)
HNPC-II, coal	520	Singareni coal, pithead, conventional	500
Simhadri II	500	Talcher coal, pithead, conventional	500
NTPC Talcher II, coal	500	Singareni coal, load centre, conventional	500
NTPC Talcher III, coal	500	Talcher coal, load centre, conventional	500
NTPC Talcher IV, coal	500	LNG, CCGT	400
		Naptha, CCGT	400
		Wind farm	100
		Mini-hydel	100

Purpose of Generic Candidate Plants

7.43 These generic candidate plants may be used for two purposes:

1. For comparison against 'real' plants. For example, to test whether a coal-fired power station, for which preliminary designs have been prepared, has lower costs than another source (e.g. RET or a CCGT). If the test suggests that RETs or CCGT may offer lower costs then conceptual designs, costs and EIAs may be developed for the new candidates. These would then be evaluated properly in comparison with the coal plant.
2. To provide background power developments for the longer term as the basis for policy analysis. Background developments, over periods from 10 years ahead, are necessary to test policies and to allow the testing of investments in the short- and medium-term. However, the generic plant need not be specified precisely.

Associated Fuels

7.44 For 'real' power plants, existing planning procedures in India will have identified sources, quantities and qualities of coals. These were reviewed in the EIPS work but no further optimisation, design or EIA work was undertaken.

7.45 For generic power plants (ie plants identified as candidates for the later part of the 20 year study period) possible sources of coal and other fuels were identified. The Inter-Fuel Substitution (IFS) study identified data on a regional basis on the costs (including transportation costs) and availability of fuels. The IFS data can be used in the assessment of delivered fuel costs for candidate power plants. Judgement should be used in the linking of coal sources to power plants. Again, no optimisation was undertaken.

Cogeneration Plants

7.46 Cogeneration plants supply both heat/steam and electricity. Capital costs are above those of an electricity-only plant and the fuel used for each kWh of electricity produced is also higher. But A/S Plan and similar models, are concerned only with meeting the demand for electricity. Without some adjustment to the capital costs and heat rates, the models would not make optimal choices about plant dispatch or investments.

7.47 In the EIPS project, cogeneration plants represented a very small share of electricity supply and these were therefore represented as DSM options (see *Section 7.5*. Where cogeneration may represent a significant share of electricity supply (eg Maharashtra or Uttar Pradesh), cogeneration must be input to the model as a plant with fuel and capital costs. In the A/S Plan and WASP models, the only acceptable way to do this will be to:

- subtract from the capital costs of the power plant, the capital costs of an equivalent steam-only boiler; and
- reduce the overall heat rate by the amount of fuel which would be used in a steam-only boiler to generate the required steam.

Emission Factors

7.48 'Emission factors' represent the emissions per kWh of electricity generated or fuel consumed.

7.49 In AP, the emission factors used in the model were based on numbers reported in various journals and published sources. These are shown in *Table 7.2.*

Table 7.2 Emission Factors

	CO_2 kg/kcal	NOx kg/kcal	SOx kg/kcal	TSP kg/kcal
Domestic Coal	382	2.57	2.70	91.26
Imported Coal	382	2.57	5.40	31.69
Gas	205	1.53	0.00	0.01
Naptha	277	0.34	0.16	0.00

In Bihar, the emission factors were calculated by MECON from first principles.

Renovation and Modernisation

7.50 Renovation and modernisation (R&M) offers benefits of:

- improved availability and reliability;
- improved output (MW);
- improved heat rates;
- life extension; and
- better environmental performance.

7.51 It often represents a very attractive investment opportunity. Data on the improvements available from R&M were obtained for the Bihar work from a previous study prepared by IRG under World Bank funding. In Bihar, R&M offered a particularly important form of investment. In AP, the power plants were considered to be in good condition and the opportunities from new plants were thought to be much greater. R&M was not therefore not a significant issue in AP.

7.52 In A/S Plan and similar models, the parameters of plants can be changed within the study period. But choices between investing in R&M or closing plants and building new plants cannot be modelled directly and must be evaluated using a more circuitous route.

7.53 In some instances, R&M is unambiguously better in all respects than new investments. Where this is the case, R&M can be assumed to take place - except in the BAU scenario - and the parameters of the plants adjusted accordingly. The cost of the R&M measure is then added to the overall costs outside the A/S Plan model.

7.54 In many instances, renovated (existing) plant is in competition with new plants for a place in the least-cost development programme. Where this is the case, the modelling in A/S Plan and some similar models becomes cumbersome. In the EIPS project, the selection process was made as follows:

1. Choose a date when, in the judgement of the program user, there could be a choice between R&M or retiring the plant and building a new one. The date could be indicated because it has reached the end of the normal life for this type of plant or it could be because new technology has become available (eg CCGT) which makes the old technology appear to be relatively inefficient.

2. 'Retire' the existing plant on the chosen date and offer the refurbished plant as a candidate, after allowing the elapse of time necessary for the refurbishment to take place. The alternative new plant is also offered as a candidate.

3. If the optimisation selects this refurbished plant as soon as the refurbishment has been completed then it can be assumed that the refurbishment is least-cost.

4. If the optimisation does not select the plant then the R&M is not least-cost on the date chosen.

5. If the optimisation selects the refurbished plant but at some later date then some thought needs to be given to whether it is likely that the plant will be moth-balled for several years before being bought back into operation. The cost of moth-balling needs then to be considered.

However, there will continue to be a number of uncertainties:

- would different R&M measures be more attractive?
- would a different date for R&M lead to different conclusions?
- does R&M offer environmental benefits not available from the new technology?

7.55 These issues need to be considered by the program user and judgement used in decided on practical options.

Renewable Energy Technology

Data Sources

7.56 Sources of data on RET for the two case studies was taken, in part, from the Special Study on RET (Ref: 14). This was supplemented by state specific data. In the Case Study in Bihar, much of the RET data came from MECON's own in-house database. In AP, data on RET potential was obtained from APSEB, local experts and the 1996 IRP study prepared for APSEB.

Representation of RETs in Probabilistic Simulation Models

7.57 Renewable energy technologies (RET) differ from conventional thermal plant in that their operation typically depends on the availability of the energy (wind, sun, water, biomass, etc). The operation of conventional thermal plants, by contrast, is not normally constrained by the availability of fuel.

7.58 This constraint is particularly problematic for software developed around probabilistic simulation. The latter attempts to find production costs based on the optimal dispatch of plants subject to outage probability.

7.59 Fortunately, where the non-availability of fuel is random then this can be treated exactly as for the non-availability due to unscheduled outages. The non-availability of the plant due to energy is simply added to the non-availability due to unscheduled outages. For example, suppose a wind generator has a forced outage rate of 10% and the wind regime allows the plant to operate with an availability of 35%, its combined outage rate could be entered in the model as 45%.

7.60 Many of the RETs considered in the EIPS work can be assumed to have random energy availability. In Bihar, the RETs considered were:

- biomass;
- biogas;

- micro and mini-hydel.

In AP, the options were:

- wind; and
- mini-hydel.

7.61 The energy availability, in most cases, is not purely random. The availability of biomass, for example, is seasonal rather than random and could be modelled more realistically in A/S Plan in terms of scheduled outages in certain months or seasons. Energy availability of mini-hydel, based mostly on canal-drop schemes, will be predictable to some extent since it is linked to irrigation.

'Green' Scenarios

7.62 The RETs were offered as candidates in base-case analyses for the AP study (ie for the IFS Scenario). But RETs were not selected as part of the least-cost plan. In Bihar, screening analysis had suggested that the RETs would not be selected in the IFS analysis and it was not therefore offered as a candidate.

7.63 In the 'Green' scenarios, RETs were 'forced' into the programme. This allowed an assessment of the trade-off between additional system cost against environmental benefits.

RETs and Transmission/Distribution Costs

7.64 As discussed in *Section 5,* RETs can avoid the need for transmission and/or distribution. A method for including this benefit is described in *Section 5.*

Model Inputs - Demand-Side

Load Data

7.65 In probabilistic simulation, the hourly loads over a year are ranked by size of demand (MW) and formed into a cumulative frequency distribution or, equivalently, a probability distribution.

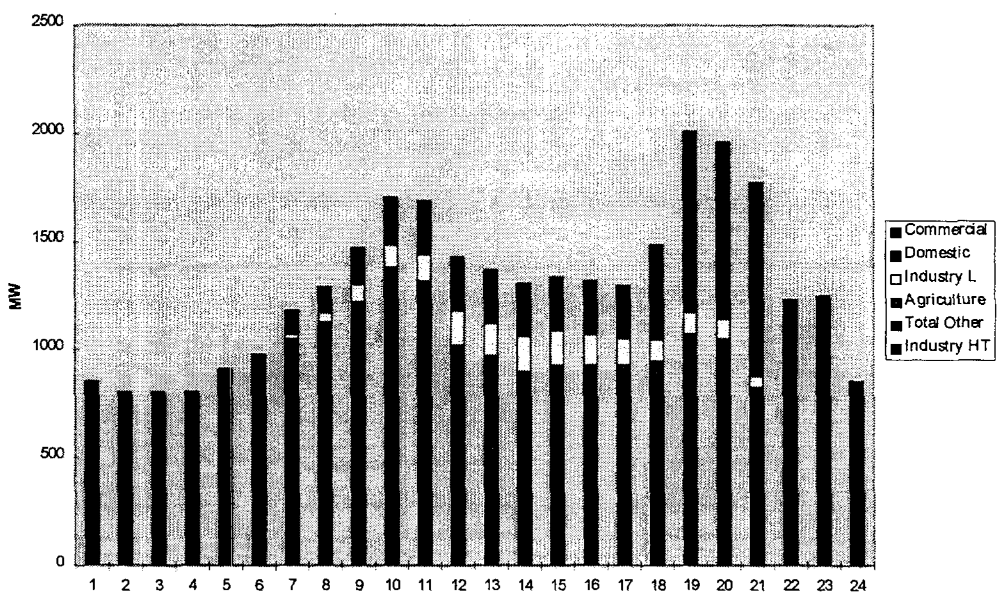
7.66 The load data can be real; taken from the actual hourly loads which are normally measured by the power companies at their dispatch centres. Or the load data can be synthesised, from typical daily load curves.

7.67 In India, in most states, the loads supplied by the power companies are normally constrained. The actual data supplied by the power companies would therefore represent 'supply' but not 'demand'.

7.68 In the AP and Bihar, the load curves were synthesised. An example of a 'supply' curve and an estimated unconstrained demand curve for Bihar is given in *Figure 7.2.*

Figure 7.2 Load Curve Synthesis : Rainy Season (July - October)

Hours	Domestic	Commercial	Industry L	Industry HT	Lighting	Agriculture	PHED	Railway	Bulk Supply	Interstate	Total
1	100	20	10	500	9	110	40	50	8	5	852
2	100	20	10	450	8	110	40	50	8	5	801
3	100	20	10	450	8	110	40	50	8	5	801
4	100	20	10	450	8	110	40	50	8	5	801
5	100	20	10	450	8	220	40	50	8	5	911
6	90	20	10	450	4	300	40	50	8	5	977
7	90	20	20	450	0	525	20	40	8	5	1178
8	100	20	45	450	0	600	20	40	9	6	1290
9	100	70	80	500	0	650	10	45	10	7	1472
10	100	120	100	500	0	810	10	45	10	7	1702
11	100	150	120	550	0	700	10	40	10	7	1687
12	100	150	160	550	0	400	10	40	12	7	1429
13	100	150	150	500	0	400	10	40	12	7	1369
14	100	150	160	450	0	380	10	40	11	7	1308
15	100	150	160	500	0	360	10	40	10	7	1337
16	100	150	140	500	0	360	10	40	10	7	1317
17	100	150	120	500	0	360	10	40	10	8	1298
18	250	190	100	500	5	360	10	50	10	9	1484
19	470	370	100	600	9	360	10	67	15	9	2010
20	570	250	90	630	10	300	20	65	16	9	1960
21	800	100	50	500	11	200	30	60	16	7	1774
22	450	40	10	500	10	110	40	50	14	7	1231
23	200	20	10	790	9	110	40	50	13	6	1248
24	100	20	10	500	9	110	40	50	8	6	853
Total	4520	2390	1685	12220	108	8055	560	1142	252	158	



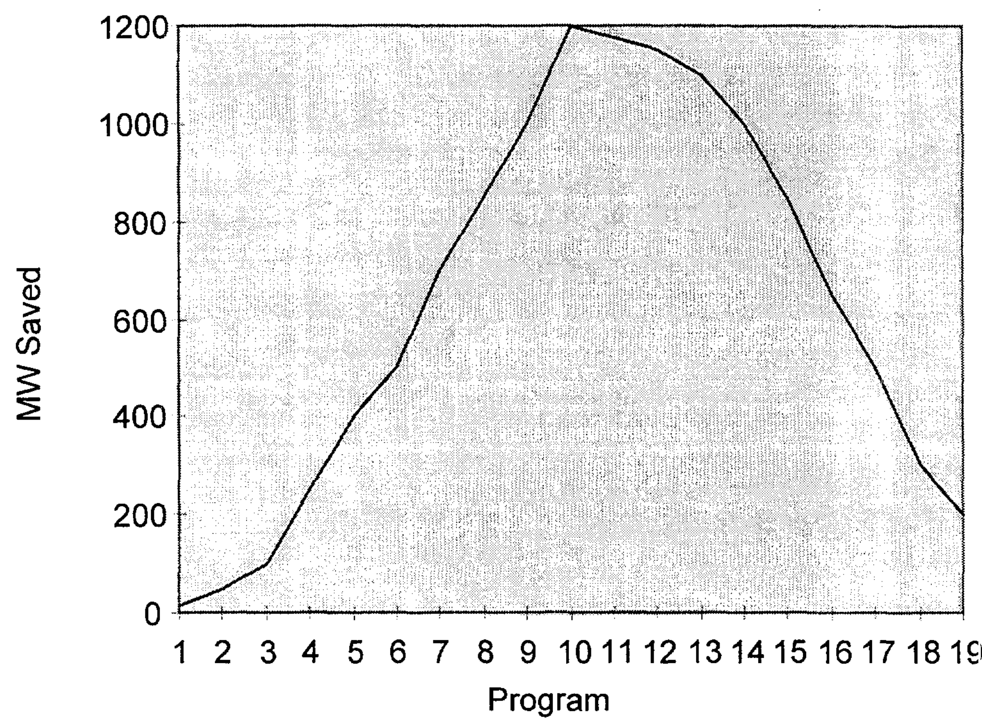
7.69 In AP, the synthesised load curve was based on an assessment undertaken as part of an earlier study. This in turn had been based on data provided by APSEB on the incidence of load shedding and their own estimates of the extent of the load which was shed.

7.70 In Bihar, power cuts and load shedding are considerably worse than in AP. The estimate of the unconstrained load curve was based on typical load curves by consumer group indicated from the earlier work in the IRP Study (Ref: 15, for AP).

Impact of DSM Measures

7.71 The synthesised load curves used in the AP and Bihar studies were modified to reflect the impact of DSM programmes. The impact of high efficiency pumpsets on the daily load curve for AP is illustrated in *Figure 7.3*.

Figure 7.3 Peak Demand Impact [MW]



Objective Functions

General

7.72 The 'objective function' reflects, in mathematical terms, what we are attempting to achieve. Whichever software is chosen, least-cost power system planning is concerned to choose supply-side and demand-side programmes and other policies which minimise costs - subject to constraints. So the 'objective' is minimum cost. But the 'costs' included in this objective can incorporate a range of factors - financial, economic and environmental. They typically include:

1. capital costs of new investments or refurbishment of existing equipment (generation and, possibly, transmission and distribution);
2. system fuel and variable operating costs;
3. energy not-served; and
4. environment.

7.73 The models differ in the way they estimate costs but most models with international credibility will normally include the option of costing all of these items.

7.74 The first two of the above are straightforward. The cost of energy not-served and the environment are discussed below.

Energy Not-Served

Definitions

7.75 *Energy Not-Served* (ENS) is the energy which, were it not for power cuts, would be taken by consumers. ENS is inevitable in any power system. By building more power plants and increasing the reserve margin, the probability of load shedding reduces and the expected ENS goes down - but at a cost. The optimal reserve margin is where the cost of the incremental investment is equal to the value of the reduction in expected ENS.

7.76 Expected ENS is closely related to the Loss of Load Probability (LOLP). LOLP represents the probability that load shedding will occur. It takes a value between 0 and 1. Multiplying the LOLP by 8,760 hours in a year gives the Loss of Load Expectation (LOLE) which represents the number of hours in a year when load shedding is likely to occur. For example, a LOLP of 0.005 (or 0.5%) is equivalent to an LOLE of 43.8 or an expectation that load shedding will occur on average during 43.8 hours in a year.

Alternative Approaches in Power System Planning

Power system planning models typically examine this in one or more different ways:

- By specifying a constraint that the reserve margin shall not fall below of a given level, typically between 20% and 40%. Other, similar, rules-of-thumb are also possible such as reserve margin shall exceed the size of the largest unit plus a certain percentage. The reserve margin approach provides a rule-of-thumb measure of the optimal system reliability. It does not, however, take account of the factors which affect system reliability, such as the size of plant and their availability.
- By specifying a constraint that the LOLP shall not go above a given level. This is also a rule-of-thumb measure of the optimal system reliability. It is more rigorous than the reserve margin criterion in that it takes account of unit sizes and plant availability. In some circumstances it may be a good approximation to an optimal reserve margin.
- By including a value of ENS or a Value of Lost Load (VOLL) in the optimisation. This gives a monetary value to expected ENS and allows a full optimisation to take place.

The Value of ENS

7.77 The cost to be associated with expected ENS should be based on studies of the value to consumers of avoiding power supply interruptions (expressed in Rp./kWh). The value is typically high. In the UK, for example, the value used in the pool is approximately £2.50/kWh (Rs. 175/kWh) which is approximately 50 times the average tariff. In France, Electricite de France uses a value for planning purposes equal to approximately £10/kWh.

7.78 The value is very dependent on the level of unserved energy. In India, with high levels of curtailments the value is likely to be considerably lower. As reliability improves, the value of ENS per kWh is likely to increase. Where, as in the reform and IFS scenarios, major improvements are foreseen in the level of reliability, any values used in the model should be based on those appropriate to a more reliable system.

7.79 In the EIPS work, AP based their analysis on a value of ENS equivalent to 10 times the average tariff. In Bihar, where system reliability changes were dramatic, the team imposed a constraint on the LOLP that it should not exceed 5% (equivalent to over 400 hours per year).

Problems in Finding Solutions

7.80 During the EIPS work, problems were encountered when the model could choose from large numbers of options. The model sets an upper limit to the number of possible development paths it will consider. Where no constraint was placed on the reserve margin, the number of development paths invariably exceeded the upper limit. It was therefore found necessary to place an additional constraint on the reserve margin.

7.81 A similar problem is likely to be encountered with similar probabilistic simulation models.

Environmental Impacts

7.82 Most models will estimate at least some environmental emissions. Those most commonly used are SO_2, CO_2, NOx and particulates because the impact can be easily calculated from the fuel used and the power plant efficiency and abatement technology.

7.83 Most models offer the option of allowing these emissions to affect the choice of the least-cost investment programme. The three options are:

- include abatement costs, to meet the appropriate environmental standards, in plant costs and assume that residual emissions have no cost;
- constrain the emissions to a given level and let the model choose an optimal programme, subject only to those constraints;
- include additional environmental externalities in the costs.

7.84 The EIPS work took as a starting point the assumption that in general the existing environmental standards were optimised and that, implicitly, the costs incorporated environmental externalities. The basis for this assumption is described in *Section 3.4.2*. Where problems are defined differently alternative assumptions could be made and environmental damage costs or emission constraints could be incorporated.

7.85 One aspect of the EIPS work did involve the introduction of environmental damage costs. These were used to establish a supply curve of CO_2 abatement measures. A CO_2 cost was introduced and the model re-optimised to estimate a revised programme with corresponding costs. This showed the CO_2 abatement which could be achieved for this CO_2 cost.

7.86 It should be noted however that the A/S Plan and similar software face the problem that when there is an overall emission limit constraint (for the whole power system), the software cannot take account of the possibility to change the merit order dispatch to reduce emissions. The software is only able to modify the development programme to reduce emissions and may therefore miss some cost effective constraints on dispatch. This represents a limitation on this type of software which cannot be avoided.

Screening Analysis

7.87 A preliminary screening analysis was undertaken as part of the EIPS project to identify a number of candidate power plants, with corresponding fuel sources, which could be offered as options to the optimisation model. The screening analysis is valuable in reducing the options to numbers which are manageable by the software. The screening analysis is prepared on a spreadsheet and is illustrated in *Table 7.3.*

Table 7.3 Screening Analysis

Plant Type	Capital+ Fixed O&M $/kW/year	Variable Fuel & O&M $/kWh	Total Costs ($/kW/year)				
			Operating Hours per Year (plant load factor)				
			0	2000	4000	6000	8000
OCGT	50	0.05	50	150	250	350	450
Coal	150	0.02	150	190	230	270	310
CCGT	100	0.03	100	160	220	280	340

Note: Costs are examples only and should not be used for specific analysis.
OCGT = open-cycle gas turbine.
CCGT = combined-cycle gas turbine.

7.88 In this example, the OCGT is lowest cost when operating in peaking mode for around 2,000 hours per year. When a plant is called upon to operate for more than 2,000 hours then the choice is between a coal plant and a CCGT. Between approximately 2,000 and 6,000 hours, the CCGT plant offers the lowest cost while above 6,000 hours the coal plant is cheapest. In this example, all of the three plant have a potential role to play in the supply-side mix.

7.89 An power plant option can be excluded from further consideration if, at all plant load factors, its costs are higher than the alternatives unless it has other qualities (eg environmental) which make it worthy of further consideration.

7.90 The screening analysis was also used for other purposes:

- to provide a cross-check on results from the A/S Plan model;
- to examine sensitivities to fuel prices.

Operation

General

7.91 Details of the operation of the models will be contained in the User Manuals issued with the software. Some issues are, however, worth mentioning in this Manual which are common to probabilistic simulation models or to the analysis conducted:

- the tunnel approach;
- optimisation in the BAU scenario;
- merit order dispatch under some scenarios.

The Tunnel Approach

7.92 Because the dynamic optimisation used in these models is only able to handle a limited number of development paths, it is necessary for the user to limit these options. This is known as the 'tunnel' approach.

7.93 An example of this is the use of the reserve margin. It is a reasonable assumption that optimisation of system reliability would ensure that the reserve margin does not exceed, say 50%. Placing a restriction of 50% on the reserve margin will then ensure that options with higher reserve margins are not considered. This reduces the options without changing the solution. An iterative procedure may be used to constrain other options (eg the date when new plant is commissioned, the number of units which can be commissioned in a year, etc). In the EIPS work, the teams ran the model initially over five year periods to find solutions and then introduced a tunnel around these solutions before going on to the next five years.

7.94 It should be mentioned that this approach does give rise to the possibility of a 'local optima' (ie it is optimal within the tunnel but not optimal from all the options available). A good understanding of the power system and the model is necessary to use the model effectively.

Optimisation in the BAU Scenario

7.95 The BAU scenario is, by definition, a continuation of current policies. In Bihar, optimal operation and development of the power system is not possible under current policies. For this reason, in the BAU scenario, no optimisation was undertaken. The investment programme was entered using informed judgement by the Bihar team based on their knowledge of the political and financial circumstances in Bihar (the assumption was made that no new investments would be made).

7.96 In AP, it was assumed that the SEB would be able to take optimal investment decisions, even under the BAU scenario.

Merit Order Considerations

Economic or Financial Costs in the Merit-Order Dispatch

7.97 Most power system simulation models will choose to dispatch plant in order of lowest cost. In the EIPS work, the BAU analyses use financial costs (as opposed to economic costs - see *Section 4*) in dispatch decisions. Thus, for example, SEB plant may be dispatched preferentially to state-owned plant because of one-part tariffs for transfers between NTPC and the SEB - when the NTPC plant is more efficient and has lower costs from an economic point of view. In the Reform and scenarios developed around IFS, the costs used in the dispatch decisions were based on economic costs.

Externalities or Environmental Taxes in Merit Order Dispatch

7.98 In some models and some analyses, it is possible to add external environmental costs or environmental taxes to the fuel costs. (But note that in the EIPS work, the economic costs were assumed to be adjusted to reflect external costs - see *Section 3.4.2).* In some instances, the decision-maker may wish to consider the impact of adding external costs to fuel costs; if this is the case then the dispatch order should reflect these external costs. In other instances, the decision-maker may wish to examine the level of external costs associated with a particular scenario; if this is the case then the dispatch order should not reflect these external costs. Many models will allow the user to specify whether external costs or taxes are allowed to affect the dispatch order.

Outputs from the Model

7.99 The outputs which are useful from the power system planning exercise will depend on the definition of the problem to be analysed (*Section 2*) and the design of the framework (*Section 3*).

7.100 Where, for example, the framework is being used to develop a least-cost power investment programme then the most important outputs will be the demand-side and supply-side programmes. For analyses, such as EIPS, which consider a complete range of policies and options, many of the outputs are valuable. Chief among these in the EIPS project are:

- the present-valued costs of the optimal investment programmes;
- the emissions of SO_2, CO_2, NOx and particulate matter;
- fuel consumption.

7.101 From these outputs, many other emissions can be estimated off-model, such as ash production, land pre-emption, etc.

8

Environmental Analysis

Introduction

8.1 In the EIPS work, the Terms of Reference did not place emphasis on reviewing existing environmental standards. The Terms of Reference noted that "*While the study will be based on existing environmental objectives (for example, as embodied in the emission standards), the study will also analyse how sensitive the costs of meeting these standards are to possible changes*". The implicit assumption is that environmental costs are internalised through compliance with existing standards (see *Section 3.4.2*) - this has important implications for the environmental analysis undertaken in the EIPS project. New power projects are, on paper, designed to comply with current environmental standards and incorporate the costs necessary for compliance.

8.2 *Section 8* begins with a review of the various levels of design of a power plant and notes that, in general, further environmental analysis is not generally required for new power plants as part of the EIPS work (unless, it is considered that environmental standards are not optimal). It then describes:

- the current environmental standards;
- the analysis which was undertaken, particularly for existing plants; and
- the role of air dispersion modelling in the decision-making framework.

Levels of Design

General

8.3 There are various levels of design as summarised in *Table 8.1*.

Table 8.1 Levels of Power Plant Design

Design Level	Description
generic design	Very general. No drawings, impact assessments or location would be considered. It would be simply a typical plant of a typical size and efficiency and burning a typical quality of fuel. Costs would be derived from a database of recent projects. This information might be used in a pre-feasibility study.
conceptual design	Less general. The location would normally be decided together with the source of the fuel. Some general details of the plant might have been optimised such as size, number of units, requirements for FGD or ESPs. A preliminary EIA might have been undertaken. Costs would be further refined, again from a typical database. The information might typically be used in a feasibility study.
definite design	Detailed engineering designs would be prepared and a full EIAs undertaken. Costs would be built up using the services of a quantity surveyor and would incorporate a detailed assessment of compensation claims for affected populations.

In practice, designs do not fall neatly into these three categories and may fall somewhere in-between.

Environmental Analysis in the EIPS Work

8.4 Most of the candidate power projects examined in the EIPS work had definite designs. In other words, they were described by location, size, fuel type and source, combustion technology, fuel handling facilities, stack height, requirements for electrostatic precipitators, etc. Environmental impact assessments (EIAs) are now a standard requirement for power plant designs in India and these include, for example, air dispersion modelling and analysis of population affected peoples, social impacts and the cost of compensation.

8.5 The EIPS work did not prepare basic project designs and costs, there was generally little requirement for environmental analysis of new projects. The main focus of the environmental analysis has therefore been on the environmental performance of *existing* plants and the costs necessary to bring the plants up to level which could meet the mandatory environmental standards.

Environmental Analysis in Future Analysis using this Framework

8.6 In some future analyses using the framework described in this Manual, it may be required to undertake some assessments of general siting policies (eg, a policy to locate all power plants close to mines). Or a State Electricity Board might wish to establish the optimal locations of a series of power plants and might wish to use the EIPS framework to do this. (In AP, for example, the EIPS work did consider some siting issues in general terms).

8.7 In these circumstances, it may be necessary consider plants without definite designs but with a specific location. Some environmental analysis such as air dispersion modelling might, in these circumstances, be undertaken for a generic plant at a specific location.

Environmental Standards

Indian Standards

8.8 Ambient air quality standards are prescribed by the Central Pollution Control Board (CPCB) which sets maximum permitted national levels. The State Pollution Control Boards (SPCBs) may impose more stringent standards.

8.9 SOx and NOx emissions are controlled through stack height restrictions but emission standards are in place for particulate matter.

8.10 A comprehensive description of current Indian environmental standards and the institutions which implement them is contained in *Annex E.*

World Bank Standards

8.11 The World Bank has proposed as a part of its *Pollution Prevention and Abatement Handbook* some draft environmental guidelines for new thermal plant. The guidelines are based on the concept of air-sheds and they distinguish air-sheds of good, moderate and poor quality. The guidelines state maximum plant emission levels which should be followed in achieving the site specific emission guidelines.

8.12 Current Indian emission standards for TSP are 150mg/m^3 for power generation units of capacity above 200MW and 350 mg/m^3 for units less than 200 MW. The proposed World Bank standards are much lower at 50 mg/m^3.

8.13 According to the proposed standards, many air-sheds in India would be classified as poor with respect to TSP. The annual average concentrations of TSP permitted by present Indian standards (360μg/m^3) substantially exceed the limit in the World Bank alternative (80 μg/m^3 for moderate and 160 μg/m^3 for poor).

8.14 There are no fixed emission standards for SO_2 in India at present. The World Bank has prescribed the emission standard for SO_2 to be 2000 mg/m^3.

8.15 Present Indian ambient quality standards for SO_2 in residential areas (60 μg/m^3) correspond roughly to moderate quality air-sheds and industrial areas (80 μg/m^3) correspond to poor.

Environmental Analysis of Existing Power Plants

8.16 Inadequate compliance with existing environmental standards is one of the more important problems in the energy sector in India. Environmental monitoring is required by the

SPCB but the data supplied by the SEBs or central power authorities to the SPCBs on emissions or ambient concentrations may not accurately represent the true problems. Additionally, problems relating to rehabilitation and resettlement are not recorded by the SPCB. One of the most important aspects of work in the EIPS framework is to attempt to obtain accurate information on:

- non-compliance with standards;
- the costs necessary to remedy the non-compliances;
- environmental problems for which there is no standard (eg implementation of R&R measures).

8.17 Obtaining reliable data from the SEBs is difficult. However, if decisions are to be taken based on rigorous quantitative analysis, it is important that the analysis be based as much as possible on reliable data.

8.18 Another source of information on non-compliances and other environmental problems, is the NGO community. As described in *Section 9*, the involvement of NGOs in the work can be valuable and they can, in some circumstances, provide quantitative information to support the analysis.

8.19 The collection of primary data through monitoring of emissions at power station sites is not possible for this type of analysis. However, where independent monitoring has been undertaken then this should be used.

8.20 In the EIPS work in Bihar, information on non-compliance and the costs of compliance was based on:

- data provided by Bihar SPCB;
- MECON's own monitoring data where permission had been given by the client to use that data;
- the cost estimates provided by the Consultants as part of the restructuring study (Ref. 2).

Air Dispersion Modelling

Objectives

8.21 Air dispersion modelling is normally required for EIAs for site-specific power plants as part of the definite design studies to identify the need for emission control equipment or to confirm that the plant meets standards for ambient concentrations.

8.22 Additionally, air dispersion modelling could be used in the EIPS framework to quantify the incremental environmental impacts associated with various forms of power generation and their siting, in order to track these impacts under different policy options. (Such analysis was not done as part of the EIPS work - but could be done if required).

8.23 As described in *Section 8.2*, plants whose location has been identified and for which detailed designs have been prepared, will also have EIAs. Additional air dispersion modelling for these plants is not therefore required. Some plants considered in the EIPS framework are, however, generic. In AP some siting investigation was undertaken as part of the work and modelling was necessary as part of this work. Air dispersion modelling for generic plant is unusual and requires special mention.

Air Dispersion Modelling for Generic Plant

8.24 There can be several types of generic plant which emerge from the least cost planning. All of these types will have individual characteristics with regard to their emissions to atmosphere. In order to compare their relative impacts on air quality, it will be necessary to model the dispersion of emissions from each of the possible types of power station at particular sites. Pollutants considered in the EIPS work were SO_2, NOx and suspended particulate matter.

8.25 Each generic type of plant can be assigned a 'standard' set of emission characteristics, including stack height.

8.26 A dispersion model should be used to generate a plot of isopleths of the additional annual average concentrations within 10 km of the plant. The annual average concentration serves as a useful surrogate for human health impacts and enables the spatial dimension of impact to be considered in siting analyses.

8.27 The power station siting policies could then be compared in terms of the annual average ground level concentrations or in terms of the costs of abatement necessary for compliance with standards. This does not, however, take account of the possibility that population exposure may vary from location to location. The concentrations should, if possible, be combined with a representative population density. A view needs to be taken as to the range of population densities which might be encountered. A simple approach to this problem would be to define a 'rural' and an 'urban' density.

Example of Air-Dispersion Modelling in the EIPS Work

8.28 In the AP case study, air quality modelling was considered both for generic plants and plants with definite/conceptual designs. For those with definite/conceptual designs, air dispersion modelling had been undertaken by consultants on behalf of APSEB.

8.29 For the generic plants in the AP case study, seven 'hot spots' were identified where the future power plants are likely to be concentrated. Air quality at these seven sites was modelled assuming that an additional 500MW generic power plant operates in these areas. The result provides an indication of the possible range of impacts due to additional atmospheric pollutants generated from the power plant. Background information on existing air quality at these sites was not, however, available for the case study so that the results provided only a partial view of the impacts. In general it is desirable to have information on background air quality at the proposed power station locations in order to identify the full impact of siting. This is not, of course, possible where no specific locations are proposed.

8.30 In Bihar, air quality analysis was based on the work undertaken for environmental impact assessments, prepared for definite or conceptual designs.

Dose-Response Functions and Damage Costs

8.31 It is theoretically possible for population exposure to be used with dose response functions in order to quantify specific health impacts, eg mortality and morbidity. However, the research on dose response functions and damage costs has yielded very wide estimates and little research has been undertaken in India. Dose-response functions and damage costs should be treated with considerable caution. [See Refs: 5 to 8]. The EIPS work tended to avoid quantitative analysis which could not be readily substantiated.

Types of Air Dispersion Models and Data Requirements

8.32 Any recognised and validated Gaussian plume model will be adequate for the above purposes. For example the ISC model (or its derivative ATDM) would be suitable.

8.33 Code to create a model can be obtained direct from the US Environmental Protection Agency (EPA). This costs very little but requires greater staff time to adapt and to use. Alternatively, it can be purchased in the form of a user-friendly Windows version from a supplier, such as Trinity Consultants, for approximately $2,000.

8.34 SCREEN or ATDM are two models offered, for example, by Trinity Consultants (Dallas, Texas). These are approved for regulatory use in the United States by the US EPA. ATDM is a combination of two models, ISC and COMPLEX.

- SCREEN is very simple and therefore limited in its capabilities;
- ATDM (a derivative of the ISC model) is capable of more complex input and output and would be a more powerful tool for environmental impact studies for work beyond the EIPS framework.

8.35 ADTM does however require input data of a certain complexity and format in order for its potential to be realised. These data may be available from sources such as Trinity Consultants or the UK Met Office. The value of the model will therefore depend on whether the observations from suitable stations in India are used for global numerical weather predictions and therefore stored on synoptic data banks in the UK and USA.

8.36 A requirement of the Indian Ministry of the Environment is that on-site meteorological measurements are made and used in dispersion modelling predictions for EIA purposes. The consultants used by SEBs for conducting EIA's of new power stations collect meteorological measurements at the sites of proposed power stations. If such measurements could be transformed into input files for dispersion models used in subsequent work under the EIPS framework, then this could be a useful alternative source of data.

Use of Air Dispersion Models in the EIPS Project

Andhra Pradesh

8.37 In AP, stack monitoring of flue gases is carried out at intervals of one month over a 24 hour period, to measure concentrations of SO_2, SPM and NO_x. This monitoring is undertaken by APSEB using portable equipment. Results are reported to the State Pollution Control Board, who also visit the power station when monitoring takes place.

8.38 The APSEB also undertake ambient air quality monitoring around power stations, with small networks of monitoring site around each.

8.39 EIAs are carried out for APSEB by consultants, who typically use USEPA dispersion models.

Bihar

8.40 In Bihar, MECON itself is one of the consultants employed by BSEB to undertake air dispersion modelling. Over the years, MECON has developed its own modelling techniques and adapted the source code of US EPA approved models. Their mainstay model is ISC3. This is a well used model for sources such as power stations and is used internationally.

8.41 However, the model only provides 24-hour averages and MECON considered the purchase of models which could provide annual averages.

9

Financial Analysis

Introduction

9.1 The financial analysis was used in the EIPS project to:

- examine the financial constraints to investment under the BAU and reform scenarios;
- examine the financial viability of the SEBs under these two scenarios.

The Financial Model

9.2 The financial model used in Bihar and AP was a basic spreadsheet together with various sub-modules. The spreadsheet comprises the standard Profit & Loss Account, Balance Sheet and Cash Flow analysis.

9.3 This model, though simple, was adequate for the purposes of the EIPS project and should be suitable for most similar projects in other states. The model was not, however, designed for preparing detailed financial projections. For this purpose, other suitable financial models can be developed based on frameworks used by, for example, the World Bank or other international financial institutions.

The Data Requirements

9.4 The following describes the key data requirements used in the financial analyses in AP and Bihar:

1. *Annual* capital expenditure for *each plant* is take from the least-cost generation expansion sequence (in the EIPS work this was taken from the A/S Plan model). In the least-cost generation planning model this is represented in constant prices, net of any taxes/duties. Taxes and duties should be added back. The capital expenditure in A/S Plan is represented as a single sum incurred at the date of commissioning (including IDC). For the purpose of the financial model it was necessary to represent these as phased expenditures (the phasing of capital expenditures was prepared in a supporting spreadsheet). (Other least-cost generation planning software may represent capital costs phased over time).

2. *Annual* additions (or reductions) to installed capacity (MW) for *each category of plant* (by technology, fuel and set size) - including existing, committed and new plant.
3. Fixed O&M cost (Rs/kW installed/year for each category of plant). Items 2 and 3 are required to calculate annual fixed O&M costs, in financial terms.
4. Annual energy generation by each individual (named) plant.
5. Annual fuel consumption (tonnes, m^3) for each plant, and fuel used.
6. Specific fuel consumption (kg/kWh), or average heat rate for each plant. Items 4-6 are required to calculate annual fuel costs, in financial terms.
7. Non-fuel variable cost (Rs/kWh) for each category of plant.

The above information relates *only to plant owned and operated by the SEB.* Data on IPP plant is not required - other than energy generated by the IPP plant and the tariff for electricity purchased from the IPP.

8. Annual IPP plant outputs (GWh at the busbar).
9. Bulk purchase tariff for IPP energy outputs.

Adjustment from Economic to Financial Prices

9.5 The BAU scenario uses financial costs and prices, so that the costs and prices used in the power system planning model *(Section 7)* can be used directly in the financial model. The Reform scenario uses economic prices but economic and financial prices are assumed to be identical in the reform scenario. So, apart from the addition of taxes and duties, no adjustment was required in the EIPS work.

9.6 For the purposes of the financial model, current prices were used. A common and consistent set of assumptions on Indian inflation rates, exchange rates and US$ inflation rates was agreed.

10

Organisation and Resources

Introduction

10.1 The following Section describes in general terms how the work was organised in the EIPS project and the type of resources which may be required for similar work in the future.

Organisation of the Overall EIPS Project

General

10.2 The funding for the study was provided by the UK's Department for International Development (DFID) through the joint United Nations Development Program/World Bank Energy Sector Management Assistance Program (ESMAP).

The study comprised four phases :

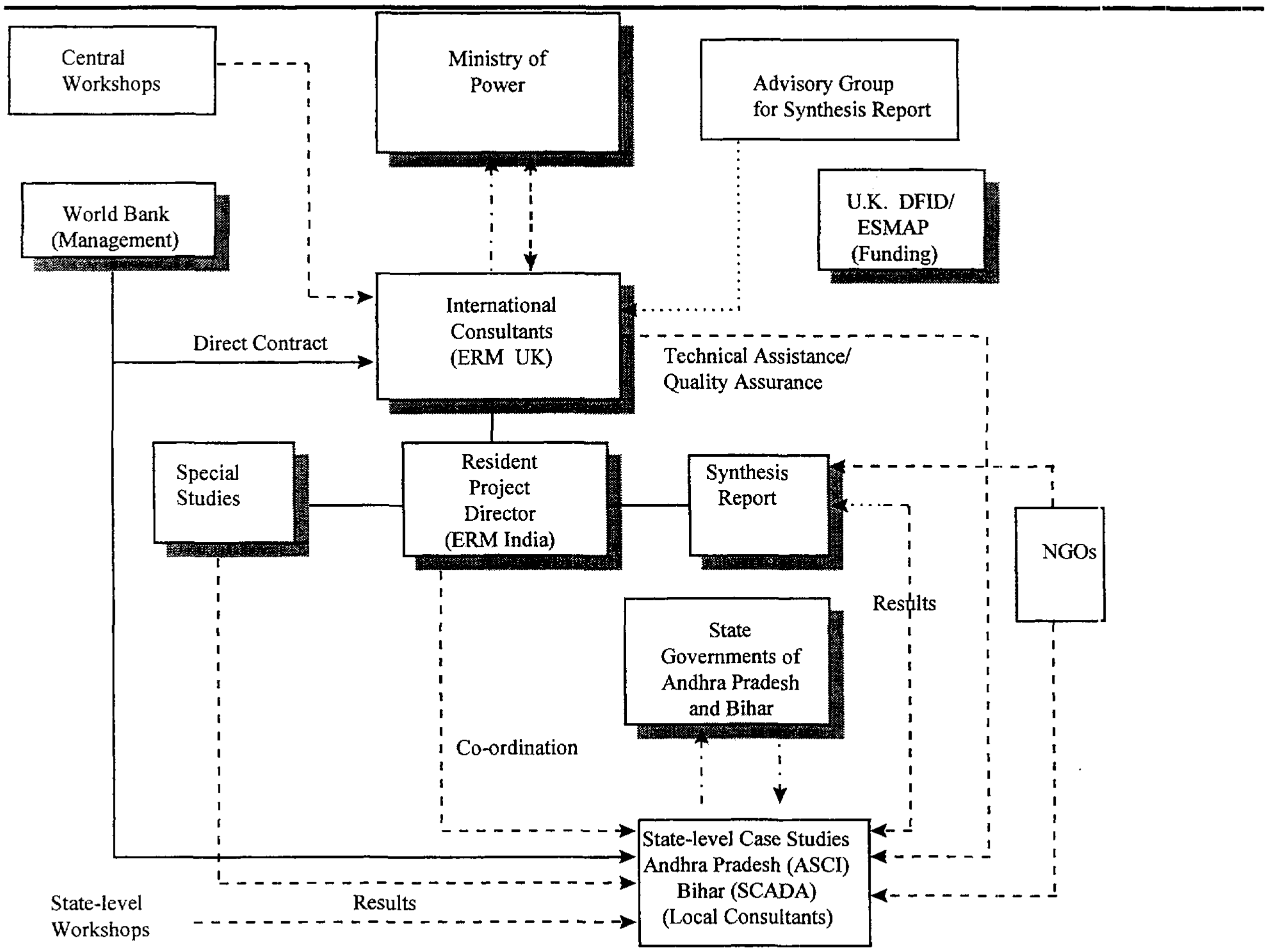
Phase 1, Inception;
Phase 2, Special Studies and Procurement of Model;
Phase 3, Case Studies in Andhra Pradesh and Bihar;
Phase 4, Synthesis.

10.3 International Consultants (ERM supported by the CRE Group) were responsible for phases 1, 2 and 4 although the work for the Special Studies in Phase 2 was subcontracted to local consultants. The Case Studies in phase 3 were undertaken by two state nodal institutions ASCI and SCADA/ MECON. ASCI and SCADA/MECON were contracted directly by the World Bank. ERM also provided assistance to ASCI and SCADA during the Case Studies.

Overall Philosophy

10.4 The principal objective of the EIPS work was to provide a framework for assisting decision makers. The process was therefore characterised by extensive preliminary consultation and continual consultation thereafter. The organisation of the study is shown schematically in *Box 10.1.*

Box 10.1 Organisation of the Study



10.5 The initial stage of the work began with the design of a questionnaire which was subsequently delivered to a large number of senior officials in the energy and environment sector and to NGOs. The questionnaire sought to obtain the views of decision makers and interest groups on the main issues relating to the environment in the power sector. This was used to aid in focusing the subsequent work toward issues and problems considered to be most pressing in India.

10.6 The work was then launched in earnest with a series of three Workshops and Seminars designed to encourage the participation and interest of a wide audience. One workshop, for a technical audience, was used to encourage debate on the modelling tools available to help in the analysis. Another workshop was attended by NGOs who were invited to open a discussion of the most appropriate issues and analysis and to nominate individuals to represent them at subsequent workshops. These were followed by a major Inception Seminar attended by key decision makers from the Indian ministries and from the industry. A number of key decisions were taken at the Seminar which formed the basis for state-level Case Study analysis and for the Special Studies.

10.7 The role of the survey and Inception Seminar in the work is described in *Section 2*. Alternatives to questionnaires are also discussed. Whatever approach is adopted, a consultation exercise is a necessary component of the EIPS philosophy. An Inception Seminar, to launch the work, forms part of the consultation exercise.

10.8 Mid-Way Workshops were undertaken in each of the two states - Bihar and Andhra - and a combined workshop took place in Delhi. The latter was attended by senior officials from the central ministries, representatives of the state electricity boards, teams from the state-level nodal institutions (ASCI and SCADA) and representatives of the NGOs. These workshops discussed the preliminary results from the Case Studies and exchanged views on the implications of the outputs from the work.

10.9 The participation of the NGO community was encouraged through the recruitment of a co-ordinator whose role was to disseminate the intermediate results and to organise workshops.

10.10 The work culminated in a Decision Makers Workshop and an NGO Workshop in Delhi. The former was attended by representatives from a number of state electricity boards, officials from both state and central level agencies, academic and research institutes, and from international organisations. This final Decision Makers Workshop helped to disseminate the methodology established as part of the project and demonstrate the value of the methodologies in other states in India. The NGO Workshop provided an opportunity for a cross-section of NGOs from across India to review the issues and options considered in the Synthesis Report and the two Case Studies. Decision Makers' Workshops were also held at the state level in Bihar and AP.

10.11 Finally, an Advisory Group for the Synthesis was established; and the Special Studies, Case Studies and the Synthesis Report itself were subjected to extensive peer review. The Advisory Group, consisting of representatives of the central Ministries and agencies, met in October 1997 and April 1998, to advise ERM on the design and scope of the Synthesis Report. The panel of peer reviewers included local academics and researchers, NGOs, officials familiar with the power sector and with the environmental impacts of power generation, and consultants; as well as international experts and NGOs.

Special Studies

10.12 The Special Studies were designed to provide inputs to the Case Studies. They were not intended to be specific to Bihar and AP and may therefore be used as inputs to similar work in other states. The Special Studies deal with:

- Inter-Fuel Substitution (the economic costs of delivered fuels);

- Welfare Effects of Power Policies (particularly raising electricity tariffs);
- Renewable Energy Technology;
- Demand Side Management;
- Market Based Instruments;
- Mitigation Options for Power Development (the options available for, and costs of, clean-coal technologies and abatement technology at power plants and coal mines); and
- Management of Ash from Thermal Power Stations.

10.13 With the exception of the special study on ash management, these studies were undertaken by Indian consulting organisations under contract to the International Consultant.

Organisation of the Case Studies

General

10.14 The Case Studies were undertaken by state nodal institutions in AP (ASCI) and Bihar (SCADA). In Bihar, SCADA associated closely with MECON. ASCI and SCADA were contracted directly by the World Bank but the international consultant provided assistance and guidance to these organisations.

10.15 Co-ordination of the two teams was undertaken by the international consultant. This was achieved through a number of mechanisms including:

- the role of the Project Manager (an Indian national) based in Delhi;
- visits by experts from the international consultants team to both states to discuss specific topics (demand forecasting, power system planning, air dispersion modelling, financial analysis) and review progress;
- a technical workshop attended by both teams and the international consultant;
- a co-ordination manual which was developed in the early stages of the project.

The Coordination Manual

10.16 The creation of a coordination manual proved useful to the two teams. This helped to standardise some assumptions and approaches between teams operating from different parts of India. The coordination manual was not an attempt to impose uniformity on the two teams. They were each attempting to tackle issues particularly relevant to their states. However, some common approaches and assumptions were highly desirable relating to, for example, the study boundary, the approach to captive power plants, the discounting of emissions and the choice of discount rate or study period.

10.17 Even if in future the framework is used in one state alone, the work often involves several different organisations working together. In Bihar, for example, the organisations involved included SCADA, MECON, BSEB and IIT, Delhi. A coordination manual helps to ensure that all these organisations are working to similar assumptions and approaches.

The Role of the SEBs

10.18 In AP, ASCI was able to secure the close involvement of APSEB throughout the project and a senior staff member of APSEB staff was made available for discussion with team members, to ensure that data was made available and to attend Workshops and make presentations at those workshops.

10.19 In Bihar, similarly, the involvement of BSEB was obtained and a member of BSEB staff was seconded to the project during the early phases of the work.

10.20 In Bihar, MECON's engineering database and knowledge of power projects in the state proved invaluable in filling gaps in data available from the BSEB.

Workshops

10.21 Mid-way workshops and dissemination workshops were held to communicate the results of the work to state level decision makers and to communicate between the team members.

Resources Required by the Case Study Teams

10.22 The resources required in future work in other states will depend on a number of factors such as the availability of previous work on:

- demand forecasts;
- environmental analyses;
- financial analysis;
- power system planning;
- air dispersion modelling;
- evaluation of fuel sources.

10.23 Based on the work undertaken in AP and Bihar, the following broad guidelines have been drawn.

Computer Hardware and Software

Hardware

10.24 The work is relatively computer intensive and access to two good PCs is essential together with standard office software of good spreadsheet and word-processor packages. In the EIPS work, Excel and Word were used.

Power System Planning Software

10.25 The single most important and expensive software required for the work will be the power system planning model. This model is discussed in *Section 7*. The cost of the model ranges from nothing (eg for ENPEP/WASP) through to more than US$150,000 for EGEAS. A/S Plan cost US$12,000 for an indefinite licence.

10.26 Some of these power system planning models require an annual maintenance fee although Anylec Solutions, who market A/S Plan, does not levy a maintenance fee and will update their software with the latest version, free of charge.

10.27 Most providers of software will provide training although this is an additional cost.

Air Dispersion Model

10.28 An air dispersion model may, or may not, be required. It is necessary if one of the 'Problems' examined relates to power station siting and where these power station sites have not yet been investigated in EIAs.

10.29 The air dispersion models used in the EIPS work were based on the model used by US's Environmental Protection Agency. The computer code for this can be downloaded from the internet. However, the compilation of this code will give a very simple, DOS-based program which will require extensive manipulation of data inputs and outputs. More expensive and more user friendly models are available at a cost of around US$2,500.

10.30 In addition to the model, meteorological data will need to be collected. The only source of data for this is the Indian Meteorological Office. Data can be obtained in hard copy or on a diskette. The latter is easier to input to the models, but more expensive to purchase.

Financial Model

10.31 A financial model may not always be required. It will not be required if there are no problems with funding investments or if the problem being examined relates only to a small subset of issues (eg a CO_2 abatement curve).

10.32 The financial model is normally based around a spreadsheet. No formal software is necessary. Moreover, most formal financial analysis software would be too inflexible and complex for the analysis required for this type of work.

Demand Forecasting Model

10.33 This model will normally be developed specifically for the state's power sector and will be based on a spreadsheet. Some models are available which are designed specifically for demand forecasting (eg MEDEE) or some models incorporate demand forecasting modules.

These may be used if desired but they are not necessary. In some cases a demand forecasting model will already exist for the state.

10.34 In both AP and Bihar, demand forecasting models were developed, for the EIPS project, around a spreadsheet.

Bibliography

Chapter 1

1. *Environmental Issues in the Power Sector: A Case Study of Bihar*, SCADA, March 1998.
2. *Environmental Issues in the Power Sector: Andhra Pradesh Case Study*, ASCI, March 1998.
3. *Environmental Issues in the Power Sector: Synthesis Report*, Environmental Resources Management, June 1998. (Published as UNDP/ESMAP report no. 205/98).

Chapter 2

The following is a small selection of publications which consider issues and options relating to the power sector and the environment:

1. *Energy and Economic Growth: is sustainable growth possible*? Proceedings of the 20th Annual International Conference of the International Association of Energy Economics, Tata Energy Research Institute, 1997.
2. *Planning for the Indian Power Sector: Environmental and Development Considerations*, Canadian Energy Research Institute and Tata Energy Research Institute, 1995.
3. *Environmental Considerations and Options in Managing India's Long-Term Energy Strategy*, Tata Energy Research Institute supported by United Nations Environment Programme, 1995.
4. *The Climate Change Agenda: An Indian Perspective*, A. N. Achanta (ed), Tata Energy Research Institute, 1993.
5. *India's Environment: Taking Stock of Plans, Programs and Priorities*, World Bank, South Asia Regional Office, January 1996.
6. *Clear Water, Blue Skies: China's Environment in the New Century*, The World Bank, 1997.

Chapter 3

1. *Incorporating Environmental Concerns into Power Sector Decisionmaking, A Case Study of Sri Lanka*, Meier and Munasinghe, World Bank Environment Paper no. 6, 1994.
2. *Environmental Performance Indicators*, A First Edition Note, World Bank Environment Department, February 1996.
3. *Urban Air Quality Management Strategy in Asia (URBAIR): Greater Mumbai Report*, J. Shah and T. Nagpal (Eds.), World Bank, October 1996.
4. *Air Pollution and the Social Costs of Fuels, A Methodology with Application to Eight Cities*, Maddison, et al., World Bank, unpublished (1998).

Chapter 4

Discount Rates and Discounting

1. *Economic Analysis of Projects,* L.Squire & H.G. Van der Tak, The World Bank, 1975
2. *Blueprint for a Green Economy*, Pearce, Markandya and Barbier, Earthscan Publications, 1989.

Tariff Studies in India

3. *Orissa Power Sector Restructuring Project*, World Bank Staff Appraisal Report, April 1996.
4. *Uttar Pradesh Power Sector Restructuring Project,* World Bank Staff Appraisal Report.

Chapter 5

Demand Elasticities

1. *Elasticities of Electricity Demand in India, EIPS Special Study*, prepared by TATA Energy Research Institute, 1997.

Demand-Side Management

2. *Demand-Side Management, EIPS Special Study*, prepared by Energy Economy & Environmental Consultants, 1997.
3. *Bihar Power Sector Restructuring Program: Sector Performance Improvement Plan,* prepared for the Government of Bihar by IRG and Fichtner, 1996.
4. *Strategic Approach for DSM in India*, by RCG/Hagler Bailly, 1995
5. *Integrated Resource Plan for Andhra Pradesh*, Hagler Bailly Consulting, 1994
6. *Orissa State Pre-Feasibility Studies on Demand-Side Management*, prepared by Energy Economy & Environmental Consultants, 1997
7. *Planning for Demand Side Management in the Electricity Sector*, Jyoti K. Parikh, et al., Indira Gandhi Institute of Development Research, Tata McGraw Hill, July 1994.
8. *DSM in transition: from mandates to markets*, Energy Policy, Vol. 24, no. 4, April 1996, Special Issue.
9. *Commercial Energy Efficiency and the Environment,* Robin W Bates and Edwin A Moore, Background Paper for World Development Report, WPS 972, The World Bank, September 1992.

Data Sources

9. *TERI Energy Data Directory & Yearbook*, Annual, Tata Energy Research Institute.
10. *Welfare Effects of Power Policies, Special Study for EIPS*, prepared by ERM India, 1997. (Examines the share of electricity in household expenditure and the effect of price changes on demand for irrigation).
11. *Fifteenth Electric Power Survey of India*, Central Electricity Authority, July 1995

Chapter 6

1. *Inter-Fuel Substitution, EIPS Special Study,* prepared by Tata Energy Research Institute, 1997
2. *Energy Modelling for India, Planning Commission, 1993 - the EMI Report*
3. *Inter-Fuel Substitution: Cointegration Tests of Long-Run Fuel Price Relationships*, Palaskas, Imran, Duncan, World Bank.
4. *Substitutability of Energy in Developing Countries*, Imran and Quan, World Bank.
5. *Andhra Pradesh Case Study, EIPS, Volume III Coal Model,* prepared by Administrative Staff College of India, 1998.
6. *Energy Modelling for India,* Planning Commission, 1993.
7. *Long-Term Issues in the Power Sector,* for Ministry of Power, Government of India, through the World Bank, 1992.
8. *Coal Sector Environmental and Social Mitigation Project,* World Bank Staff Appraisal Report, April 1996.

Chapter 7

Power System Planning

1. Various User Manuals available from model authors/distributors.
2. *Policy Alternatives for Western and Southern Power Systems in India,* Jyoti Parikh and S. G. Deshmukh, Indira Gandhi Institute of Development Research, Reprint no. 28, 1992.
3. *Simulation of National Grid Operation in India,* Jyoti Parikh, D. Chattopadhyay and U. Nandapurkar, Utilities Policy, Vol 5, No. 1, 1995.
4. *Integrating Demand-Side Management in Electricity Utility Planning: A Multi-objective Approach,* D. Chattopadhyay, R. Banerjee and Jyoti Parikh, Indira Gandhi Institute of Development Research, Reprint no. 115, 1993.
5. *DSM Matters. Demand-Side Management in the Electricity Sector,* Jyoti Parikh (ed), Indira Gandhi Institute of Development Research, Reprint no. 26, 1992.

Clean Coal and Pollution Abatement Parameters

6. *Clean Coal Technologies for Developing Countries*, Tavoulareas and Charpentier, World Bank Technical Paper no. 286, 1995.
7. *National Programme for Environmental Management for Coal-Fired Power Generation,* for Ministry of Environment and Forests, Government of India with support from the Asian Development Bank, 1994.
8. *Ash Management, Disposal and Utilisation Study, EIPS Special Study,* prepared by Water & Earth Science Associates, 1996.

9. *Mitigation Options for Power Development, EIPS Special Study*, prepared by Ghosh, Bose & Associates PVT Ltd with support from CRE Group, 1997. (Two volumes on Mitigation Options in Coal Mining and Mitigation Options in Power Generation).

10. *Coal Beneficiation: A Technology Option for Clean Coal Supplies*, Report submitted as part of EIPS by ASCI Consultancy, 1997.

Characteristics of Fossil-Fuelled Plants

11. *Andhra Pradesh Case Study*, EIPS, by Administrative Staff College of India, 1998. *Volume II, Appendix 13* contains parameters for power generation based on refinery residues.

12. *Performance Review of Thermal Power Stations*, Annual, Central Electricity Authority.

13. *Annual Report on the Working of State Electricity Boards and Electricity Departments*, Power & Energy Division, Planning Commission, Govt. of India.

Renewable Energy Technologies

14. *Renewable Energy Technology, EIPS Special Study*, prepared by ERM India, 1997.

15. *Integrated Resource Planning for APSEB*, Hagler Bailey Consulting under USAID funding, 1996.

Fuel Resources

16. *Fourth National Power Plan: 1997-2012*, Central Electricity Authority, 1997.

17. *Coal Sector Environmental and Social Mitigation Project*, World Bank Staff Appraisal Report, April 1996.

Chapter 8

General.

1. *Pollution Prevention and Abatement Handbook*, environmental guidelines for new thermal plant, World Bank, 1998.

2. *Bihar Power Sector Restructuring Program: Sector Performance Improvement Plan*, prepared for the Government of Bihar by IRG and Fichtner, 1996.

Air Dispersion Modelling.

Useful information can be obtained from the US EPA web site and, if required, source code is available from there. Other useful references include:

3. *Workbook of Atmospheric Dispersion Estimates: An Introduction to Dispersion Modeling*, D. B. Turner, Trinity Consultants; published by Lewis Publishers, 1994.

4. *Air Pollution Modeling: Theories, Computational Methods and Available Software*, P. Zannetti; published by Van Nostrand Reinhold, 1990.

Damage Costs and Dose-Response Functions

The first of the following references are Papers resulting from the ongoing World Bank project: *Air Pollution and the Social Costs of Fuels*. The third reference is a Report produced as part of another ongoing research project, run by the European Commission.

Damage Costs and Dose-Response Functions

The first of the following references are Papers resulting from the ongoing World Bank project: *Air Pollution and the Social Costs of Fuels*. The third reference is a Report produced as part of another ongoing research project, run by the European Commission.

5. *Addressing the Environmental Costs of Fuels in Developing Countries*, K. Lvovsky and G. Hughes, World Bank, Paper prepared for the World Congress of Environmental and Resource Economists, June 25-27, 1998.
6. *Economic Cost of Air Pollution with Special Reference to India*, K. Lvovsky, World Bank, Paper prepared for the National Conference on Health and the Environment, Delhi, July 7-9, 1998.
7. *Externalities of Energy (ExternE)*, European Commission, DGXII, 1995.
8. *Quantification of the Effects of Air Pollution on Health in the United Kingdom*, Department of Health, 1998.

Chapter 9

A standard Indian textbook describing financial accounts and financial analysis would be useful for guidance for the financial analysis. For example:

1. *Financial Management*, I. M. Pandey.
2. *Projects, Planning, Analysis, Selection, Implementation and Review*, P. Chandra, Tata McGraw Hill, 1995.

Annexes

Annex A

Terms of Reference

Attachment 1 International Consultant
Attachment 2 Overall Study
Attachment 3 Bihar Case Study
Attachment 4 Andhra Pradesh Case Study

INDIA: ENVIRONMENTAL ISSUES IN THE POWER SECTOR

Terms of Reference for the International Consultant

1. Background and Objectives

The Government of India (GoI), the State Governments of Andhra Pradesh (A.P.) and Bihar, the British Overseas Development Administration (ODA) and the World Bank are implementing a study of environmental issues in the power sector in India. Technical assistance is a fundamental component of the study and will be provided by the international consultant to the experts, officials and institutions in India, that are directly engaged in dealing with issues related to power system development and the environmental issues associated with it. Indeed, one of the measures of the success of the study will lie in the extent to which it leaves behind and institutionalizes a planning capability at the central government level; and in the states of A.P. and Bihar. In both A.P. and Bihar, the creation of such a capability will depend crucially on the "on-the-job" training which the international consultant provides. The study is also a vehicle to promote better communication and dialogue between the main involved parties in India. Such communication and dialogue is especially critical at the central government level; and between NGOs and officials handling power system planning in the states and central government.

The Overall Study Terms of Reference are in Annex I. It is expected that the overall study will take about 20 months to complete. The main features of the overall study are as follows:

1.1 Objectives

The overall study will identify the main environmental effects related to the expansion of electricity generation from coal, including the environmental externalities and costs caused by the associated increase in the production of coal. On the basis of the identified environmental effects, the study will present a menu of options to mitigate those effects. The menu will be presented in a way that facilitates a practical selection between the options and allows decision-makers in India to assess more explicitly the trade-offs involved between options. In particular, to compare options adequately, a provision for the environmental cost of coal mining (based on existing environmental standards) needs to be included in the cost of power.

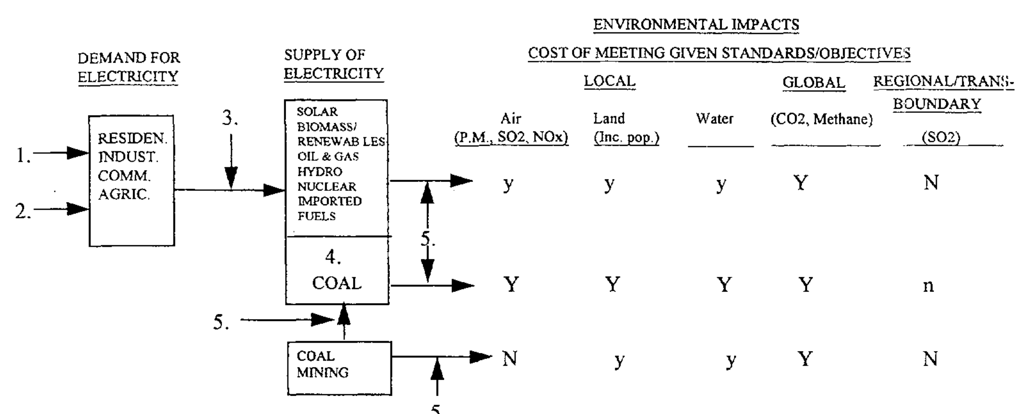
The main environmental effects to be covered include: air pollution, due (for example) to emissions of particulate matter (PM), sulphur dioxide (SO_2) and oxides of nitrogen (NO_x); the contribution of coal-fired power generation to emissions of greenhouse gases (GHG); land degradation and pre-emption, for example through the accumulation of bottom ash at power station sites and open-cast coal mining; and water pollution. However, the questions of mine safety and coal fires will not be addressed. The study considers the environmental effects of hydroelectric power, hydrocarbons, biomass and nuclear power to the extent that they are relevant in the context of inter-fuel substitution.

1.2 Options

The study will examine a broad number of options for reducing the environmental impacts of the expansion of electricity generation from coal. These options include: electric power pricing; demand-side management (DSM); inter-fuel substitution, considering both domestic and imported fuel possibilities and renewable energy sources; a range of technological solutions, such as coal beneficiation, ESPs, FGD, clean-coal technologies, ash pond management and improved ash disposal and utilization; economic instruments, notably environmental taxes and emissions trading; institutional and managerial reforms to improve efficiency in the power sector, for example through better maintenance, plant dispatch, and reduced line losses; and the siting of power plants. A schematic representation of the main environmental impacts and options to be considered is in Figure 1.

Figure 1

Schematic for Environmental Impacts and Options in the Power Sector



Impacts Considered
Y=YES y=YES, but selective only, to get rough estimate of impact on cost of electricity per kWh
N=NO n=Not covered in modelling but implication for forestry and rain-fed agriculture considered
P.M.=Particulate Matter SO2=Sulphur Dioxide NOx=Nitrogen Oxide CO2=Carbon Dioxide

Options Considered

1. Electric Power Pricing
2. DSM (inc. environmental taxes)
3. Efficiency in Supply (maintenance of equipment, T&D losses), Institutional and Managerial Reform, Regional Interconnections
4. Inter-fuel substitution, including the effect of economic instruments on fuel choice. Analysis to be extended outside modelling to consider energy options in moderating fuelwood depletion
5. Technology mitigation options (coal beneficiation, ash disposal, clean coal technologies, IGCC and AFBC technologies, resettlement, compensation, land restoration, power plant siting, sulphur control, particulate control)

1.3 Methodology

Following implementation of the activities leading up to the study Inception Seminar (as specified in paras. 25-26 of the Overall Study Terms of Reference), the study will be carried out on the basis of case studies in two states, *viz.* A.P. and Bihar. These case studies will provide an empirical basis for a national synthesis, which will draw quantitative conclusions at the national level about the environmental and cost consequences of broad energy policy options. The national synthesis and the state-level case studies will be supported by a set of cross-cutting special studies, for example those identified in Section 4.1 below, which will examine subjects with a broader and more generic interest than the individual states.

In both states, the study will identify the relevant environmental objectives. Then, for each option, the development of the power generation system will be simulated, along with the required coal transport and coal production. Each option will be required to meet the forecast electricity demand in the state, subject to environmental constraints. In particular, it will be necessary to comply with existing environmental objectives, notably as expressed in ambient air quality, emissions standards and effluent discharge standards. Also, the financial implications of the various options will be considered, especially relative to the financial objectives for the power sector laid down by the central and state governments, as well as international lending agencies. While the study will be based on existing Indian environmental objectives (for example, as embodied in the emissions standards), the study will also analyze how sensitive the costs of meeting these standards are to possible changes, e.g. towards those of the EC or the World Bank guidelines.

1.4 Relationship with Other Activities

A special effort will be made to link the study with the substantial amount of work that has already been completed, or that is currently under way on related topics, for example: (i) the World Bank's Coal Sector Rehabilitation Project; (ii) the GEF-funded Study on Selected Options for Stabilizing GHG Emissions; (iii) the Environmental Power Manual (EM), which is being managed by the World Bank; (iv) the various activities on DSM, which the World Bank has proposed supporting in the State Power Sector Restructuring operations currently under preparation in Haryana, Orissa, Andhra Pradesh and Uttar Pradesh; (v) the E-7 Network Support being provided to India; (vi) the National Program for Environmental Management for Coal-Fired Power Generation, funded by the Asian Development Bank (ADB); (vii) the Power Tariff Policy Study, financed by ADB for the Andhra Pradesh State Electricity Board (APSEB); (viii) the Urban Energy Study, funded by the Energy Sector Management Assistance Programme (ESMAP); (ix) the Asia Acid Rain project, funded by a multi-national trust fund, through the World Bank and ADB; (x) the USAID-financed work on Integrated Resource Planning (IRP) for APSEB; and (xi) the Metropolitan Environmental Improvement Program (MEIP), funded by UNDP, through the World Bank. One of the contributions of the study will be to bring together and build upon the results of this other work in a way that will allow policy-makers in India to make well-informed decisions.

2. Contractual Arrangements

The funding for this study will be provided by ODA, through the joint United Nations Development Program/World Bank Energy Sector Management Assistance Program (ESMAP). The World Bank will contract with the international consultant. The Indian counterpart agency for the study is the Ministry of Power (MoP), acting jointly with the Department of Economic Affairs, although the Energy Management Centre (EMC) has been designated by MoP as the Study Coordinator, to represent MoP in day-to-day liaison with the international consultant and to interact with the study counterparts. No central steering committee is envisaged at this stage, since the organizational structure for the study described in Section 3 and Figure 2 is judged adequate to ensure national coordination and dissemination of the study's information and results. However, the international consultant and study participants will keep this under review, and advise the World Bank and ODA if a coordination or dissemination gap becomes evident.

3. Relationship between the International Consultant, ASCI and SCADA

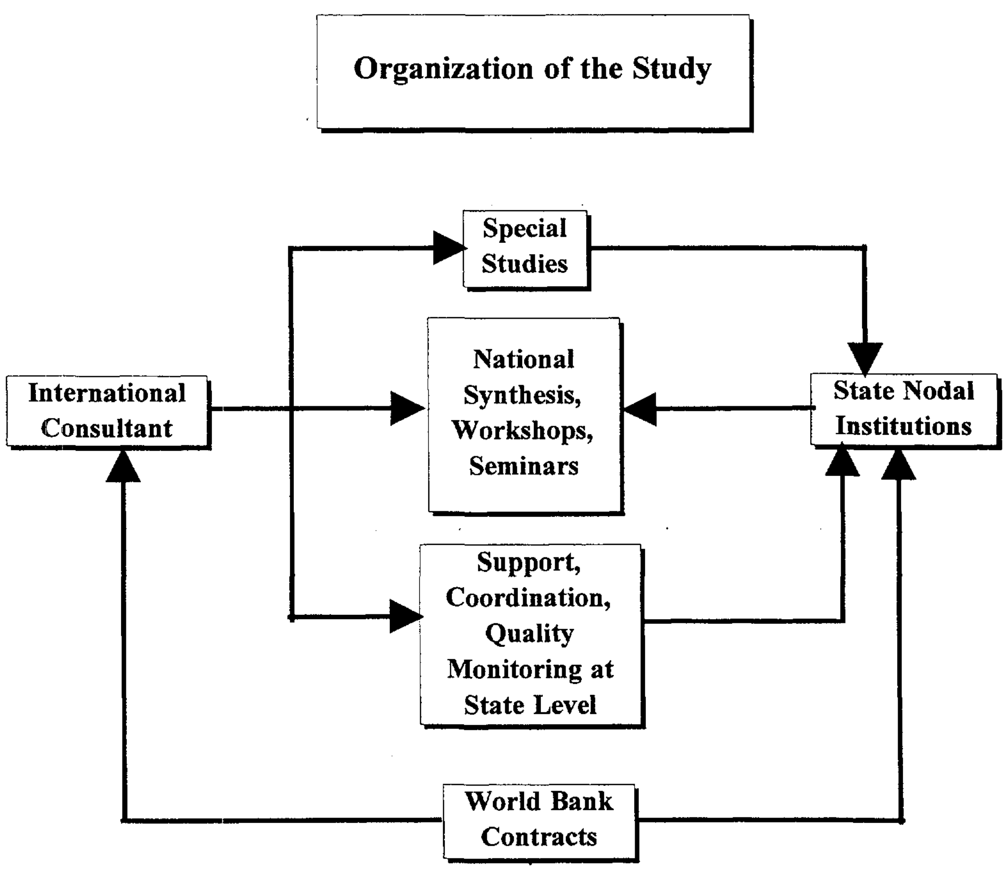
The work of the international consultant will be conducted within the management framework of the overall study, as shown in Figure 2. The Administrative Staff College of India (ASCI) and the Sone Command Area Development Agency (SCADA) will prepare the case studies for Andhra Pradesh and Bihar respectively The international consultant is responsible for the following major work elements:

- Conducting special studies of a cross cutting nature, to serve as inputs to the state case studies and the national synthesis;
- Supporting ASCI and SCADA in carrying out the state-level case studies, ensuring consistency and comparability of output, data and methodology, and coordinating and monitoring the quality of their work;
- Preparing the national synthesis;
- Organizing and conducting workshops and seminars;
- Designing and administering a "Decision-Making and Power Sector Planning Process Questionnaire";
- Managing the selection of the power systems planning model; and
- Facilitating the peer review of the case studies and national synthesis.

These elements are described in more detail in Section 4.

Although ASCI and SCADA are responsible for the state-level case studies, special importance is given in these terms of reference to the technical assistance role of the international consultant in supporting ASCI and SCADA. A substantial portion of the resources of the international consultant will be given to the installation and testing of planning, financial and environmental models, which will permit a more effective evaluation of power system development in India, taking into account both environmental and financial, as well as social and economic considerations; and to training ASCI and SCADA in the use of these models. Aside from the importance of this role to the study itself, the long-term goal of the study is to put in place a planning capability in the states and central government. Furthermore, the international consultant must ensure the effective dissemination of the results of the work; and make every effort to promote a better communication and dialogue with and between the main parties involved in the study or affected by power system development and coal mining in India. Such communication and dialogue is especially critical at the central government level; and between NGOs and officials handling power system planning in the states and central government.

Figure 2



4. Description of Services to be Provided

The international consultant shall provide the following services:

4.1 Conduct Special Studies

In order to fill gaps in available data and information, the consultant will conduct a number of special studies on cross-cutting issues and options which could be applied to reducing environmental externalities. The findings of these special studies will feed into the state case studies and the national synthesis. The special studies will draw upon the many related studies on environmental issues in the power sector that have recently been completed. Technical, economic, social and institutional constraints and opportunities will be assessed to define and evaluate options that could be applied to reduce environmental impacts. It will be the responsibility of the consultant to ensure that on-going work is properly reflected in these special studies (see Section 1.4 above for a list of other activities). The consultant will be responsible for determining what cross-cutting studies are necessary, in consultation with the state-level steering committees, the World Bank and ODA; but the final balance that should be struck with respect to the level of resources required for each special study relative to each state will be based upon the outcome of the Inception Seminar (see Section 4.4). The special studies are likely to include:

- Electric power pricing. An important factor underlying the efficiency of use of electric power in India is the existing power pricing policy. A study based upon an econometric analysis of electricity demand, addressing price elasticity and analyzing the impacts associated with alternative pricing reforms, is therefore proposed. This study would, *inter alia*, review the literature on price elasticity and inter-fuel substitution studies for India, conduct any necessary additional econometric analyses from available data series, and provide the state case studies with estimates of price elasticity of demand and the elasticity of substitution between fuels, to be used for modeling.

- Demand-side management. A study would be undertaken to consider the scope for increasing end-use efficiency and realistic ways to achieve this potential. This study would incorporate a review of assumptions underlying the market potential for equipment that improves the efficient use of electricity. Notably, this special study of DSM should: (i) draw on actual experience in India and elsewhere in Asia; (ii) analyze the sustainability of DSM implementation programs, in terms of the economic and financial incentives they provide; (iii) address the role of private-sector energy supply companies (ESCOMs), as well as programs sponsored by the state electricity boards and other utilities; and (iv) incorporate fully the costs of the implementing agency. Furthermore, estimates of market penetration should allow for the significant changes to tax incentives and import duties on energy efficient equipment and pollution control equipment, which have occurred since 1991. The work of the international consultant on DSM should result in the construction of a supply curve for DSM measures.

- Inter-fuel substitution. A range of inter-fuel substitution options would be considered. Some of these are likely to lead to "win-win" solutions, which are both economically and environmentally sound, while others (e.g. hydroelectric power, the use of gas and imported fuels) may involve trade-offs between economic, environmental, social and institutional factors. As an extension to the study, an analysis would also be carried out, to give some rough estimates of the extent to which fuelwood depletion can be moderated, through the use of alternative energy sources in rural households in India.

- Mitigation options at power plants (technology options). A range of technological options to mitigate the environmental impacts of coal-fired power generation would be examined. These would include traditional "end-of-pipe" pollution control options as well as available "clean-coal" technologies. Recent developments in clean coal technology should be reviewed, internationally as well as in India itself, distinguishing between developed and developing countries; and technology characterizations prepared for a selected number of “clean-coal” technology options to be used for the state case studies. These characterizations should include estimates of cost, dates of commercial-scale availability, and technical and environmental performance. The study would analyze the power sector’s "willingness to pay" for different options, in order to reflect the financial and economic costs associated with improved fuel quality.

- Economic instruments for pollution control. The study would assess the scope for using market-based instruments in addition to regulatory approaches, in order to meet environmental objectives.

- Institutional and managerial reforms. The study would consider factors underlying existing plant inefficiencies, the potential introduction of incentives to bring about reforms in the power sector, and the impacts associated with increased "commercialization". It would also examine the institutional implications of a more environmentally focused approach to power generation.

- Power plant siting policies. This study would assess, in broad terms, the environmental impacts associated with aggregated, as opposed to disaggregated power and coal developments.

- Social implications. Some of the options for dealing with the environmental impacts of power generation could have adverse social impacts, at least in the short term. For example, the plight of the poor could be exacerbated by enforcement of the "polluter pays principle" (without regard to ability to pay), the impact of alternative electricity pricing reforms and job losses due to technology changes. These issues will be identified and addressed in this study, along with the environmental benefits that could accrue to poorer groups, to ensure that they are incorporated into the overall constraints analysis of options available.

- Renewable energy options. This study would include technology characterizations and costs for renewable energy options and review the significant amount of information available from renewable energy projects in India and elsewhere. An attempt would be made to quantify the long-term energy potential that is economically feasible for the different renewable energy options.

- Mitigation options in coal mining. The study would provide generic characterizations of mitigation options in coal mining and generic cost estimates, to supplement the specific local data gathered by SCADA and ASCI. The study would analyze the large body of information in recent studies which has been compiled on this subject in India and elsewhere.

In the case of ash management, disposal and utilization, the international consultant is expected to rely on the results of a special study which is being implemented independently, by Canadian consultants, with funding from the Canadian Trust Fund for the Environment. The terms of reference are in Annex IV.

In agreement with the World Bank, it is expected that the consultant will subcontract work for some of these special studies to local Indian consultants and specialized Indian institutions, with expertise relevant to the study, to the extent possible. The international consultant will be expected to prepare detailed terms of reference for such subcontracting and agree them with the World Bank.

The consultant will supervise these special studies, and ensure that they meet the requirements for data and information of both the state-level studies and the national synthesis.

The special studies described here are the ones that might reasonably be considered necessary. However, the consultant is free to make suggestions for studies of other topics of a cross-cutting nature in his proposal, or to demonstrate that one of the above studies is not necessary because an in-house capability already exists. Moreover, if the consultant teams with an Indian institution, that teaming partner may also have the necessary capability in-house.

4.2 Support the State-level Case Studies

The consultant shall provide support to the two state-level case studies. The draft terms of reference for these case studies are in Annexes II and III. This support shall consist of the following elements:

- Assist ASCI and SCADA with the development of demand forecasting models.

- Supply, install and help test a generic power systems planning model, and provide the necessary "on-the-job" training to ASCI and SCADA to run it. As part of this training responsibility, the international consultant will advise ASCI and SCADA on the data requirements for the model and appropriate data collection methods; as well as the identification of relevant options for power system development. The primary purpose of the state case studies will be to develop the generic planning model to offer practical selection between different options for power sector expansion; and to allow decision-makers to assess explicitly the trade-offs between environmental protection and power generation.

- Advise ASCI and SCADA on the development of a coal model. This is expected to be a relatively simple spreadsheet, that will map plant-by-plant coal requirements to coal mines for the purpose of estimating the environmental impacts associated with coal mining. The initial output of this model will be a mine-by-mine forecast of coal output as a function of the generation plan forecast by the supply model.

- Advise ASCI and SCADA on the selection of an appropriate air quality model or the adaptation and upgrading of models which are already being used in A.P. and Bihar. The model must be able to translate emissions from major generating stations into changes in ambient concentrations. The model should be suitable for the type of meteorological data actually available in the states in question.[1]

- Supply and install a financial model for use in the study and provide the necessary "on-the-job" training to run it. Such a model must be able to examine the tariff implications of alternative policy options. In particular, it must have the capability of determining tariff levels, given: (i) the program of investments as determined from the least-cost system planning model; (ii) a set of balance sheet ratios that must be met (e.g. minimum rates of

1 For example, simple Gaussian plume-type models have been used by the engineering consultants who prepared recent environmental impact statements for major coal generating stations in both A.P. and Bihar, e.g. by Vimta Labs for Krishnapatnam; by IIT for the 2 x 210 Rayalaseema expansion Stage II; and by Vimta Labs for the Ramagundam extension (see Annexes II and III).

return on assets, equity, self financing ratios, etc., as typically set forth in covenants with multilateral institutions); and (iii) assumptions about other financial variables (depreciation rates, treatment of construction work in progress etc.). The financial model must also be linked to the demand forecasting model in order to determine the impacts of tariff reforms. As an example, the financial model could be based on the financial spreadsheet model developed by APSEB under the auspices of a USAID-funded project, which has as its main objective the preparation of an integrated resource plan (IRP) for A.P. The model will be made available to ASCI and SCADA. However, the consultant may propose an alternative financial model. The model will be used to estimate the impact of each option on tariffs.

- Assist ASCI and SCADA in: (i) defining appropriate policy options and scenarios to be used in the case studies; (ii) using the system planning model to conduct the scenario and multi-attribute analysis; and (iii) defining a set of environmental constraints to be used as an alternative to the existing Indian regulations, standards and objectives.

4.3 Prepare a National Synthesis

The consultant shall be responsible for the national synthesis, whose objectives are elaborated in the Overall Study Terms of Reference (Annex I).

It is expected that, in order to conduct this national synthesis successfully, and meet the overall study objectives, the consultant will:

- Appoint a full-time technical study director, resident in India;

- Establish a national study secretariat to house the study director and appropriate staff. It is expected that this national study secretariat will be located in Delhi;

- Appoint from the consultant's existing staff a study manager, who will be responsible for all of the administrative and contractual aspects of the work, and who will serve as the principal interface with the World Bank on contractual matters; and

- Interview and administer a pre-prepared questionnaire, prior to the Inception Workshop, to a range of key officials, including, *inter alia*, the Department of Economic Affairs (DEA), MoP/EMC, Ministry of Coal (MoC), Ministry of Environment and Forests (MoEF), Ministry of Non-Conventional Energy Sources (MNES), NGOs, ODA and the World Bank.

4.4 Organize and Conduct Workshops and Seminars

The consultant will organize and conduct the following workshops and seminars, all to be held in Delhi:

- An Inception Seminar, to take place within four to six weeks of the start of work. The aim of the inception seminar, which should last one or at most two days, is to consult and engage the involvement of a wide range of interested parties, in order to ensure that the planning model is relevant and appropriate to Indian needs. To the extent possible, a broad consensus should be reached with all the main groups, during the Inception Seminar, on the objectives and methodology of the study. There should be no more than 30 participants. They are expected to include, but may not be confined to, representatives of the case study states (e.g. ASCI, SCADA, the state Secretaries of Energy and Environment, the state Pollution Control Boards, and the state Electricity Boards), NGOs (including key ones that have previously made representations to GoI and donor agencies on power-related environmental issues), MoP/EMC, DEA, MoC, MoEF, MNES, the Central Pollution Control Board, leading academic and research institutions with recognized expertise in the fields of energy and the environment (e.g. the Tata Energy Research Institute and the Indira Gandhi Institute of Development Research), electric power consumer groups, private sector parties that are potential investors in the electric power sector, ODA, and the World Bank. Consensus is required to be achieved at the Inception Seminar concerning the activities and outputs to be derived from the case studies and the special studies and the timetable for completion of those studies. It is essential that, during the Inception Seminar, the directors of the case studies reach general agreement on information transfer between the two states, internal project management and reporting details. Furthermore, based on the debate within the Inception Seminar, the international consultant will advise on the balance that should be struck with respect to the level of resources required for each special study with regard to each state, and if appropriate, permission to reallocate funds within the overall special studies budget should be sought from the World Bank.

- A Technical Workshop, to be held within four to six weeks of the Inception Seminar. The intention of the Technical Workshop is to discuss progress with regard to the proposed methodology and modeling. The number of participants should not exceed 15, including representatives of the international consultant, the case-study states, the World Bank, ODA, NGOs and other recognized institutions with expertise in the field of energy and the environment.

- A Mid-way Workshop, to be held as soon as preliminary drafts of the state-level case studies are available (i.e. roughly one year after the start of work). The purpose of the Mid-way Workshop, which should last two days, is to review progress and the technical issues arising from the studies; as well as to give the international consultant feedback on results, to assist with the preparation of the national synthesis. The participants are expected to include, but may not be confined to, representatives of the case study states, NGOs, MoP/EMC, DEA, MoC, MoEF, MNES, the Central Pollution Control Board, leading academic and research institutions with recognized expertise in the fields of energy and the environment, ODA, and the World Bank.

- A Decision-makers' Workshop, to be held after the state-level case studies and a draft national synthesis have been prepared (i.e. roughly 18 months after the start of work). The goal of the Decision-makers' Workshop will be to discuss the preliminary findings of the study, to bring the recommendations to the attention of key decision-makers and to encourage adoption of the planning model as national policy. Hence, participation will be much more targeted than the Inception Seminar and the Mid-way Workshop, comprising (inter alia) the state Secretaries of Energy and Environment, the state Pollution Control Boards, the state Electricity Boards, NGOs, MoP/EMC, DEA, MoC, MoEF, MNES, and the Central Pollution Control Board. ASCI, SCADA, ODA and the World Bank would also be expected to take part. At the Workshop, the case study directors and the international consultant will present the computer models, products and findings of the study to date. The key decision-makers comments and reactions shall be considered and taken into account when the Final National Synthesis Report is prepared. The latter shall include detailed proposals on how its findings and recommendations should be incorporated into the formal power sector planning process.

4.5 Design and Administer a "Decision-Making and Power Sector Planning Process Questionnaire"

It is considered essential that, prior to commencement of the case studies, agreement be reached between all relevant parties concerning the major outputs, purpose and goal of the project. This process is to be formalized through: (i) research and enquiry by the international consultant; (ii) the subsequent design of a short "Decision-Making and Power Sector Planning Process Questionnaire", which will be administered through a mixture of postal enquiry and structured personal interview with key central and state government officials, case study institution representatives, NGOs, ODA, the World Bank and potential beneficiaries; and (iii) a study Inception Seminar. The international consultant will collate and analyze the information gathered in the steps (i) and (ii) and use it to prepare a summary of stated priority interests and concerns. The international consultant will, *inter alia*, use the results of the Questionnaire to prepare the agenda for the Inception Seminar.

4.6 Manage the Selection of the Power Systems Planning Model

The information gathered in steps (i) and (ii) in Section 4.5 will also be used to prepare a shortlist of appropriate generic power systems planning computer models, the final selection and use of which must be agreed with study participants at the study Inception Seminar. In preparing the shortlist, the consultant should bear in mind that the states included in the study must have free access to the selected model during and also after completion of the study; and that other states not included in the study that wish to take advantage of the model as a planning tool also should have free access to the model. Hence, the process for selecting the model should be managed to satisfy the following criteria: (i) the selected model shall be available to any state after completion of the study for use in power system planning, without additional cost to the users; (ii) the selected model must be commensurate with the data likely to be available; (iii) the selected model must be compatible with the likely analytical capabilities of the staff of the respective institutions, recognizing the extent to which that capability will have been enhanced by the training and technical assistance provided as an objective of the study; (iv) the selected model must have an optimization capability, so that least-cost solutions for power system development can be identified; and (v) the selected model must be able to optimize subject to environmental variables and constraints. The final selection of the power systems planning model must be agreed with the Bank and ODA.

4.7 Facilitate the Peer Review of the Case Studies and National Synthesis

In consultation with the World Bank, ODA and GoI, the consultants will facilitate a series of "peer reviews" for the state-level case studies and the national synthesis. Specifically, the consultants will assist in identifying suitable local and international experts and interested NGOs to serve as Peer Reviewers; and in preparing their draft terms of reference. The Peer Reviewers will then be appointed by the World Bank, under terms of reference finalized in consultation with ODA and GoI.

5. Teaming Arrangements

The consultant is free to propose teaming arrangements with other international consultants, or with Indian institutions, particularly if such teaming partners have strengths in one or more of the special study areas.

Where teaming arrangements are proposed, the consultant must clearly indicate his management plan, and identify individuals in each partner institution who will be responsible for specific tasks. The ultimate responsibility for the quality and deliverability of output, however, will lie with the international consultant, who will contract with the World Bank.

6. Coordination, Reporting Requirements and Progress Meetings

Recognizing that the principal objective of the overall study is the preparation of a national synthesis that is grounded in the detailed results of the individual state case studies, great importance will be placed on coordination between the case study directors and the national study director.

In order to facilitate communication and coordination between all of the parties involved in the study, and in particular to keep the national study secretariat abreast of issues and problems likely to affect its ability to prepare a national synthesis, timely progress reporting and review meetings are an essential part of the study. The reporting requirements are as follows:

6.1. Quarterly Progress Reports

A quarterly progress report will be prepared for the World Bank, copied to ODA, with the following elements:

- Technical sections, indicating progress achieved in meeting the study's objectives for the quarter, identifying any points of weakness and (where appropriate) recommending changes in the study's activities/inputs;
- Discussion of objectives for the following quarter, with particular emphasis on any problems or constraints that may be faced in meeting the proposed schedule; and
- A budget report, showing actual versus planned expenditures.

These Quarterly Progress Reports will be submitted to the World Bank. They are expected to be succinct documents (5-10 pages), designed primarily as a management tool, rather than as a vehicle for communicating actual technical results.

6.2 Review Meetings

Review meetings will be held with the two state case study directors in Delhi, probably on at least four occasions. These meetings will be also be attended by whatever senior technical staff may be deemed appropriate. The timing of these meetings will be determined by the international consultant, in consultation with the state case study directors, and will generally be attended by ODA and the World Bank study team. These review meetings will typically be of two days duration, and will have the following general agenda (to be modified as appropriate by the National Study Director):

- Progress reports by state case study directors;
- Progress reports by consultants in charge of special studies; and

- Progress report by the National Study Director.

At the Inception Seminar, it is expected that all of the study directors will agree upon a common word processing software format for the exchange of documents and reports.

7. Schedule

The master schedules for the study are in Tables 1-3. It will be the responsibility of the international consultant to coordinate carefully the timing of the main components of the overall study (Tables 1 and 2). The special studies (Table 3) must be completed in time to serve as inputs for the state case studies.

8. Outputs

The deliverables are as follows:

8.1 The National Synthesis Report

A detailed technical report on the national synthesis, with an appropriate executive summary of no more than 30 pages, and technical annexes as appropriate, constitutes the principal deliverable. The schedule for this deliverable is in Table 2.

The final report shall be prepared in a format suitable for international distribution. The budget should provide for the preparation of 100 copies of the final report.

8.2 Workshops

The consultant will conduct the workshops as described under task 4.4, above.

The international consultant will prepare, in advance of each workshop, a set of appropriate workshop materials, including copies of papers to be presented at the workshop.

Table 1: Master Schedule for Overall Study Workshops and Seminars (National Synthesis)

Event	Date
Initial Questionnaire	6/96
Inception Seminar/Selection of Computer Model	7/96
Technical Workshop	10/96
Mid-Way Workshop	4/97
Decision-Makers Workshop	11/97

Table 2: Master Schedule for Case Studies and National Synthesis

	Initiate Work	First Draft Report	Final Draft Report
A.P. Case Study	7/96	12/96	6/97
Bihar Case Study	7/96	1/97	6/97
National Synthesis	5/96	11/97	1/98

Table 3: Master Schedule for Special Studies

Study	Initiate	Report
Electric Power Pricing	5/96	9/96
Demand-Side Management	5/96	9/96
Inter-Fuel Substitution	5/96	9/96
Economic Instruments for Pollution Control	5/96	9/96
Institutional and Managerial Reforms	5/96	9/96
Power Plant Siting Policies	5/96	9/96
Social Implications	5/96	9/96
Renewable Energy Options	5/96	9/96
Ash Pond Management/Ash Disposal/Ash Utilization	10/95	6/96
Power Plants Mitigation Costs	5/96	9/96
Coal Mining Mitigation Costs	5/96	9/96

INDIA: ENVIRONMENTAL ISSUES IN THE POWER SECTOR

Overall Study Terms of Reference

Motivation

1. The goal of the study is to reduce the adverse impact on the environment of power generation in India. The principal purpose is to improve environmental planning, management and decision-making in power generation. The key output will be development of a decision-making tool, which would enable government officials and institutions in India to evaluate alternative options for power development. The evaluation would use a power systems planning model to take explicit account of the environmental impacts, as well as the financial and economic implications. The central hypothesis of the study is that the development of the electric power sector in India will continue to emphasize the coal option for some years to come, although other options will not be excluded. The study will, therefore, first identify the main environmental effects related to the expansion of electricity generation from coal, including the environmental externalities and costs caused by the associated increase in the production of coal. In particular, the study will examine the impact on air, land and water. The study will also assess the relative environmental costs associated with alternative fuels. On the basis of the identified environmental effects, the study will put together a menu of options, to mitigate those effects. To serve as a decision-making tool, the results of the model must be presented in a way which facilitates a practical selection between the options. To the fullest extent possible, the options must be comparable: the model tackles comparability by requiring that, wherever feasible, each option meet the existing environmental regulations, standards and objectives established by the central and state governments. Where environmental impacts are different, for example because some environmental dimensions may not be addressed, at least in a quantifiable way, under the existing environmental regulations, standards and objectives, the quantitative analysis, supplemented by any necessary qualitative information, will be presented in a way that allows decision-makers in India to assess more explicitly the trade-offs involved between the options. While the power sector is the main focus of the study, the coal sector will be dealt with to the extent required to assess the environmental implications of alternative power sector policies.

2. The implementation of the study is to be seen as a step in a process. Indian officials and experts are to play an integral part in the work, in order to create the basic conditions for replicability. By successfully establishing a process, implementation of the study will assist with institution-building and help to create a better capacity to incorporate routinely the environmental effects of energy policy in the decision-making process. Furthermore, to be effective as a decision-making device for the Government of India (GOI), prominence must be given to the financial effects of the policy options, for example on the state electricity boards (SEBs).

Background

3. Environmental issues in the power sector are of major importance in India, due first to the significance of electric power in the economic development process: during the 1980s, GDP grew at an annual rate of about 5%, whereas electricity use was increasing at nearly 9% annually. Second, within the power sector, coal is by far the most important single source of fuel: about 70% of power generation is coal-based. Third, the environmental impacts of power production in general, but especially coal-based production in particular, are serious, in terms of human health and well-being. The expansion of coal-based power generation affects air, land and water resources. Air pollution is a high-priority concern, because of the health consequences, and the study will examine the contribution of coal-fired power generation to emissions of particulate matter (PM), sulphur dioxide (SO_2) and oxides of nitrogen (NO_x), as well as to air quality. The accumulation of ash at power station sites preempts land and endangers both ground and surface water. If additional coal is burned, the associated increase in coal production can degrade more land, deplete water resources and cause water pollution: the study will analyze these backward linkages with the coal sector, to consider their impact in relation to existing environmental standards. Specifically, to compare options adequately, a provision for the environmental cost of coal mining (based on existing environmental standards) needs to be included in the cost of power. However, the questions of mine safety and coal fires will not be addressed. The study considers the environmental effects of hydroelectric power, hydrocarbons, biomass and nuclear power only selectively, to the extent that they are relevant in the context of inter-fuel substitution.

4. The role of SO_2 in acid rain formation is an important issue in many Asian countries. While coal-based thermal power generation is responsible for an estimated 55% of all SO_2 emissions in India, the low sulphur content of Indian coals (0.5%) implies that acid rain is not a high-priority issue in India at the international or inter-regional level, although some more localized effects are a cause for concern. For example, the preliminary results of the RAINS Asia project show China, Korea, Japan, Thailand and Malaysia to be the areas that suffer the most significant sulphur deposition rates; and India does not figure prominently in the critical loads assessment. In India, the highest deposition rates occur in the eastern states (Bihar, Orissa, and West Bengal), which appear to be areas least sensitive to acid rain impacts. Nevertheless, the study should give limited attention to the impact of acid rain on forestry and rain-fed agriculture in the case-study states; and most of the options likely to be considered will decrease SO_2 emissions.

5. Emissions of carbon dioxide (CO_2) do not contribute to air pollution, although they are an important factor in global warming. India is one of the leading sources of world-wide CO_2 emissions in absolute terms, but on a *per capita* basis its contribution is relatively insignificant. Given this fact, and India's low standard of living, it would not be reasonable to expect India to incur additional costs to alleviate global warming, without compensation from richer countries. Accordingly, the study should estimate the magnitude of the incremental costs which could be necessary if India were to pursue

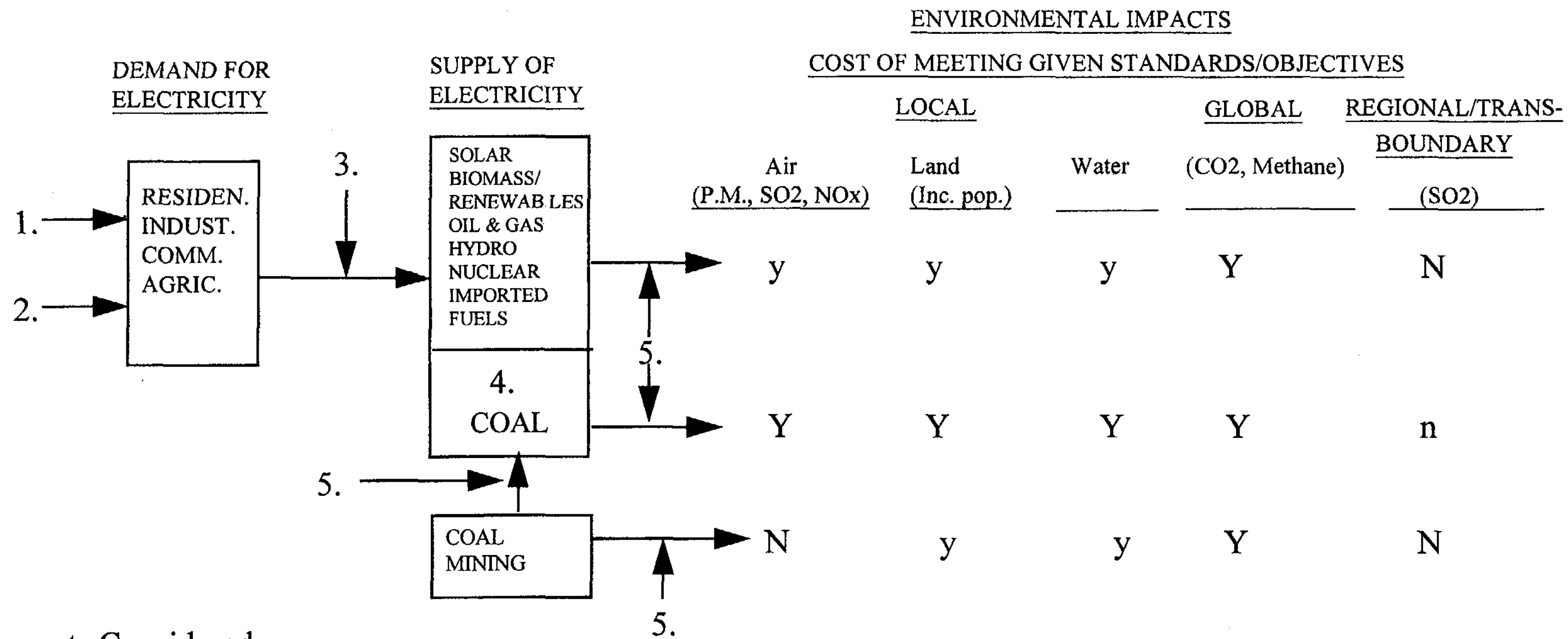
explicit objectives for reducing or stabilizing the emissions of greenhouse gases (GHG). The numerical results should help in defining the possible nature and scale of contributions to India from the global environment facility (GEF). Of course, as in the case of SO_2, many of the options likely to be considered will also decrease GHG emissions.

6. The consumption of electricity in India is expected to continue to expand, due to the link with economic and social development. Under the assumption of robust economic growth, increasing population and rising *per capita* income, the growth rate could be in the order of 7%-9% p.a. in the short- to medium-term, which would mean a doubling from the 1990 level by the year 2000. With such increases in electric power production and consumption, it is not unreasonable to anticipate substantial growth in the emissions of PM, SO_2, NO_x, and CO_2; deterioration of air quality; the accumulation of ash at power station sites; and an increase in the amount of coal required by the power sector, along with the concomitant environmental and social impacts. Although one of the problems facing the study will be the forecasting of these consequences, all emissions and ash production are likely to double at power stations by the year 2000.

Options

7. The study is expected to examine a broad number of options for reducing the environmental impacts of the expansion of electricity generation from coal. For example, it should cover "win-win" approaches, in which the measures are economically justified and also have environmental benefits; policy instruments, which induce the power sector to take into account the environmental effects of its actions, by "internalizing the externalities"; and institutional and managerial reforms in the power sector, which typically take effect through the other options. The study will not confine itself to "end-of-pipe" options for pollution mitigation, but will also examine (within the framework of the power system) the potential role of policies, institutional strengthening, improved management practices, clean coal technologies and improved efficiency. In working through these options, the study must constantly keep in mind the fact that the specific measures available to address national and global environmental concerns ultimately are local; and that many of the most important ones have to be implemented at the state-level. A schematic representation of the environmental impacts and the main options to be considered in the study is in Fig. 1.

Fig. 1: Schematic for Options and Environmental Issues in the Power Sector



Impacts Considered

Y=YES y=YES, but selective only, to get rough estimate of impact on cost of electricity per kWh
N=NO n=Not covered in modelling but implication for forestry and rain-fed agriculture considered
P.M.=Particulate Matter SO_2=Sulphur Dioxide NO_x=Nitrogen Oxide CO_2=Carbon Dioxide

Options Considered

1. Electric Power Pricing
2. DSM (inc. environmental taxes)
3. Efficiency in Supply (maintenance of equipment, T&D losses), Institutional and Managerial Reform, Regional Interconnections
4. Inter-fuel substitution, including the effect of economic instruments on fuel choice. Analysis to be extended outside modelling to consider energy options in moderating fuelwood depletion
5. Technology mitigation options (coal beneficiation, ash disposal, clean coal technologies, IGCC and AFBC technologies, resettlement, compensation, land restoration, power plant siting, sulphur control, particulate control)

Electric Power Pricing

8. A precondition for improving the efficiency of use of electric power in India is undoubtedly pricing policy reform: serious distortions exist in both the levels and structures of electricity tariffs. A key element in quantifying the relationship between pricing policy and the environment is the price elasticity of demand, so that existing estimates of price elasticity will need to be studied and updated. While many states have increased the average level of tariffs over the past few years, in an attempt to ease their cash-flow problems, distortions in structure have been perpetuated or even worsened. In analyzing the impact of alternative pricing reforms, special attention should be paid to implementation issues. Clearly, it is unrealistic to suppose that the low agricultural tariffs, for example, can be brought to the level of long-run marginal cost (LRMC) overnight. However, farmers may well be prepared to countenance tariff increases, provided they can be assured of better quality power.

Demand Side Management (DSM)

9. Several recent studies point to the significant potential for more efficient utilization of electricity in India, although the market penetration assumptions made for these technologies often seem highly questionable. The study will consider both the scope for increasing end-use energy efficiency, and realistic ways to realize that potential. Notably, the DSM component of the study should: draw on actual experience in India, e.g. the DSM program in Bombay, and elsewhere in Asia; analyze the sustainability of DSM implementation programs, in terms of the economic and financial incentives they provide; address the role of private-sector energy supply companies (ESCOMs), as well as programs sponsored by the state electricity boards and other utilities; and incorporate fully the costs of the implementing agency. Furthermore, estimates of market penetration should allow for the significant changes to tax incentives and import duties on energy efficient equipment and pollution control equipment, which have occurred since 1991.

Inter-Fuel Substitution

10. A range of inter-fuel substitution options will be considered, to decrease the environmental impacts associated with fuel use in the power sector. Some options may be of the "win-win" variety, but in general, they are likely to incur higher costs and different environmental consequences, so that trade-offs will have be analyzed. Hence, the capital and operating costs of the options must be placed on a comparable basis in economic as well as financial terms, e.g. by adjusting the market prices of key fuels (oil, gas, LNG, imported coal, domestic coal, etc.) to reflect shadow prices.

11. Conventional hydroelectric power is a potentially important alternative to coal-based generating stations in India, and in most states hydroelectric resources have not been fully exploited. Increasing the share of hydroelectricity is a major policy objective

of the GOI. While it will not be possible, within the context of this study, to conduct a detailed analysis of the resettlement and environmental issues that may arise in accelerating hydroelectric projects, basic indicators of impact should be tabulated (probable number of people to be resettled, approximate cost of meeting current resettlement and rehabilitation standards, loss of forest, etc.), and set against the coal-related impacts avoided.

12. The penetration of imported fuels could also have a significant impact on power sector emissions, since imported coal, oil, LNG and gas have lower air emissions and less ash. An important factor in this context will be the ability of foreign private power developers to obtain permission to use imported fuels.

13. It is widely recognized that substituting gas-fired generation for generation based on domestic coal would have a strongly beneficial impact on emissions, especially in urban areas. However, the environmental opportunity cost of using gas for power generation must also be recognized, to the extent that additional allocations of gas for power generation reduce supplies available to other sectors.

14. Nuclear power is a feasible but controversial alternative to coal in India. While an examination of the radiological risk, waste disposal and decommissioning issues associated with nuclear power lies outside the scope of this study, the substitution of nuclear energy for coal serves as a yardstick for comparing the cost-effectiveness of other options for reducing coal-related environmental impacts: nuclear energy may incur the highest system cost, but with the lowest environmental impact for all non-radiological impact attributes.

15. While the last version of the national power plan, prepared by the Central Electricity Authority (CEA), noted the ambitious targets established by the Ministry of Non-Conventional Energy Sources (MNES) for renewable energy sources, such options were not included in the supply plan. The study will assume that these resources are available to the expansion plan and constrain the optimization model to accept them, if they do not enter the least-cost solution. It is likely that the attainment of targets for solar and wind energy, mini-hydro etc. will be a function of the ability to attract private investors: the package being offered by the Tamil Nadu Energy Development Agency, in an attempt to develop a series of wind projects, is a case in point. Similarly, the commercialization of bagasse for supply to the main grid will depend on bulk pricing arrangements. As an extension to the study, an analysis should also be carried out, to give some rough estimates of the extent to which fuelwood depletion can be moderated, through the use of alternative energy sources in rural households.

Technology Options

16. The study will examine a range of technological options to mitigate the environmental impacts of fossil fuels used for power generation. For this purpose, it is

necessary to analyze the effect of alternative energy price structures on technical choice. A useful analytical approach will be to identify the power sector's "willingness to pay" for different energy sources, to reflect the impact of fuel quality on the financial and economic costs (e.g. through heat value, ash content and sulphur content).

17. It has long been recognized that beneficiated coal could bring economic and environmental benefits, and over the past decade a number of studies have been executed, including field tests. While the proponents of coal beneficiation have tended to stress the economic benefits, the field trials point to major environmental benefits as well, in terms of the improvement in the efficiency of electrostatic precipitators (ESPs), and a reduction in their failure rates.

18. Despite the low sulphur content of Indian coal, and the priority given to particulate rather than SO_2 emissions control, large new thermal plants are obliged to set aside sufficient land to permit flue gas desulphurization systems (FGD) to be installed . In a number of recent cases, environmental clearance has mandated an FGD system, e.g. for unit 7 of Chandrapur. Other options for SO_2 control may be more cost-effective, and the study should quantify the costs of FGD in comparison with alternatives for SO_2 reduction.

19. Considerable quantities of ash are already being utilized by a variety of industries. Improvements in ash utilization are likely to be highly site-specific. Moreover, conducting market surveys to examine the potential utilization goes beyond the scope of the study. However, there should be sufficient information at the SEB level for the study to develop scenarios for increased ash utilization, and to estimate the possible impact on the reduction of ash disposal problems and economics.

20. The possibility of applying clean coal technology in India has been discussed for some time. Several technologies are particularly well suited, in principle, to low quality coals. For example, there is now discussion of integrated coal gasification-combined cycle (IGCC) technology; and atmospheric fluidized bed combustion (AFBC) technology is under development.

Economic Instruments for Pollution Control

21. The scope for using market-based instruments (MBIs) to achieve environmental objectives at lower total cost than purely regulatory approaches has been well studied in the literature; and some important lessons have been drawn from the practical experience to date. The study should include the following typical MBIs in the range of options: emissions taxes (on PM, SO_2, and NO_x); and trading among firms in the right to exceed legal emissions limits. A particularly challenging aspect will be to allow for institutional obstacles and costs.

Institutional and Managerial Reforms in the Power Sector

22. Improving the efficiency of electricity supply presents an important opportunity for reducing the environmental impacts of coal utilization. For example, average transmission and distribution losses have increased over the past decade, although there are serious problems in measuring such losses, and the record varies widely across SEBs. Similarly, Indian coal-fired power plants have low heat rates, due to poor and inconsistent coal quality, as well as management inefficiency. However, it may be difficult to identify statistically the main factors which explain plant inefficiency, since it is caused by more than coal quality and ownership: age and size of plant, the difference between current and design heat rates, and the variation in coal quality will be additional factors. Furthermore, the dispatch of plants is constrained by the lack of sufficient inter-tie capacity between regions and poor grid discipline within regions. Nevertheless, if improved systems operations shifts generation from less efficient to more efficient plants, there are substantial environmental as well as economic benefits.

23. Evidently, incentives will be required to bring about the necessary reforms in the power sector which are a pre-condition for its improved efficiency. Notably, the study should consider the impact of increased private sector participation, competition, and "commercialization" in the power sector (e.g. through hard budget constraints and profit-seeking behavior). Quantifying the impact of such reforms on the environment will be a complex task: it is likely that the effects will be taken into account indirectly, through the use of proxies, such as better plant heat rates, improved load dispatching, and more efficient pricing of electric power. Increasing the role of the private sector has predictable impacts on load dispatch, as a result of take-or-pay provisions contained in the power purchase agreements. While private generators may be high-cost, in financial terms, they will likely displace older coal-fired plants in urban areas, with relatively high emissions.

Power Plant Siting Policy

24. India has increasingly followed a siting strategy for its coal-burning power plants that emphasizes large mine-mouth plants. The share of mine-mouth capacity in the total thermal capacity has increased from 10% in 1985 to 25% in 1991. Many of these plants are also very large, some in excess of 2,000 MW. However, such large concentrations of coal-burning capacity aggravate local environmental impacts. Clearly, one alternative would be a more dispersed siting of plants, accompanied by the construction of a purpose-built rail connection. While expensive, so is the construction of FGD systems. Detailed study of potential power plant sites goes beyond the resources of the study; however, with the participation of local consultants and the SEBs, some alternative strategies, with their cost and environmental impacts, can be examined.

Methodology

General

25. It is considered essential that, prior to commencement of the case studies, agreement be reached between all relevant parties concerning the major outputs, purpose and goal of the project. This process is to be formalized through:

- Research and enquiry by the international consultant;

- The subsequent design of a short "Decision-Making and Power Sector Planning Process Questionnaire", which will be administered through a mixture of postal enquiry and structured personal interview with key central and state government officials, case study institution representatives, NGOs and potential beneficiaries; and

- A study Inception Seminar.

26. The international consultant will collate and analyze the information gathered in the first two steps above and use it to prepare a summary of stated priority interests and concerns, and a shortlist of appropriate computer models, the final selection and use of which must be agreed with study participants at the study Inception Seminar.

27. The major portion of the study will be carried out on the basis of case studies in two states, *viz.* Andhra Pradesh (A.P.) and Bihar. In both states, it will be necessary to identify the relevant environmental objectives; and quantify the costs and environmental impacts associated with each option, by simulating the development of the power generation system and the required coal transport and coal production. In addition to providing an empirical basis for drawing quantitative conclusions about the environmental and cost consequences of broad energy policy options available at the national level, the individual case studies are expected to provide useful information to state officials, to help them in judging energy development strategies, defining pollution mitigation programs, and assessing investments and financial requirements to implement them. The national synthesis and the state-level case studies will be supported by a set of cross-cutting special studies, which will examine subjects with a broader and more generic interest than the individual states.

28. Most of the options can be simulated directly. The policy options related to institutional and managerial reform in the power sector, and the macroeconomic policies affecting demand management will likely be evaluated indirectly, by exploring their implications for improvements in such basic parameters as energy efficiency, system losses etc., using sensitivity analysis. In addition, qualitative analysis of some environmental effects may be necessary.

29. All of the options will be required to satisfy, as far as possible, existing environmental objectives (notably as expressed in ambient air quality, emissions standards and effluent discharge standards). Nevertheless, the study should analyze how sensitive the costs of meeting existing Indian standards are to possible changes, e.g. towards those of the EC or the World Bank guidelines. However, the purpose of the work is more to analyze a range of energy policy options rather than alternative environmental policies, so the study will not attempt to evaluate the benefits of alternative standards. The costs of each option will, of course, incorporate estimates of externalities, such as the social impacts of resettlement under coal and hydroelectric development.

Special Studies

30. A number of special studies will be prepared, as inputs to the national synthesis and the two state-level case studies. These special studies could include but may not be confined to the following:

- An econometric analysis of electricity demand, especially the price elasticity of demand;
- The scope for non-price DSM;
- Economic instruments for pollution control;
- The range of inter-fuel substitution options;
- Institutional and managerial reforms in the power sector, notably their impact on efficiency;
- The social implications of the options for dealing with the environmental impacts of power generation;
- An analysis of different technologies for coal-based power generation, especially "clean-coal" technologies, distinguishing between developed and developing countries;
- Power plant siting policies;
- The prospects for renewable energy options;
- A study for improving the management of ash ponds, the disposal of ash, and ash utilization (especially new uses);
- A review of the costs of mitigating the environmental effects of power generation, in existing as well as new facilities; and

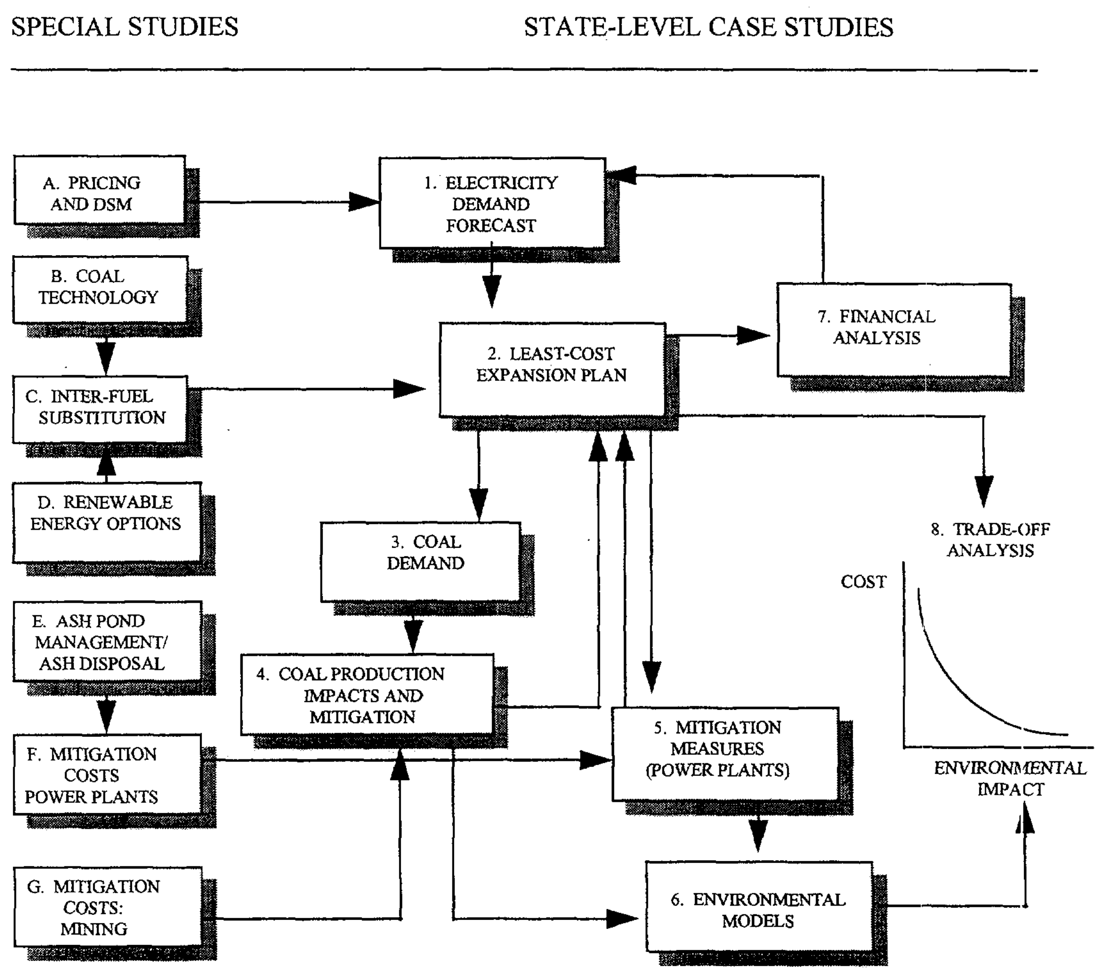
- A review of the costs of mitigating the environmental effects of coal mining.

State-Level Case Studies

31. Figure 2 outlines the proposed methodology for the state-level case studies. The analytical sequence begins with an electricity demand forecast (1), which can provide sensitivity to electricity tariffs as well as to hypotheses about market penetration of energy-efficient equipment. Demand in each major consuming sector will be separately modeled; assumptions about system losses at each voltage level integrated into the analysis; and load shapes synthesized from available data. The proposed special studies on pricing and DSM (A) would represent an important input to step (1). Next, a power system planning model must be developed or adapted from existing software to optimize the generation mix (2), using cost and performance assumptions provided by other studies (notably the special studies B, C and D on coal technology, inter-fuel substitution options and renewable energy options). The power system planning model can be constrained in some runs to select increasing amounts of non-coal resources, and can be made to respond to a wide range of options that follow from alternative power plant siting policies, improved management in the power sector and better plant operation and maintenance. The demand for coal in the power sector (3) is a function of the projected resource mix in power generation, from which in turn the costs of the environmental impacts of coal production and their mitigation can be estimated (4). The impact of alternative fuel input prices on the power sector will be simulated in the power system planning model, including a scenario in which the full social and environmental costs of coal development are included in the coal price. Given the mitigation measures for coal mines and power plants in effect, from steps (4) and (5), power plant emissions and the environmental impacts of coal production are then supplied to environmental models (6), for prediction of environmental impacts. The special studies of ash pond management and ash disposal (E) and the mitigation costs of power plants (F) and mining (G) would provide basic data for steps (4) and (5). The costs of mitigating the environmental effects of producing the coal to supply the power stations, and of power generation itself, can be fed back into the least-cost expansion plan, from steps (4) and (5). In addition to the attributes of direct interest to coal use (PM, NO_x etc.), some environmental attributes associated with non-coal resources will need to be selected, in order to provide a proper comparison of the environmental impacts of coal and non-coal resources. It is expected that the study can make use of existing models for predicting local air quality impacts.

32. The power system planning model provides the supply-side investment requirements for power system expansion, which in turn are given to a financial model of the SEB, for calculation of the financial impacts and the corresponding tariff (7). The projected tariff is then passed back to the demand forecast (1), to close the model. The financial model will permit explicit account to be taken of a wide range of practical issues, including the implementation costs of DSM programs, the financial and financing

Fig. 2: Methodology



Note: The Special Studies shown are illustrative only. For example, the figure does not show the possible Special Studies on economic instruments for pollution control, institutional and managerial reform in the power sector, power plant siting policies and the social impacts of policy options, which are discussed in the text.

implications of the options considered, and the structural changes that result from institutional and managerial reforms in the power sector, e.g. commercialization and an increased role for private enterprise in generation (which has significant tariff impacts).

33. Several specific pricing policy scenarios for electric power will be studied: (i) maintaining the existing tariff; (ii) setting the average tariff at the level required to meet a

typical package of balance sheet ratios; (iii) imposing a strict LRMC tariff; and (iv) adjusting the LRMC tariff to reflect environmental externalities and social objectives. In this way, the trade-off between specific elements of subsidy and the financial and environmental impacts can be clearly identified. In each case, the load forecasts will be adjusted, using the price elasticities of demand (A); and the capacity expansion program recalculated.

34. The social implications of the options may be pervasive and will need to be treated at various points in Figure 2. For example, the impact on the poor of changes in the level and structure of power tariffs can be approached in (1) and (7); as can the incorporation of special affordability provisions, through lifeline rates.

35. The financial model is also one of the mechanisms for quantifying the potential impact of MBIs. Fuel taxes and emissions taxes are readily imposed in the financial model (with feedback to electricity demand through the tariff), while fuel taxes also affect the supply-side resource choices made by the least-cost expansion model. Finally, the trade-off analysis (8) provides the link between the quantitative analysis and the ability to make specific recommendations about priorities and the implementation of programs.

National Synthesis

36. The state case studies, supplemented by the special studies, will provide empirical bases for a national synthesis, which will draw conclusions at the national level about the environmental costs and other implications of energy policy options. A.P. and Bihar offer a good cross-section of the issues and options facing the power sector in India. Bihar's large coal resources and the high degree of dependence of its power sector on coal will permit an in-depth analysis of the environmental impacts of coal mining and coal use in power generation, and of the social and economic costs and benefits of mitigation. A.P., on the other hand, has a wider range of supply options, including hydropower, wind and solar energy, as well as coal. In both states there is ample scope for an analysis of policy options, including improved power pricing and DSM, along with institutional reform and restructuring.

37. For the national synthesis, only selective tabulations of national aggregate emissions will be attempted, based on national projections of coal-fired power generation, because they are of limited value. However, the study will track total emissions of CO_2, SO_2, and PM. Otherwise, different types of options will have to be extrapolated to the national level in different ways. For example, efficient power pricing is likely to emerge as a cost-effective way to minimize environmental impacts per unit of useful energy consumed. The impacts of changes in power prices can be aggregated meaningfully only if tariff simulations are performed in each state. However, if the environmental importance of rational power pricing can be demonstrated quantitatively in two case studies, there is likely to be an adequate basis for general policy recommendations. Similarly, it may be possible to reach more general conclusions about the social

ramifications of the policy options from the case studies, supplemented by the findings of the special study on social implications.

38. A great many of the options are presented at the plant level, but the results of case studies in two states should provide an adequate sample for national extrapolation. The existing database of coal-fired stations, augmented if possible by CEA's database for planned facilities, will then be used to make national-level estimates. The critical step will be to incorporate additional site-specific indicators in the study's database. The task should not be onerous, as there are at most 200 sites. These indicators might include population (in the district in which the plant is located), distance to its coal source, predominant soil type, and air quality: the exact definition of the variables to be used will emerge from the case studies.

Organization of the Study

39. The study will be organized to give as much 'ownership' as possible to the Indian authorities. Appropriate Indian agencies and specialized institutions, with expertise relevant to the study, will therefore be identified, which can contract, to the extent possible, with the international and local consultants involved with carrying out the state-level case studies and the national synthesis.

Outputs

40. The outputs from the study can be classified in three categories: (i) the reports that will be generated from the special studies, from the case studies at the state-level, and from the national level synthesis; (ii) workshops that will be organized at both the state and national levels; and (iii) the learning experience by Indian officials from participation in the study. For each state-level case study, a draft report will be prepared and then presented in a workshop, involving officials from the power, coal and environment fields at the state-level. Following the workshop, the draft would be revised and finalized, to reflect the discussions. In a final phase, the findings of both case studies would be consolidated; conclusions inferred at the national level; recommendations formulated; and a draft overall report prepared. As with the state-level case studies, the draft national synthesis would be presented and discussed in a workshop, involving officials from the power, coal and environment fields at both the state and national levels; and then finalized to take into account the workshop discussions.

41. The learning experience and "on-the-job" training from having Indian officials participate in the study is especially important, as the entire study is designed as a collaborative approach with the main Indian actors concerned by the issues addressed. The goal is to establish a planning process and leave behind a capability to handle environmental issues in energy planning. By involving Indian institutions, leading experts, consultants and NGOs in the execution of the study and in the workshops, both at

the (case study) state and the national levels, all the stakeholders can be actively involved in the evaluation of the different options and the formulation of recommendations with which the stakeholders identify. The goal is thereby to reduce (although clearly not eliminate) the risks that the power and coal sectors will fail to implement the recommendations.

Relationship with Other Activities

42. In order to avoid duplication, a special effort will be made to link the study with (and incorporate the results of) the substantial amount of other work that has already been completed, or that is currently under way on related topics. Notably, this related work covers many of the individual components of the issues and options proposed in this study. This other work includes, but may not be confined to: (i) the World Bank's Coal Sector Rehabilitation Project; (ii) the GEF-funded Study on Selected Options for Stabilizing GHG Emissions; (iii) the Environmental Power Manual (EM), which is being managed by the World Bank; (iv) the various activities on DSM, which the World Bank has proposed supporting in the State Power Sector Restructuring operations currently under preparation in Haryana, Orissa, Andhra Pradesh and Uttar Pradesh; (v) the E-7 Network Support being provided to India; (vi) the National Program for Environmental Management for Coal-Fired Power Generation, funded by the Asian Development Bank (ADB); (vii) the Power Tariff Policy Study, financed by ADB for the Andhra Pradesh State Electricity Board (APSEB); (viii) the Urban Energy Study, funded by the Energy Sector Management Assistance Programme (ESMAP); (ix) the Asia Acid Rain project, funded by a multi-national trust fund, through the World Bank and ADB; (x) the USAID-financed work on Integrated Resource Planning (IRP) for APSEB; and (xi) the Metropolitan Environmental Improvement Program (MEIP), funded by UNDP, through the World Bank. One of the contributions of the study will be to bring together and build upon the results of this other work in a way that will allow policy-makers in India to make well-informed decisions.

Timing

43. A provisional timetable for the study is in Tables 1-3. The timetable is predicated on the basis that bids are invited from international consultants by April 1, 1996; and the contracts with the international consultants and the local consultants carrying out the state-level case studies are awarded and signed by May 1, 1996.

Table 1: Master Schedule for Overall Study Workshops and Seminars (National Synthesis)

Event	Date
Initial Questionnaire	6/96
Inception Seminar/Selection of Computer Model	7/96
Technical Workshop	10/96
Mid-Way Workshop	4/97
Decision-Makers Workshop	11/97

Table 2: Master Schedule for Case Studies and National Synthesis

	Initiate Work	First Draft Report	Final Draft Report
A.P. Case Study	7/96	12/96	6/97
Bihar Case Study	7/96	1/97	6/97
National Synthesis	5/96	11/97	1/98

Table 3: Master Schedule for Special Studies

Study	Initiate	Report
Electric Power Pricing	5/96	9/96
Demand-Side Management	5/96	9/96
Inter-Fuel Substitution	5/96	9/96
Economic Instruments for Pollution Control	5/96	9/96
Institutional and Managerial Reforms	5/96	9/96
Power Plant Siting Policies	5/96	9/96
Social Implications	5/96	9/96
Renewable Energy Options	5/96	9/96
Ash Pond Management/Ash Disposal/Ash Utilization	10/95	6/96
Power Plants Mitigation Costs	5/96	9/96
Coal Mining Mitigation Costs	5/96	9/96

INDIA: ENVIRONMENTAL ISSUES IN THE POWER SECTOR

Bihar Case Study

Terms of Reference

1. Background and Objectives

The Government of India (GoI), the State Governments of Andhra Pradesh (A.P.) and Bihar, the British Overseas Development Administration (ODA) and the World Bank are implementing a study of environmental issues in the power sector in India. The Overall Study Terms of Reference are in Attachment I. It is expected that the overall study will take about 20 months to complete. The main features of the overall study are as follows:

1.1 Objectives

The overall study will identify the main environmental effects related to the expansion of electricity generation from coal, including the environmental externalities and costs caused by the associated increase in the production of coal. On the basis of the identified environmental effects, the study will present a menu of options to mitigate those effects. The menu will be presented in a way that facilitates a practical selection between the options and allows decision-makers in India to assess more explicitly the trade-offs involved between options. In particular, to compare options adequately, a provision for the environmental cost of coal mining (based on existing environmental standards) needs to be included in the cost of power.

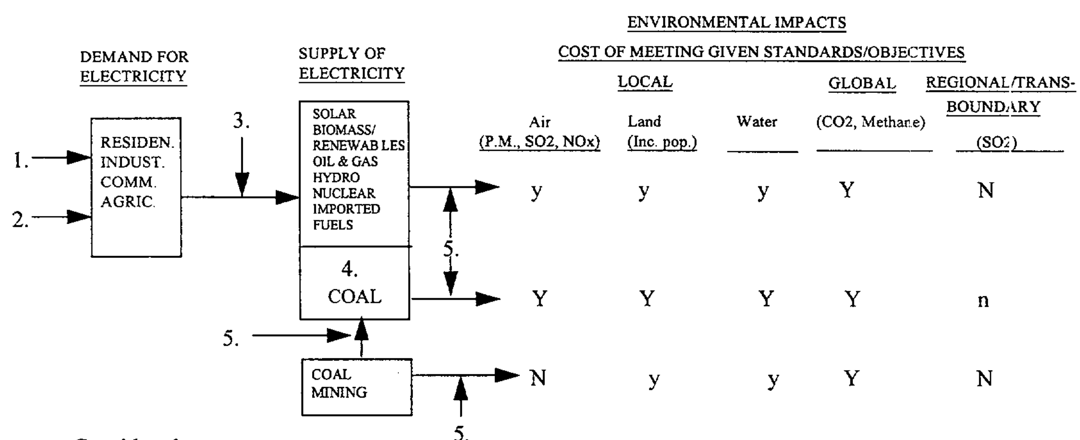
The main environmental effects to be covered include: air pollution, due (for example) to emissions of particulate matter (PM), sulphur dioxide (SO_2) and oxides of nitrogen (NO_x); the contribution of coal-fired power generation to emissions of greenhouse gases (GHG); land degradation and pre-emption, for example through the accumulation of bottom ash at power station sites and open-cast coal mining; and water pollution. However, the questions of mine safety and coal fires will not be addressed. The study considers the environmental effects of hydroelectric power, hydrocarbons, biomass and nuclear power to the extent that they are relevant in the context of inter-fuel substitution.

1.2 Options

The study will examine a broad number of options for reducing the environmental impacts of the expansion of electricity generation from coal. These options include: electric power pricing; demand-side management (DSM); inter-fuel substitution, considering both domestic and imported fuel possibilities and renewable energy sources; a range of technological solutions, such as coal beneficiation, ESPs, FGD, clean-coal technologies, ash pond management and improved ash disposal and utilization; economic instruments, notably environmental taxes and emissions trading; institutional and managerial reforms to improve efficiency in the power sector, for example through better maintenance, plant dispatch, and reduced line losses; and the siting of power plants. A schematic representation of the main environmental impacts and options to be considered is in Figure 1.

Figure 1

Schematic for Environmental Impacts and Options in the Power Sector



Impacts Considered
Y=YES y=YES, but selective only, to get rough estimate of impact on cost of electricity per kWh
N=NO n=Not covered in modelling but implication for forestry and rain-fed agriculture considered
P.M.=Particulate Matter SO2=Sulphur Dioxide NOx=Nitrogen Oxide CO2=Carbon Dioxide

Options Considered

1. Electric Power Pricing
2. DSM (inc. environmental taxes)
3. Efficiency in Supply (maintenance of equipment, T&D losses), Institutional and Managerial Reform, Regional Interconnections
4. Inter-fuel substitution, including the effect of economic instruments on fuel choice. Analysis to be extended outside modelling to consider energy options in moderating fuelwood depletion
5. Technology mitigation options (coal beneficiation, ash disposal, clean coal technologies, IGCC and AFBC technologies, resettlement, compensation, land restoration, power plant siting, sulphur control, particulate control)

1.3 Methodology

Following implementation of the activities leading up to the study Inception Seminar (as specified in paras. 25-26 of the Overall Study Terms of Reference), the study will be carried out on the basis of case studies in two states, *viz.* A.P. and Bihar. These case studies will provide an empirical basis for a national synthesis, which will draw quantitative conclusions at the national level about the environmental and cost consequences of broad energy policy options. The national synthesis and the state-level case studies will be supported by a set of cross-cutting special studies, which will examine subjects with a broader and more generic interest than the individual states: possible examples would be DSM, price elasticity of demand, "clean-coal" technologies,

renewable energy, ash utilization and the management of ash ponds, and the costs of mitigating the environmental effects of power generation and coal mining.
In both states, the study will identify the relevant environmental objectives. Then, for each option, the development of the power generation system will be simulated, along with the required coal transport and coal production. Each option will be required to meet the forecast electricity demand in the state, subject to environmental constraints. In particular, it will be necessary to comply with existing environmental objectives, notably as expressed in ambient air quality, emissions standards and effluent discharge standards. Also, the financial implications of the various options will be considered, especially relative to the financial objectives for the power sector laid down by the central and state governments, as well as international lending agencies. While the study will be based on existing Indian environmental objectives (for example, as embodied in the emissions standards), the study also will analyze how sensitive the costs of meeting these standards are to possible changes, e.g. towards those of the EC or the World Bank guidelines.

1.4 Relationship with Other Activities

A special effort will be made to link the study with the substantial amount of work that has already been completed, or that is currently under way on related topics, for example: (i) the World Bank's Coal Sector Rehabilitation Project; (ii) the GEF-funded Study on Selected Options for Stabilizing GHG Emissions; (iii) the Environmental Power Manual (EM), which is being managed by the World Bank; (iv) the various activities on DSM, which the World Bank has proposed supporting in the State Power Sector Restructuring operations currently under preparation in Haryana, Orissa, Andhra Pradesh and Uttar Pradesh; (v) the E-7 Network Support being provided to India; (vi) the National Program for Environmental Management for Coal-Fired Power Generation, funded by the Asian Development Bank (ADB); (vii) the Power Tariff Policy Study, financed by ADB for the Andhra Pradesh State Electricity Board (APSEB); (viii) the Urban Energy Study, funded by the Energy Sector Management Assistance Programme (ESMAP); (ix) the Asia Acid Rain project, funded by a multi-national trust fund, through the World Bank and ADB; (x) the USAID-financed work on Integrated Resource Planning (IRP) for APSEB; and (xi) the Metropolitan Environmental Improvement Program (MEIP), funded by UNDP, through the World Bank. One of the contributions of the study will be to bring together and build upon the results of this other work in a way that will allow policy-makers in India to make well-informed decisions.

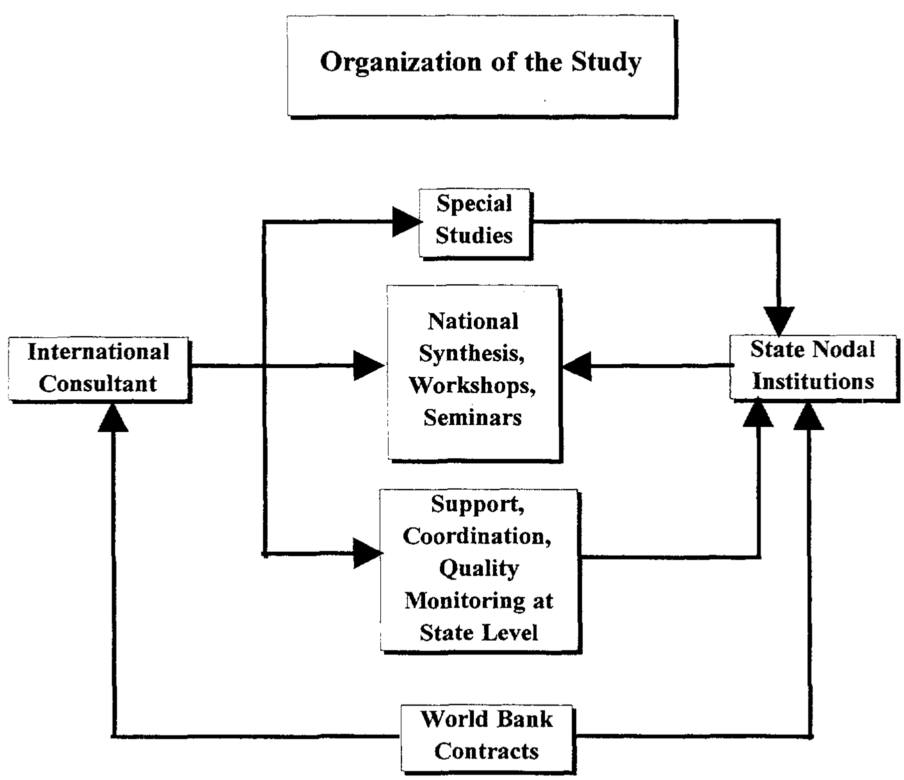
2. Contractual Arrangements

The funding for this study will be provided by ODA, through the joint United Nations Development Program/World Bank Energy Sector Management Assistance Program (ESMAP). The World Bank will contract with the Sone Command Area Development Agency (SCADA).

3. Relationship between SCADA and the International Consultant

The Bihar case study will be conducted within the management framework of the overall study, as shown in Figure 2. In terms of responsibilities, the international consultant will carry out the national synthesis. As part of that function, the international consultant will provide to SCADA the results of a set of special studies, as indicated in the Overall Study Terms of Reference. The international consultant will serve as technical advisor to the state case studies. Especially, the international consultant will provide Bihar with the systems planning model and financial model; assist in installing these models; and provide training in their use. The international consultant will also assist in the development of a demand forecasting model and advise on the selection of an air quality model. Finally, the international consultant must coordinate the state-level case studies, to ensure consistency of approach and quality. The draft terms of reference for the international consultant are in Attachment II.

Figure 2



4. Description of Services to be Provided

SCADA shall provide the following services:

4.1 Establish a Steering Committee

The overall management plan for the study anticipates that each state case study will have its own state-level steering committee, to oversee and coordinate the work. The SCADA study director shall be responsible for:

- Establishing a steering committee, within one month of starting the work, which would be chaired by the State Secretary of Energy and include, *inter alia*, the State Secretary of Environment, the Head of the State Electricity Board, the Head of the State Pollution Control Board, appropriate NGOs, and independent experts in energy/environment; and
- Convening meetings of this steering group at least every three months.

4.2 Prepare a Technical Case Study for the State of Bihar

The preparation of the technical case study for Bihar constitutes the major component of the services to be provided. A general discussion of the proposed methodology, and its relationship to the national study, is provided in the Overall Study Terms of Reference.

Special importance is attached in these terms of reference to the collection, organization, and analysis of all relevant data in Bihar. SCADA is expected to devote a substantial effort to this part of the work. Appropriate and reliable information will be needed at all stages of the analysis: as input to the demand forecasting model, the power system planning model, the environmental stocktaking, the use and environmental effects of coal mining, the financial model, the air quality model, the scenario analysis (especially the environmental impacts) and the multi-attribute analysis. Aside from the importance of appropriate and reliable information to the technical case study itself, the collection, organization and analysis of data entailed in the study is seen as major first step in establishing a solid data bank, to serve as a foundation for the analysis of policy questions related to energy and the environment in the state of Bihar.

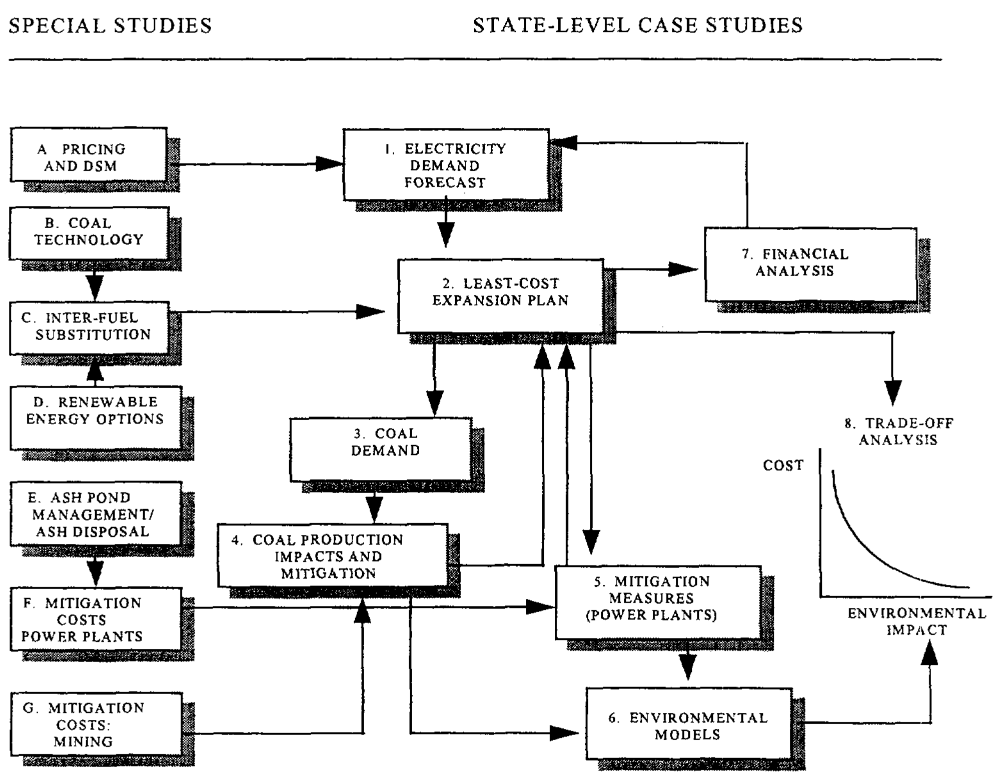
The major subtasks for this case study and the relationship between them are summarized in Fig. 3. In particular, it will be noted that SCADA shall require inputs from the special studies to be carried out by other contractors. The major sub-tasks for which SCADA will be responsible are as follows:

4.2.1 Construct a Demand Forecasting Model

With the assistance of the international Consultant, SCADA will construct a demand forecasting model. This will project demands by the major subsectors and tariff classes (e.g. agriculture, industry supplied at HT, MT and LT, etc.) using an appropriate set of forecasting variables, one of which shall be price. Guidance on values of price elasticity to be used in this model will be provided by a special study. In sectors showing high seasonal variability (e.g. agriculture), demand shall be projected by season. The output of the demand model, which will forecast energy and peak power demands, and associated load shapes, will need to drive the capacity expansion planning model (see Task 4.2.2).

The demand forecasting model shall be designed in such a way as to permit modification of demands at the generation level, and the associated load shapes, by DSM projects, and

Fig. 3: Methodology



Note: The Special Studies shown are illustrative only. For example, the figure does not show the possible Special Studies on economic instruments for pollution control, institutional and managerial reform in the power sector, power plant siting policies and the social impacts of policy options, which are discussed in the text.

by T&D system rehabilitation projects that will reduce T&D losses. The starting point for the demand forecasting model could be the model that is currently under way in the state of Andhra Pradesh, under a USAID-funded project. This model would be made available to SCADA for adaptation to Bihar.

4.2.2 Install the System Planning Model

A suitable system planning model will be provided by the international consultant, who will assist in the installation and testing of the model at SCADA, and will provide a training program in its use. SCADA, supported by the international consultant, will use the generic planning model to examine a broad range of options for reducing the environmental impacts associated with the expansion of electricity power generation in Bihar. Options will be identified to reduce environmental impacts to acceptable levels (taking Indian environmental standards as the baseline), while meeting the forecast electricity demand in the state and complying with known financial constraints (based upon financial objectives defined by the central and state governments).

4.2.3 Carry out Environmental Stocktaking

SCADA will identify and describe the existing environmental regulations, standards and objectives established by the central and state governments which must be met by the power sector in Bihar. Such regulations, standards, and objectives should be formulated, as far as possible, in a quantitative manner, as they will be incorporated formally, to the extent possible, as constraints in the power system scenario analysis (Section 4.2.8). SCADA will then review the extent to which Bihar's existing power generation facilities conform with these regulations, standards, and objectives.

4.2.4 Develop a Coal Model

In consultation with the international consultant, SCADA will develop a coal model. This is expected to be a relatively simple spreadsheet, that will map plant-by-plant coal requirements to coal mines for the purpose of estimating the environmental impacts associated with coal mining. The initial output of this model will be a mine-by-mine forecast of coal output as a function of the generation plan forecast by the supply model.

4.2.5 Develop a Financial Model

A financial model will be provided by the international consultant, who will assist in the installation and testing of the model at SCADA, and will provide a training program in its use. The model will be used to examine the tariff, financial and financing implications of alternative policy options. This must have the capability of determining tariff levels, given: (i) the program of investments as determined from the least-cost system planning model; (ii) a set of balance sheet ratios that must be met (e.g. minimum rates of return on assets, equity, self financing ratios, etc., as typically set forth in covenants with multilateral institutions); and (iii) assumptions about other financial variables (depreciation rates, treatment of construction work in progress etc.). The financial model must also be linked to the demand forecasting model in order to determine the impacts of tariff reforms.

It is possible that the financial model will be based on the financial spreadsheet model developed by the USAID/APSEB IRP project (see Section 4.2.1), which will be made available to SCADA. The model will be used to estimate the impact of each option on tariffs.

4.2.6 Install an Air Quality Model

In consultation with the international consultant, SCADA will select an appropriate air quality model for use in the study. This will likely be a relatively simple Gaussian plume-type model that can translate emissions (notably particulates, SO_2 and NO_x) from major generating stations into changes in ambient concentrations. The model should be suitable for the type of meteorological data actually available in Bihar. Such models have been used by the engineering consultants who prepared recent Environmental Impact Statements (EIS) for major coal generating stations in India.

The air quality model will be installed at SCADA, and an interface written to permit easy modification of its data input files from the output of the systems planning model.

4.2.7 Define Policy Options and Scenarios.

In coordination with the international consultant, the policy options, environmental attributes and scenarios to be used in the case study will be defined. This coordination is necessary because the national synthesis requires a certain level of consistency between the individual state case studies.

The policy options that are of potential interest to this study are discussed in the Overall Study Terms of Reference. These general options need to be defined in the form of specific programs and options suitable for implementation in Bihar, but they should include DSM, T&D and renewable energy alternatives to conventional supply augmentation options. Others would focus on environmental mitigation, clean coal technology etc.: inputs from the special studies will help in the definition of the specific assumptions to be used. A further set of options would capture the impacts of significant structural and institutional changes. For example, in a future in which distribution was privatized, assumptions would need to be made about the impact on the technical and financial performance of the sector (e.g. technical and non-technical loss rates). These assumptions might be based upon experience in other countries (e.g. what might be accomplished in the way of loss rates in a privatized distribution company might reasonably be based upon the experience of the privatized distribution company in Sri Lanka, which in the ten years of its existence has reduced losses in its service territory from rates in excess of 30% to 10%). For every policy option, it will be necessary to identify the specific environmental attributes relevant to that option, e.g. emissions of SO_2, particulate matter and greenhouse gases; population resettlement; and loss of forest cover.

Scenarios capture those factors that are beyond the immediate control of state policy-makers in the power sector. Examples of variables that could be treated in this way include: world coal, oil, and gas prices; domestic and foreign interest rates; exchange rates; rates of import duty; and taxes. Those variables within the power of the GoI to influence will be analyzed in the national synthesis. These scenarios must be common among the various state case studies. The number and definition of scenarios will be agreed with the international consultant. One of the main objectives of establishing a range of scenarios is to be able to test the robustness of policy options to uncertainty.

4.2.8 Conduct Scenario Analysis

With the assistance of the international consultant, SCADA will start the scenario analysis by defining a base-case scenario for a 20-year planning horizon. In defining the base-case scenario, SCADA will incorporate the state government's plans for meeting the official demand projections. These plans might involve only modest tariff reforms and DSM, a continued emphasis on large coal-fired power plants using domestic coals, and limited penetration of renewables, gas and oil. The base-case scenario also needs to make assumptions about the likely progress of structural and institutional change. Using the system planning model, SCADA will simulate the base-case scenario; calculate the present value of system costs; and evaluate the environmental impacts and the extent to which the existing environmental regulations, standards and objectives are not satisfied. The air quality model will serve to verify how far emissions exceed the air quality standards. Estimates will then be made of the cost and financial implications of ensuring the compliance of the base case with existing environmental regulations, standards and objectives.

Again with the assistance of the international consultant, in the second phase of the scenario analysis, the system planning model will be used to simulate each of the policy options defined in Section 4.2.7, one at a time, up to the maximum feasible limit for that option, as a deviation from the base case. The power sector development plan corresponding to each policy scenario will be identified as a least-cost solution, subject to the environmental constraints relating to the environmental attributes of that option (i.e. as implied by the existing environmental regulations, standards, and objectives). For some policy options, it may not be possible to satisfy even the relevant environmental constraints, due to the limits on the availability of that option, although in all cases it will be possible to trace out the supply curve for the option, i.e. relating the change in system cost to the availability. For some policy options, the same demand projections as the official ones will underlie the scenario analysis. The major policy options requiring different demand projections relate to alternative power pricing policies and DSM. Also, where a policy option affects significantly the cost of supply (as revealed through the financial model), then a new demand forecast will need to be formulated. SCADA will show explicitly the financial implications of each policy option.
No single policy option will be able to address the full range of environmental attributes of interest to decision makers. Hence, in the third phase, individual policy options will be combined into a set of policy mixes that will modify the base case in terms of meeting environmental objectives. The study seeks to present policy makers with a range of policy mixes, as alternatives to the base case (which incorporates the official demand forecast and the state government's plans).

In the fourth phase, the second and third phases should be repeated to satisfy an alternative set of environmental constraints. The alternative will be defined in agreement with the international consultant. For example, instead of taking the existing Indian environmental regulations, standards, and objectives, those recommended by the European Community might be considered. The goal of the fourth phase is not to judge the existing standards but rather to test their sensitivity to modification.

4.2.9 Conduct Multi-Attribute Trade-off Analysis

The scenario analysis is designed to make alternative policy options as comparable as possible, by making them satisfy existing environmental regulations, standards and objectives as constraints, wherever feasible. Under the scenario analysis, policy mixes will have been identified, which broadly meet existing environmental constraints. However, some policy options will impact certain other environmental attributes that are not addressed, at least in a quantifiable way, under existing environmental regulations, standards, and objectives. For example, policy options in general have different impacts on GHG; and India at this point has not established targets for GHG reduction. Where policy options differ with respect to environmental attributes outside the constraint set, SCADA will subject them to multi-attribute trade-off analysis, with the assistance of the international consultant. Trade-off graphs displaying environmental attributes against system cost will be prepared, and the implied trade-offs examined.

The main output of this process is expected to be a more comprehensive understanding of the environmental impacts of a range of policy options. By quantifying these impacts and displaying the trade-offs against cost in a form that can be understood by decision makers, the expectation is that decisions about the future development of the power sector will better reflect environmental concerns than in the past.

4.3 Convene a Technical Workshop

Roughly mid-way through the technical case study, on a date to be determined in agreement with the World Bank, SCADA shall convene in Bihar a 1-2 day technical workshop to discuss the preliminary results of the study. The purpose of this workshop is to bring the study and its early findings to the attention of the technical community in Bihar, and the invitees might include representatives from:

- The Bihar State Electricity Board, the Bihar State Pollution Control Board and other Bihar government agencies, as appropriate;
- The academic community in Bihar;
- Consulting engineering firms in Bihar and in neighboring states who have provided engineering and environmental impact assessment services; and
- NGOs.

It will be SCADA's responsibility to convene the workshop at an appropriate venue, prepare workshop materials, and organize presentations and discussion.

4.4 Assist the National Synthesis

SCADA will participate in the national seminars and workshops convened by the international consultant and assist the international consultant in drawing together the results of the individual state case studies into a national synthesis. In particular, the SCADA case study director will:

- Respond to the "Decision-making and Power Sector Planning Process Questionnaire";
- Take part in the Inception Seminar, to help reach consensus on the objectives and methodology of the study, agree on the activities and outputs to be derived from the case studies and the special studies, select the generic power systems planning model to be used in the case studies, and agree on information transfer between the international consultant and the two states, internal project management and reporting details;
- Attend the national Technical Workshop, to discuss progress with regard to the proposed methodology and modeling;
- Attend the national Mid-way Workshop, to review progress and the technical issues arising from the studies, give the international consultant feedback on results, and assist the international consultant in preparing the national synthesis report; and
- Attend the national Decision-makers' Workshop, to discuss the preliminary findings of the study, to help bring the recommendations to the attention of key decision-makers and to encourage adoption of the planning model as national policy.

4.5 Disseminate Results: Convene a Final Workshop

Great importance is given to the appropriate dissemination of the results of the study. It is anticipated that the findings of the study will be presented by SCADA towards the end of the case study at a state-level dissemination workshop. SCADA will be responsible for:

- Convening the workshop at an appropriate venue in Bihar;
- Drawing up an appropriate list of invitees;
- The preparation of workshop materials;

- The organization of the workshop itself; and
- Preparation of workshop proceedings.

4.6 Subcontract Local Indian Consultants

SCADA will engage the services of local Indian consultants, as required, to augment the in-house capabilities of SCADA. Such consultants should be drawn from experts within Bihar and elsewhere. SCADA will be responsible for engaging such consultants, including definition of their terms of reference, and for directing and supervising their work. Individual local consultants will be selected subject to the agreement of the World Bank; and rates of compensation to such consultants are subject to the terms of the contract between SCADA and the World Bank, which establishes the maximum daily rate allowable.

5. Coordination, Reporting Requirements and Progress Meetings

Recognizing that a major objective of the overall study is the preparation of a national synthesis that is grounded in the detailed results of the individual state case studies, coordination between the case study directors and the international consultant will be necessary.

In order to facilitate communication and coordination between all of the parties involved in the study, and in particular to keep the international consultant abreast of issues and problems likely to affect their ability to prepare a national synthesis, timely progress reporting and review meetings are an essential part of the study. The reporting requirements are as follows:

5.1. Quarterly Progress Reports

A quarterly progress report will be prepared with the following elements:

- Technical sections, indicating progress achieved in meeting the study's objectives for the quarter, identifying any points of weakness and (where appropriate) recommending changes in the study's activities/inputs;
- Discussion of objectives for the following quarter, with particular emphasis on any problems or constraints that may be faced in meeting the proposed schedule; and
- Budget report, showing actual versus planned expenditures.

These Quarterly Progress Reports will be submitted to the World Bank. They are expected to be succinct documents (5-10 pages), designed primarily as a management tool, rather than as a vehicle for communicating actual technical results.

5.2 Review Meetings

Review meetings will be held with the international consultant in Delhi, probably on at least four occasions. These meetings will be attended by the state case study directors, plus whatever senior technical staff may be deemed appropriate. The timing of these meetings will be determined by the international consultant in consultation with the state case study directors, and will generally be attended by the World Bank study team. These review meetings will typically be of two days duration, and will have the following general agenda:

- Progress reports by state case study directors;
- Progress reports by consultants in charge of special studies; and
- Progress report by the international consultant.

At the Inception Seminar, it is expected that the international consultant and the state case study directors will agree upon a common word processing software format for the exchange of documents and reports (see Section 7.1).

By the time of the second review meeting (but not later than six months after the start of the study) SCADA will complete a set of trial runs of the models, for the base case scenario and a sample of options, to be determined in consultation with the international consultant.

6. Schedule

6.1 *The Master Schedule*

The master schedule for the study is shown in the Table below. Since the Bihar case study is one of several inputs planned for this study, its implementation must be coordinated in order for the national synthesis to be prepared in a timely manner. The estimated deadline for completion of the overall national study is January, 1998, so the Bihar case study must be completed by June, 1997.

Master Schedule for Case Studies and National Synthesis

	Initiate Work	First Draft Report	Final Draft Report
A.P. Case Study	7/96	12/96	6/97
Bihar Case Study	7/96	1/97	6/97
National Synthesis	5/96	11/97	1/98

6.2 The Bihar Schedule

Although SCADA is free to modify the details of the scheduling of the individual tasks, as it sees appropriate, with the agreement of the World Bank, the timing of the major milestones should be met. The schedule for the Bihar case study, as agreed with the case study director, will become part of the contract between SCADA and the World Bank.

7. Outputs

The deliverables are as follows:

7.1 The Case Study Report

A detailed technical report on the state case study, with an appropriate executive summary of no more than 30 pages, and technical annexes as appropriate, constitutes the principal deliverable.

The final report shall be prepared in a format suitable for international distribution. Graphics shall be prepared in an appropriate computer-based software package, and integrated into the text prepared in modern word processing software (WordPerfect, Word), and printed on a laserjet printer. Dot-matrix printers or manual typewriters are not acceptable as a printing format for the final report. The budget should provide for the preparation of 100 copies of the final report.

7.2 Workshops

SCADA will conduct the workshops as described under 4.3 and 4.5, above.

SCADA will prepare, in advance of each workshop, a set of appropriate workshop materials, including copies of papers to be presented at the workshop.

INDIA: ENVIRONMENTAL ISSUES IN THE POWER SECTOR

Andhra Pradesh Case Study

Terms of Reference

1. Background and Objectives

The Government of India (GoI), the State Governments of Andhra Pradesh (A.P.) and Bihar, the British Overseas Development Administration (ODA) and the World Bank are implementing a study of environmental issues in the power sector in India. The Overall Study Terms of Reference are in Attachment I. It is expected that the overall study will take about 20 months to complete. The main features of the overall study are as follows:

1.1 Objectives

The overall study will identify the main environmental effects related to the expansion of electricity generation from coal, including the environmental externalities and costs caused by the associated increase in the production of coal. On the basis of the identified environmental effects, the study will present a menu of options to mitigate those effects. The menu will be presented in a way that facilitates a practical selection between the options and allows decision-makers in India to assess more explicitly the trade-offs involved between options. In particular, to compare options adequately, a provision for the environmental cost of coal mining (based on existing environmental standards) needs to be included in the cost of power.

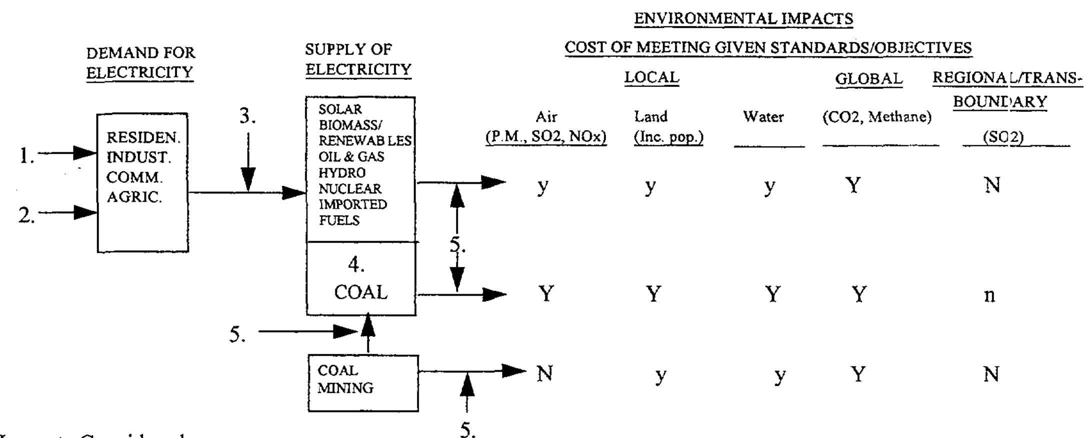
The main environmental effects to be covered include: air pollution, due (for example) to emissions of particulate matter (PM), sulphur dioxide (SO_2) and oxides of nitrogen (NO_x); the contribution of coal-fired power generation to emissions of greenhouse gases (GHG); land degradation and pre-emption, for example through the accumulation of bottom ash at power station sites and open-cast coal mining; and water pollution. However, the questions of mine safety and coal fires will not be addressed. The study considers the environmental effects of hydroelectric power, hydrocarbons, biomass and nuclear power to the extent that they are relevant in the context of inter-fuel substitution.

1.2 Options

The study will examine a broad number of options for reducing the environmental impacts of the expansion of electricity generation from coal. These options include: electric power pricing; demand-side management (DSM); inter-fuel substitution, considering both domestic and imported fuel possibilities and renewable energy sources; a range of technological solutions, such as coal beneficiation, ESPs, FGD, clean-coal technologies, ash pond management and improved ash disposal and utilization; economic instruments, notably environmental taxes and emissions trading; institutional and managerial reforms to improve efficiency in the power sector, for example through better maintenance, plant dispatch, and reduced line losses; and the siting of power plants. A schematic representation of the main environmental impacts and options to be considered is in Figure 1.

Figure 1

Schematic for Environmental Impacts and Options in the Power Sector



Impacts Considered

Y=YES y=YES, but selective only, to get rough estimate of impact on cost of electricity per kWh

N=NO n=Not covered in modelling but implication for forestry and rain-fed agriculture considered

P.M.=Particulate Matter SO2=Sulphur Dioxide NOx=Nitrogen Oxide CO2=Carbon Dioxide

Options Considered

1. Electric Power Pricing
2. DSM (inc. environmental taxes)
3. Efficiency in Supply (maintenance of equipment, T&D losses), Institutional and Managerial Reform, Regional Interconnections
4. Inter-fuel substitution, including the effect of economic instruments on fuel choice. Analysis to be extended outside modelling to consider energy options in moderating fuelwood depletion
5. Technology mitigation options (coal beneficiation, ash disposal, clean coal technologies, IGCC and AFBC technologies, resettlement, compensation, land restoration, power plant siting, sulphur control, particulate control)

1.3 Methodology

Following implementation of the activities leading up to the study Inception Seminar (as specified in paras. 25-26 of the Overall Study Terms of Reference), the study will be carried out on the basis of case studies in two states, *viz.* A.P. and Bihar. These case studies will provide an empirical basis for a national synthesis, which will draw quantitative conclusions at the national level about the environmental and cost consequences of broad energy policy options. The national synthesis and the state-level case studies will be supported by a set of cross-cutting special studies, which will examine subjects with a broader and more generic interest than the individual states: possible examples would be DSM, price elasticity of demand, "clean-coal" technologies, renewable energy, ash utilization and the management of ash ponds, and the costs of mitigating the environmental effects of power generation and coal mining.

In both states, the study will identify the relevant environmental objectives. Then, for each option, the development of the power generation system will be simulated, along with the required coal transport and coal production. Each option will be required to meet the forecast electricity demand in the state, subject to environmental constraints. In particular, it will be necessary to comply with existing environmental objectives, notably as expressed in ambient air quality, emissions standards and effluent discharge standards. Also, the financial implications of the various options will be considered, especially relative to the financial objectives for the power sector laid down by the central and state governments, as well as international lending agencies. While the study will be based on existing Indian environmental objectives (for example, as embodied in the emissions standards), the study also will analyze how sensitive the costs of meeting these standards are to possible changes, e.g. towards those of the EC or the World Bank guidelines.

1.4 Relationship with Other Activities

A special effort will be made to link the study with the substantial amount of work that has already been completed, or that is currently under way on related topics, for example: (i) the World Bank's Coal Sector Rehabilitation Project; (ii) the GEF-funded Study on Selected Options for Stabilizing GHG Emissions; (iii) the Environmental Power Manual (EM), which is being managed by the World Bank; (iv) the various activities on DSM, which the World Bank has proposed supporting in the State Power Sector Restructuring operations currently under preparation in Haryana, Orissa, Andhra Pradesh and Uttar Pradesh; (v) the E-7 Network Support being provided to India; (vi) the National Program for Environmental Management for Coal-Fired Power Generation, funded by the Asian Development Bank (ADB); (vii) the Power Tariff Policy Study, financed by ADB for the Andhra Pradesh State Electricity Board (APSEB); (viii) the Urban Energy Study, funded by the Energy Sector Management Assistance Programme (ESMAP); (ix) the Asia Acid Rain project, funded by a multi-national trust fund, through the World Bank and ADB; (x) the USAID-financed work on Integrated Resource Planning (IRP) for APSEB; and (xi) the Metropolitan Environmental Improvement Program (MEIP), funded by UNDP, through the World Bank. One of the contributions of the study will be to bring together and build upon the results of this other work in a way that will allow policy-makers in India to make well-informed decisions.

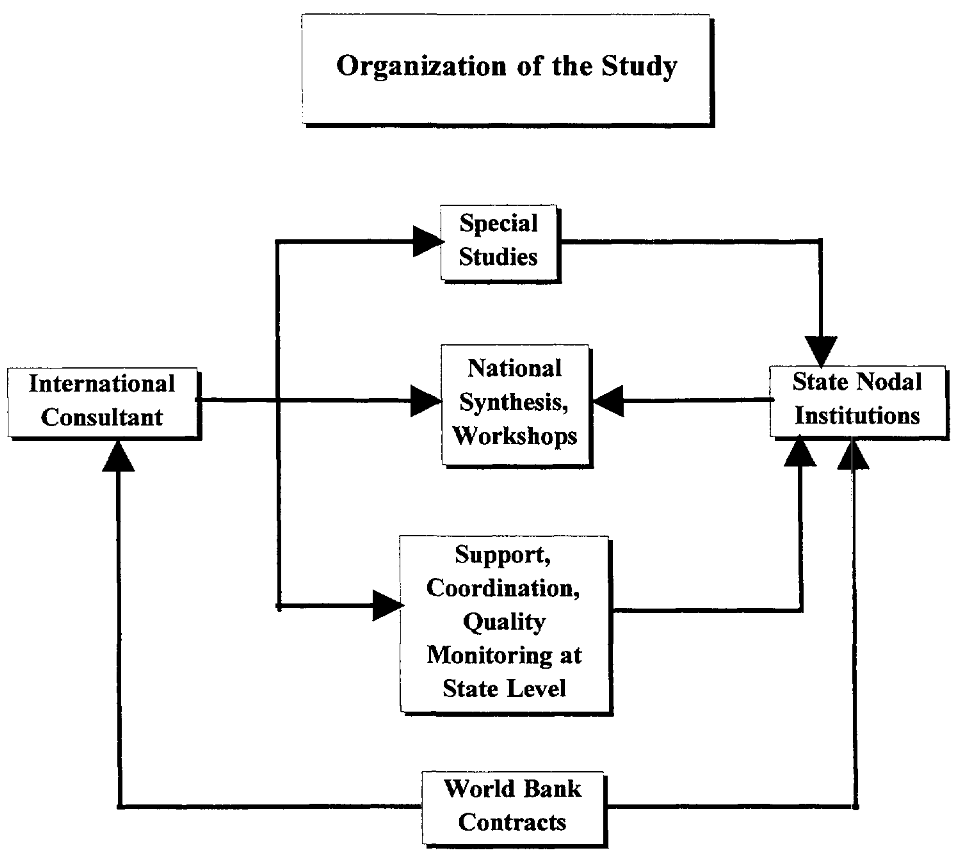
2. Contractual Arrangements

The funding for this study will be provided by ODA, through the joint World Bank/United Nations Development Program Energy Sector Management Assistance Program (ESMAP). The World Bank will contract with the Administrative Staff College of India (ASCI).

3. Relationship between ASCI and the International Consultant

The A.P. case study will be conducted within the management framework of the overall study, as shown in Figure 2. In terms of responsibilities, the international consultant will carry out the national synthesis. As part of that function, the international consultant will provide to ASCI the results of a set of special studies, as indicated in the Overall Study Terms of Reference. The international consultant will serve as technical advisor to the state case studies. Especially, the international consultant will provide ASCI with the systems planning model and financial model; assist in installing these models; and provide training in their use. The international consultant will also assist in the development of a demand forecasting model and advise on the selection of an air quality model. Finally, the international consultant must coordinate the state-level case studies, to ensure consistency of approach and quality. The draft terms of reference for the international consultant are in Attachment II.

Figure 2



4. Description of Services to be Provided

ASCI shall provide the following services:

4.1 Establish a Steering Committee

The overall management plan for the study anticipates that each state case study will have its own state-level steering committee, to oversee and coordinate the work. The ASCI study director shall be responsible for:

- Establishing a steering committee, within one month of starting the work, which would be chaired by the State Secretary of Energy and include, *inter alia*, the State Secretary of Environment, the Head of the State Electricity Board, the Head of the State Pollution Control Board, appropriate NGOs, and independent experts in energy/environment; and

- Convening meetings of this steering group at least every three months.

4.2 Prepare a Technical Case Study for the State of Andhra Pradesh

The preparation of the technical case study for A.P. constitutes the major component of the services to be provided. A general discussion of the proposed methodology, and its relationship to the national study, is provided in the Overall Study Terms of Reference.

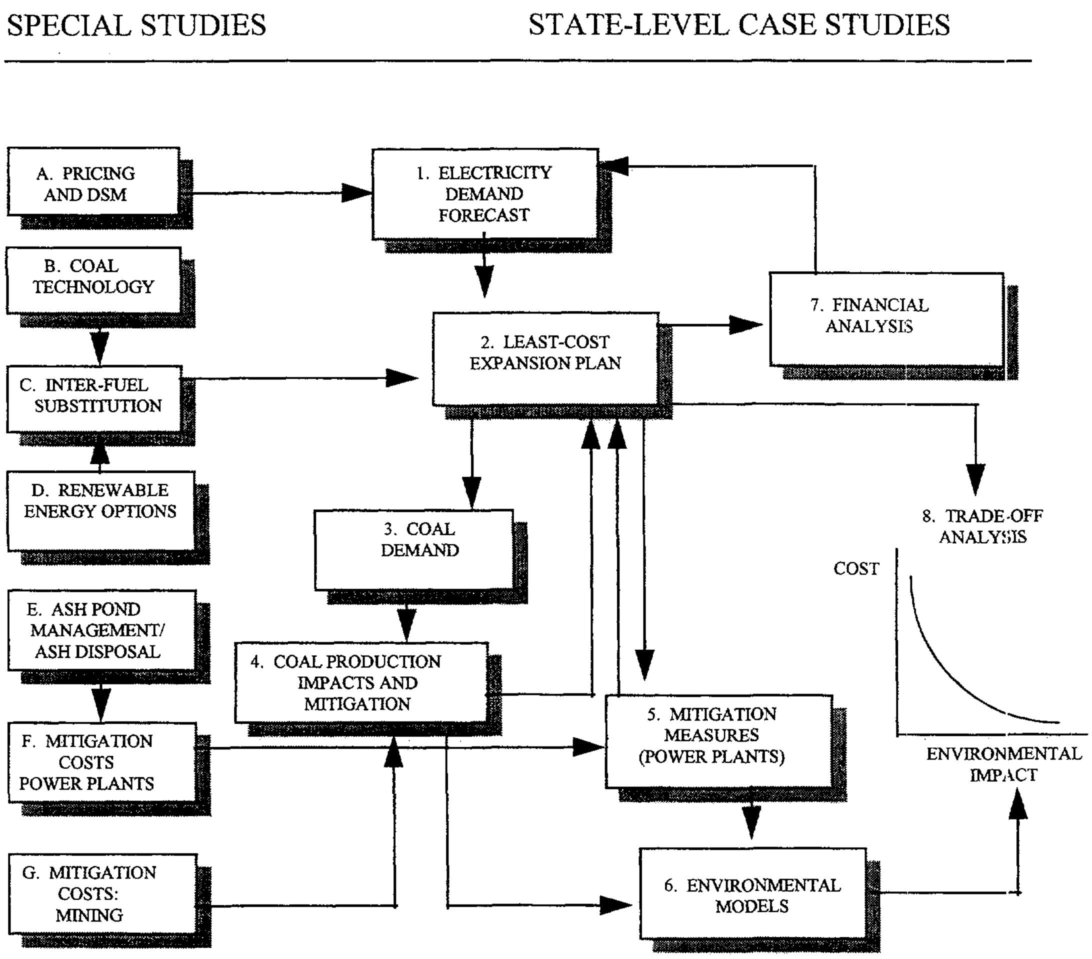
ASCI will give due attention to the collection, organization, and analysis of all relevant data in A.P.: evidently, appropriate and reliable information will be needed at all stages of the analysis. Aside from the importance of appropriate and reliable information to the technical case study itself, the collection, organization and analysis of data entailed in the study is seen as major step in establishing a solid data bank, to serve as a foundation for the analysis of policy questions related to energy and the environment in the state of A.P..

The major subtasks for this case study and the relationship between them are summarized in Fig. 3. In particular, it will be noted that ASCI shall require inputs from the special studies to be carried out by other contractors. The major sub-tasks for which ASCI will be responsible are as follows:

4.2.1 Construct a Demand Forecasting Model

With the assistance of the international consultant, ASCI will construct a demand forecasting model. This will project demands by the major subsectors and tariff classes (e.g. agriculture, industry supplied at HT, MT and LT, etc.) using an appropriate set of forecasting variables, one of which shall be price. Guidance on values of price elasticity to be used in this model will be provided by a special study. In sectors showing high seasonal variability (e.g. agriculture), demand shall be projected by season. The output of the demand model, which will forecast energy and peak power demands, and associated load shapes, will need to drive the capacity expansion planning model (see Task 4.2.2).

Fig 3: Methodology



Note: The Special Studies shown are illustrative only. For example, the figure does no
Special Studies on economic instruments for pollution control, institutional and
power sector, power plant siting policies and the social impacts of policy options,
the

The demand forecasting model shall be designed in such a way as to permit modification of demands at the generation level, and the associated load shapes, by DSM projects, and by T&D system rehabilitation projects that will reduce T&D losses. The starting point for the demand forecasting model could be the work that is currently underway at the

A.P. State Electricity Board (APSEB) under the auspices of a USAID-funded project. This project has as its main objective the preparation of an integrated resource plan (IRP) for A.P.

4.2.2 Install the System Planning Model

A suitable system planning model will be provided by the international consultant, who will assist in the installation and testing of the model at ASCI, and will provide a training program in its use. ASCI, supported by the international consultant, will use the generic planning model to examine a broad range of options for reducing the environmental impacts associated with the expansion of electricity power generation in A.P.. Options will be identified to reduce environmental impacts to acceptable levels (taking Indian environmental standards as the baseline), while meeting the forecast electricity demand in the state and complying with known financial constraints (based upon financial objectives defined by the central and state governments).

4.2.3 Carry out Environmental Stocktaking

ASCI will identify and describe the existing environmental regulations, standards and objectives established by the central and state governments which must be met by the power sector in A.P.. Such regulations, standards, and objectives should be formulated, as far as possible, in a quantitative manner, as they will be incorporated formally, to the extent possible, as constraints in the power system scenario analysis (Section 4.2.8). ASCI will then review the extent to which A.P.'s existing power generation facilities conform with these regulations, standards, and objectives.

4.2.4 Develop a Coal Model

In consultation with the international consultant, ASCI will develop a coal model. This is expected to be a relatively simple spreadsheet, that will map plant-by-plant coal requirements to coal mines for the purpose of estimating the environmental impacts associated with coal mining. The initial output of this model will be a mine-by-mine forecast of coal output as a function of the generation plan forecast by the supply model.

4.2.5 Develop a Financial Model

A financial model will be provided by the international consultant, who will assist in the installation and testing of the model at ASCI, and will provide a training program in its use. The model will be used to examine the tariff, financial and financing implications of alternative policy options. This must have the capability of determining tariff levels, given: (i) the program of investments as determined from the least-cost system planning model; (ii) a set of balance sheet ratios that must be met (e.g. minimum rates of return on assets, equity, self financing ratios, etc., as typically set forth in covenants with multilateral institutions); and (iii) assumptions about other financial variables (depreciation rates, treatment of construction work in progress etc.). The financial model must also be linked to the demand forecasting model in order to determine the impacts of tariff reforms.

It is possible that the financial model will be based on the financial spreadsheet model developed by the USAID/APSEB IRP project (see Section 4.2.1), which will be made available to ASCI. The model will be used to estimate the impact of each option on tariffs.

4.2.6 Install an Air Quality Model

In consultation with the international consultant, ASCI will select an appropriate air quality model for use in the study. This will likely be a relatively simple Gaussian plume-type model that can translate emissions (notably particulates, SO_2 and NO_x) from major generating stations into changes in ambient concentrations. The model should be suitable for the type of meteorological data actually available in A.P. By way of illustration, it can be noted that such models have been used by the engineering consultants who prepared recent Environmental Impact Statements (EIS) for major coal generating stations in A.P.[1]

The air quality model will be installed at ASCI, and an interface written to permit easy modification of its data input files from the output of the systems planning model.

4.2.7 Define Policy Options and Scenarios.

In coordination with the international consultant, the policy options, environmental attributes and scenarios to be used in the case study will be defined. This coordination is necessary because the national synthesis requires a certain level of consistency between the individual state case studies.

The policy options that are of potential interest to this study are discussed in the Overall Study Terms of Reference. These general options need to be defined in the form of specific programs and options suitable for implementation in A.P. A significant subset of suitable options will be available from the USAID/APSEB IRP study (particularly for some of the basic DSM, T&D and renewable energy alternatives to conventional supply augmentation options). Others that focus on environmental mitigation, clean coal technology etc., will need to be added: inputs from the special studies will help in the definition of the specific assumptions to be used. A further set of options would capture the impacts of significant structural and institutional changes. For example, in a future in which distribution was privatized, assumptions would need to be made about the impact

1 For example, see the EIS by Vimta Labs for Krishnapatnam; by IIT for the 2 x 210 Rayalaseema expansion Stage II; and by Vimta Labs for the Ramagundam extension.

on the technical and financial performance of the sector (e.g. technical and non-technical loss rates). These assumptions might be based upon experience in other countries (e.g. what might be accomplished in the way of loss rates in a privatized distribution company might reasonably be based upon the experience of the privatized distribution company in Sri Lanka, which in the ten years of its existence has reduced losses in its service territory from rates in excess of 30% to 10%). For every policy option, it will be necessary to identify the specific environmental attributes relevant to that option, e.g. emissions of SO_2, particulate matter and greenhouse gases; population resettlement; and loss of forest cover.

Scenarios capture those factors that are beyond the immediate control of state policy-makers in the power sector. Examples of variables that could be treated in this way include: world coal, oil, and gas prices; domestic and foreign interest rates; exchange rates; rates of import duty; and taxes. Those variables within the power of the GoI to influence will be analyzed in the national synthesis. These scenarios must be common among the various state case studies. The number and definition of scenarios will be agreed with the international consultant. One of the main objectives of establishing a range of scenarios is to be able to test the robustness of policy options to uncertainty.

4.2.8 Conduct Scenario Analysis

With the assistance of the international consultant, ASCI will start the scenario analysis by defining a base-case scenario for a 20-year planning horizon. In defining the base-case scenario, ASCI will incorporate the state government's plans for meeting the official demand projections. These plans might involve only modest tariff reforms and DSM, a continued emphasis on large coal-fired power plants using domestic coals, and limited penetration of renewables, gas and oil. The base-case scenario also needs to make assumptions about the likely progress of structural and institutional change. Using the system planning model, ASCI will simulate the base-case scenario; calculate the present value of system costs; and evaluate the environmental impacts and the extent to which the existing environmental regulations, standards and objectives are not satisfied. The air quality model will serve to verify how far emissions exceed the air quality standards. Estimates will then be made of the cost and financial implications of ensuring the compliance of the base case with existing environmental regulations, standards and objectives.

Again with the assistance of the international consultant, in the second phase of the scenario analysis, the system planning model will be used to simulate each of the policy options defined in Section 4.2.7, one at a time, up to the maximum feasible limit for that option, as a deviation from the base case. The power sector development plan corresponding to each policy scenario will be identified as a least-cost solution, subject to the environmental constraints relating to the environmental attributes of that option (i.e. as implied by the existing environmental regulations, standards, and objectives). For some policy options, it may not be possible to satisfy even the relevant environmental constraints, due to the limits on the availability of that option, although in all cases it will be possible to trace out the supply curve for the option, i.e. relating the change in system cost to the availability. For some policy options, the same demand projections as the official ones will underlie the scenario analysis. The major policy options requiring different demand projections relate to alternative power pricing policies and DSM. Also, where a policy option affects significantly the cost of supply (as revealed through the financial model), then a new demand forecast will need to be formulated. ASCI will show explicitly the financial implications of each policy option.

No single policy option will be able to address the full range of environmental attributes of interest to decision makers. Hence, in the third phase, individual policy options will be combined into a set of policy mixes that will modify the base case in terms of meeting environmental objectives. The study seeks to present policy makers with a range of policy mixes, as alternatives to the base case (which incorporates the official demand forecast and the state government's plans).

In the fourth phase, the second and third phases should be repeated to satisfy an alternative set of environmental constraints. The alternative will be defined in agreement with the international consultant. For example, instead of taking the existing Indian environmental regulations, standards, and objectives, those recommended by the European Community might be considered. The goal of the fourth phase is not to judge the existing standards but rather to test their sensitivity to modification.

4.2.9 Conduct Multi-Attribute Trade-off Analysis

The scenario analysis is designed to make alternative policy options as comparable as possible, by making them satisfy existing environmental regulations, standards and objectives as constraints, wherever feasible. Under the scenario analysis, policy mixes will have been identified, which broadly meet existing environmental constraints. However, some policy options will impact certain other environmental attributes that are not addressed, at least in a quantifiable way, under existing environmental regulations, standards, and objectives. For example, policy options in general have different impacts on GHG; and India at this point has not established targets for GHG reduction. Where policy options differ with respect to environmental attributes outside the constraint set, ASCI will subject them to multi-attribute trade-off analysis, with the assistance of the international consultant. Trade-off graphs displaying environmental attributes against system cost will be prepared, and the implied trade-offs examined.

The main output of this process is expected to be a more comprehensive understanding of the environmental impacts of a range of policy options. By quantifying these impacts and displaying the trade-offs against cost in a form that can be understood by decision-makers, the expectation is that decisions about the future development of the power sector will better reflect environmental concerns than in the past.

4.3 Convene a Technical Workshop

Roughly mid-way through the technical case study, on a date to be determined in agreement with the World Bank, ASCI shall convene in A.P. a 1-2 day technical workshop to discuss the preliminary results of the study. The purpose of this workshop is to bring the study and its early findings to the attention of the technical community in A.P., and the invitees might include representatives from:

- APSEB, Andhra Pradesh Pollution Control Board, and other A.P. government agencies, as appropriate;
- The academic community in A.P.;
- Consulting engineering firms in A.P. and in neighboring states who have provided engineering and environmental impact assessment services to APSEB; and
- NGOs.

It will be ASCI's responsibility to convene the workshop at an appropriate venue, prepare workshop materials, and organize presentations and discussion.

4.4 Assist the National Synthesis

ASCI will participate in the national seminars and workshops convened by the international consultant and assist the international consultant in drawing together the results of the individual state case studies into a national synthesis. In particular, the ASCI case study director will:

- Respond to the "Decision-making and Power Sector Planning Process Questionnaire";
- Take part in the Inception Seminar, to help reach consensus on the objectives and methodology of the study, agree on the activities and outputs to be derived from the case studies and the special studies, select the generic power systems planning model to be used in the case studies, and agree on information transfer between the international consultant and the two states, internal project management and reporting details;
- Attend the national Technical Workshop, to discuss progress with regard to the proposed methodology and modeling;
- Attend the national Mid-way Workshop, to review progress and the technical issues arising from the studies, give the international consultant

feedback on results, and assist the international consultant in preparing the national synthesis report; and

- Attend the national Decision-makers' Workshop, to discuss the preliminary findings of the study, to help bring the recommendations to the attention of key decision-makers and to encourage adoption of the planning model as national policy.

4.5 Disseminate Results: Convene a Final Workshop

Great importance is given to the appropriate dissemination of the results of the study. It is anticipated that the findings of the study will be presented by ASCI towards the end of the case study at a state-level dissemination workshop. ASCI will be responsible for:

- Convening the workshop at an appropriate venue in A.P.;
- Drawing up an appropriate list of invitees;
- The preparation of workshop materials;
- The organization of the workshop itself; and
- Preparation of workshop proceedings.

4.6 Subcontract Local Indian Consultants

ASCI will engage the services of local Indian consultants, as required, to augment the in-house capabilities of ASCI. Such consultants should be drawn from experts within A.P. and elsewhere. ASCI will be responsible for engaging such consultants, including definition of their terms of reference, and for directing and supervising their work. Individual local consultants will be selected subject to the agreement of the World Bank; and rates of compensation to such consultants are subject to the terms of the contract between ASCI and the World Bank, which establishes the maximum daily rate allowable.

5. Coordination, Reporting Requirements and Progress Meetings

Recognizing that a major objective of the overall study is the preparation of a national synthesis that is grounded in the detailed results of the individual state case studies, coordination between the case study directors and the international consultant will be necessary.

In order to facilitate communication and coordination between all of the parties involved in the study, and in particular to keep the international consultant abreast of issues and problems likely to affect their ability to prepare a national synthesis, timely progress reporting and review meetings are an essential part of the study. The reporting requirements are as follows:

5.1. Quarterly Progress Reports

A quarterly progress report will be prepared with the following elements:

- Technical sections, indicating progress achieved in meeting the study's objectives for the quarter, identifying any points of weakness and (where appropriate) recommending changes in the study's activities/inputs;

- Discussion of objectives for the following quarter, with particular emphasis on any problems or constraints that may be faced in meeting the proposed schedule; and

- Budget report, showing actual versus planned expenditures.

These Quarterly Progress Reports will be submitted to the World Bank. They are expected to be succinct documents (5-10 pages), designed primarily as a management tool, rather than as a vehicle for communicating actual technical results.

5.2 Review Meetings

Review meetings will be held with the international consultant in Delhi, probably on at least four occasions. These meetings will be attended by the state case study directors, plus whatever senior technical staff may be deemed appropriate. The timing of these meetings will be determined by the international consultant in consultation with the state case study directors, and will generally be attended by the World Bank study team. These review meetings will typically be of two days duration, and will have the following general agenda:

- Progress reports by state case study directors;

- Progress reports by consultants in charge of special studies; and

- Progress report by the international consultant.

At the Inception Seminar, it is expected that the international consultant and the state case study directors will agree upon a common word processing software format for the exchange of documents and reports (see Section 7.1).

By the time of the second review meeting (but not later than six months after the start of the study) ASCI will complete a set of trial runs of the models, for the base case scenario and a sample of options, to be determined in consultation with the international consultant.

6. Schedule

6.1 *The Master Schedule*

The master schedule for the study is shown in the Table below. Since the A.P. case study is one of several inputs planned for this study, its implementation must be coordinated in order for the national synthesis to be prepared in a timely manner. The estimated deadline for completion of the overall national study is January, 1998, so the A.P. case study must be completed by June, 1997.

Master Schedule for Case Studies and National Synthesis

	Initiate Work	**First Draft Report**	**Final Draft Report**
A.P. Case Study	7/96	12/96	6/97
Bihar Case Study	7/96	1/97	6/97
National Synthesis	5/96	11/97	1/98

6.2 *The A.P. Schedule*

Although ASCI is free to modify the details of the scheduling of the individual tasks, as it sees appropriate, with the agreement of the World Bank, the timing of the major milestones should be met. The schedule for the A.P. case study, as agreed with the case study director, will become part of the contract between ASCI and the World Bank.

7. Outputs

The deliverables are as follows:

7.1 The Case Study Report

A detailed technical report on the state case study, with an appropriate executive summary of no more than 30 pages, and technical annexes as appropriate, constitutes the principal deliverable.

The final report shall be prepared in a format suitable for international distribution. Graphics shall be prepared in an appropriate computer-based software package, and integrated into the text prepared in modern word processing software (WordPerfect, Word), and printed on a laserjet printer. Dot-matrix printers or manual typewriters are not acceptable as a printing format for the final report. The budget should provide for the preparation of 100 copies of the final report.

7.2 Workshops

ASCI will conduct the workshops as described under 4.3 and 4.5, above.

ASCI will prepare, in advance of each workshop, a set of appropriate workshop materials, including copies of papers to be presented at the workshop.

Annex B

Decision Making and Power Systems Planning Questionnaire

ENVIRONMENTAL ISSUES IN THE POWER SECTOR

DECISION MAKING AND POWER SYSTEMS PLANNING QUESTIONNAIRE

1 INTRODUCTION

The following questionnaire is concerned with the opinion and views of your organisation concerning environmental and other issues relating to the power sector.

The answers you give will remain completely confidential unless you indicate otherwise. The aggregate results may be published but will be presented in such a way that they cannot be attributed to your organisation.

2 ABOUT THE RESPONDENT

Name of respondent 2.1

Job Title of respondent 2.2

3 GENERAL ENVIRONMENTAL PROBLEMS IN INDIA

3.1 WHAT DO YOU CONSIDER TO BE THE GREATEST ENVIRONMENTAL PROBLEMS FACING INDIA? PLEASE RANK THE FOLLOWING, WHERE 1 IS THE BIGGEST PROBLEM. IF YOU DO NOT KNOW PLEASE TICK THE LAST BOX.

Water Supply ☐
Water Pollution ☐
Air Pollution ☐
Deforestation ☐
Waste Disposal ☐
Urbanisation ☐
Biodiversity issues ☐
Land degradation ☐
Other, please specify .... ☐
Do not know ☐

3.2 WHICH DO YOU CONSIDER TO BE THE GREATEST CONTRIBUTOR TO INDIA'S ENVIRONMENTAL PROBLEMS? PLEASE RANK THE FOLLOWING, WHERE 1 IS THE GREATEST CONTRIBUTOR. IF YOU DO NOT KNOW PLEASE TICK THE LAST BOX.

- Transport sector ☐
- Mining ☐
- Oil or gas exploration ☐
- Hydro power generation ☐
- Thermal power generation ☐
- Power transmission ☐
- Agriculture ☐
- Waste disposal ☐
- Industry ☐
- Tourism ☐
- Other, please specify .... ☐
- Do not know ☐

4 ENVIRONMENTAL PROBLEMS AND DECISION MAKING IN THE POWER SECTOR

4.1 WHAT DO YOU CONSIDER TO BE THE GREATEST ENVIRONMENTAL PROBLEMS RESULTING FROM THE ELECTRICITY INDUSTRY IN INDIA? PLEASE RANK THE FOLLOWING, WHERE 1 IS THE BIGGEST PROBLEM. IF YOU DO NOT KNOW PLEASE TICK THE LAST BOX.

- Air pollution ☐
- Water pollution ☐
- Ash disposal ☐
- Nuclear waste disposal ☐
- Land pre-emption (eg for power station sites) ☐
- Land degradation (eg for open cast mining) ☐
- Deforestation ☐
- Loss of biodiversity ☐
- Human resettlement ☐
- Other, please specify .... ☐
- Do not know ☐

4.2 DO YOU HAVE THE POWER TO MAKE AN IMPACT ON ENVIRONMENTAL POLICY IN THE POWER SECTOR? PLEASE TICK THE APPROPRIATE BOX.

Yes, I have considerable influence ☐
Yes, I have some influence ☐
I have very limited influence ☐
No, I have no influence ☐

4.3 ARE YOU EVER REQUIRED TO TAKE POLICY OR INVESTMENT DECISIONS WHICH REQUIRE A TRADE-OFF BETWEEN ENVIRONMENTAL IMPACTS? PLEASE TICK THE APPROPRIATE BOX

Frequently ☐
Sometimes ☐
Infrequently ☐
Never ☐

4.4 WHICH OF THE FOLLOWING STATEMENT APPLIES TO YOU ABOUT THE WAY YOU WOULD TAKE POLICY OR INVESTMENT DECISIONS INVOLVING TRADE-OFFS BETWEEN ENVIRONMENTAL IMPACTS, SOCIAL IMPACTS AND MONETARY COSTS? PLEASE TICK THE APPROPRIATE BOX.

I am in the dark about trade-offs ☐
I have some information about trade-offs ☐
I know where to obtain information about trade-offs ☐
I have enough information to make an informed decision ☐
I do not need this information to make a decision ☐

4.5 *ON WHAT BASIS ARE DECISIONS TAKEN AT THE MOMENT CONCERNING POLICIES OR INVESTMENTS WHICH REQUIRE TRADE-OFFS BETWEEN ENVIRONMENTAL IMPACTS, SOCIAL IMPACTS AND MONETARY COSTS? PLEASE TICK THE APPROPRIATE BOX*

Informed decision ☐
Expert judgement ☐
Strength of lobby groups ☐
Emotions ☐

4.6 DO YOU CONSIDER THAT POLICY DECISION MAKING CONCERNING ENVIRONMENTAL ISSUES IN THE POWER SECTOR IS ADEQUATE? PLEASE TICK ONE OF THE FOLLOWING BOXES.

There is little scope for improvement ☐
It is not perfect, but it is acceptable ☐

There is plenty of scope for improvement ☐
It is inadequate and should be improved ☐

4.7 WHICH IS THE MOST IMPORTANT WAY IN WHICH ENVIRONMENTAL DECISION MAKING CAN BE IMPROVED IN THE POWER SECTOR? PLEASE TICK ONE OF THE FOLLOWING BOXES:

More public consultation ☐
Better information on environmental impacts ☐
Encouraging awareness in power sector management ☐
Stricter regulations on power utilities ☐
Better procedures for planning power investments ☐
Better environmental management in power utilities ☐
Other, please specify .... ☐
Do not know ☐

5 GENERAL PROBLEMS IN THE ELECTRICITY INDUSTRY IN INDIA

5.1 WHAT ARE THE MAJOR PROBLEMS FACING ELECTRICITY CONSUMERS IN INDIA AT THE PRESENT TIME? PLEASE RANK THE PROBLEMS, WHERE 1 IS THE BIGGEST PROBLEM. IF YOU DO NOT KNOW PLEASE TICK THE LAST BOX.

Power cuts ☐
Poor quality of supply (low voltage or low frequency) ☐
High prices to industrial consumers ☐
Subsidies from state budgets to State Electricity Boards ☐
Long waiting lists for new connections ☐
Other, please specify .... ☐
Do not know ☐

5.2 WHAT ARE THE MAJOR PROBLEMS FACING ELECTRICITY SUPPLY COMPANIES IN INDIA? PLEASE RANK THE PROBLEMS, WHERE 1 IS THE BIGGEST PROBLEM. IF YOU DO NOT KNOW PLEASE TICK THE LAST BOX.

Lack of funds for investment ☐
Poor levels of pay for staff ☐
Low revenues ☐
Non-payment by consumers ☐

Poor training of staff ☐
Low incentives for management to be efficient ☐
Over-staffing ☐
Too much intervention by Government ☐
Non-technical losses (theft of electricity) ☐
No metering of consumers ☐
No access to cheap electricity generation in other States ☐
Other, please specify .... ☐
Do not know ☐

6. SOLUTIONS TO THE PROBLEMS

6.1 PLEASE CONSIDER THE FOLLOWING STATEMENTS AND INDICATE WHICH, FROM THE LIST, BEST DESCRIBES YOUR REACTION:

6.1.1 More information on the trade-offs between environmental impacts and economic and social costs is required.

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐
Do not know ☐

6.1.2 Environmental problems in the power sector in India could be solved cheaply.

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐
Do not know ☐

6.1.3 Environmental problems in the power sector are related to other power sector problems, such as lack of investment funds (see Question 5.2 above for a list of problems).

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐
Do not know ☐

6.1.4 Environmental improvements can only be achieved with high social costs.

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐
Do not know ☐

6.1.5 Technical solutions are the main answer to environmental problems in the power sector.

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐
Do not know ☐

6.1.6 Institutional reform would be a major help in reducing the environmental impacts of the power sector in India.

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐
Do not know ☐

6.2 WHICH DO YOU CONSIDER TO OFFER THE BEST TYPE OF SOLUTION TO THE ENVIRONMENTAL PROBLEMS IN THE ELECTRICITY SECTOR IN INDIA? PLEASE RANK THE FOLLOWING, WHERE 1 INDICATES THE BEST SOLUTION. IF YOU DO NOT KNOW, PLEASE TICK THE LAST BOX.

Inter-fuel substitution (eg renewables, natural gas, ..) ☐
Technical solutions - energy efficiency (cogeneration, insulation, ...) ☐
Technical solutions - coal (beneficiation, ...) ☐
Technical solutions - power (ESPs, low NOx burners, FGD, ..) ☐
Clean coal technology (FBC, IGCC, ...) ☐
Management solutions without institutional change (loss reduction, improved plant availability, better ash handling, ...) ☐
Policy instruments (environmental taxes, tradable permits ..) ☐
Policy instruments (DSM, energy efficiency campaigns, ...) ☐
Institutional change (privatisation, restructuring, ...) ☐
Raising electricity prices (residential or agricultural) ☐
Better approach to plant siting and inter-state trade ☐
Other, please specify .... ☐
Do not know ☐

6.3 WHICH MANAGEMENT SOLUTIONS DO YOU CONSIDER OFFER THE BEST ANSWER TO THE GENERAL PROBLEMS IN THE ELECTRICITY SECTOR IN INDIA? PLEASE RANK THE FOLLOWING, WHERE 1 INDICATES THE BEST ANSWER. IF YOU DO NOT KNOW OR DO NOT BELIEVE THERE IS A SOLUTION, PLEASE TICK ONE OF THE LAST TWO BOXES.

Technical loss reduction ☐
Non-technical loss reduction (theft) ☐
Meter all electricity supplied ☐
Enforcement of payment ☐
Improving plant availability ☐
Shedding staff ☐
Improved staff incentives ☐
Improved staff training ☐
Other, please specify .... ☐
Do not know ☐
No management solution will help ☐

6.4 WHICH INSTITUTIONAL CHANGES DO YOU CONSIDER OFFER THE BEST ANSWER TO THE GENERAL PROBLEMS IN THE ELECTRICITY SECTOR IN INDIA? PLEASE RANK THE FOLLOWING, WHERE 1 INDICATES THE BEST ANSWER. IF YOU DO NOT KNOW OR DO NOT BELIEVE THERE IS A SOLUTION, PLEASE TICK ONE OF THE LAST TWO BOXES.

Privatisation of all power utilities ☐
Unbundling and privatisation of generation in SEBs ☐
Private power generation and enforced competitive bidding by SEBs ☐
Privatisation of distribution ☐
Privatisation or deregulation of coal supply ☐
Reduction in the role of Government in power industry management ☐
Rule based regulatory arrangements (eg rate of return) for power utilities ☐
Strengthening power of regional boards governing inter-regional trade ☐
Remove restrictions on fuel imports ☐
Other, please specify .... ☐
Do not know ☐
No institutional changes will help ☐

6.5 WHICH PRICE REFORMS DO YOU CONSIDER OFFER THE BEST ANSWER TO THE GENERAL PROBLEMS IN THE ELECTRICITY SECTOR IN INDIA? PLEASE RANK THE FOLLOWING, WHERE 1 INDICATES THE BEST ANSWER. IF YOU DO NOT KNOW OR DO NOT BELIEVE THERE IS A SOLUTION, PLEASE TICK ONE OF THE LAST TWO BOXES.

Introduce price incentives for prompt payment ☐
Raise residential electricity prices ☐
Raise agricultural electricity prices ☐
SEBs to introduce cost reflective electricity charges ☐
Central electricity generators to introduce more structured tariffs ☐
Introduce price incentives for energy efficiency ☐
Other, please specify .... ☐
Do not know ☐
No price reforms will help ☐

7 IMPEDIMENTS TO SOLUTIONS

7.1 WHAT DO YOU CONSIDER TO BE THE MAIN REASONS WHY ENVIRONMENTAL PROBLEMS IN THE POWER SECTOR ARE NOT SOLVED AT THE PRESENT TIME? PLEASE RANK THE FOLLOWING, WHERE 1 REPRESENTS THE MAIN REASON. IF YOU DO NOT KNOW OR DO NOT BELIEVE THERE IS A SOLUTION, PLEASE TICK ONE OF THE LAST TWO BOXES.

Environmental regulations not strict enough or do not exist ☐
Environmental regulations not adequately enforced ☐
Lack of resources in the agencies to monitor pollution ☐
Inadequate investment funds in power utilities for pollution abatement ☐
Poor organisation of the power utilities ☐
Poor understanding of environmental impacts in India ☐
Other, please specify .... ☐
Do not know ☐

8 GENERAL QUESTIONS

8.1 PLEASE CONSIDER THE FOLLOWING STATEMENTS AND INDICATE WHICH, FROM THE LIST, BEST DESCRIBES YOUR REACTION:

8.1.1 Low residential electricity prices in India are a serious problem?

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐
Do not know ☐

8.1.2 Low agricultural electricity prices in India are a serious problem?

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐

Strongly disagree ☐
Do not know ☐

8.1.3 Raising public awareness about environmental issues and the problems of the power sector would be helpful.

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐
Do not know ☐

8.1.4 Global warming should be a concern of western countries, but not India.

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐
Do not know ☐

8.1.5 Competition in Indian electricity supply will benefit the Indian economy.

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐
Do not know ☐

8.1.6 Enough is being done to encourage energy efficiency in the generation, transmission and distribution of electricity.

Strongly agree ☐
Agree ☐
Uncertain ☐
Disagree ☐
Strongly disagree ☐

Do not know ☐

9 CONFIDENTIALITY

9.1 DO YOU WISH THE ANSWERS YOU HAVE GIVEN TO REMAIN CONFIDENTIAL?

Yes ☐
No ☐

Yes, with the following exceptions:
....
....
....
....

No, with the following exceptions:
....
....
....
....

Annex C

Environmental Issues in the Power Draft Programme on 29 July 1996

Table 1 Environmental Issues in the Power Sector- Draft Programme on 29 July 1996

Chairman : Dr. J. Horberry (ERM)

TIME		
9.00 - 9.30	Registration	
9.30 - 9.40	Welcome	Energy Management Centre
9.40 - 10.00	Inaugural Address	Ministry of Power
10.00 - 10.30	Background to Project	Mr Robin Bates, World Bank
10.30 - 11.00	Outline of the Project	Mr P. Lewington, ERM
11.00 - 11.30	Tea	
11.30 - 11.55	Environmental Issues	Prof T K Moulik, ERM India
11.55 - 12.15	Discussion	
12.15 - 12.40	General Issues in the Power Sector	Dr. P. Meier, World Bank
12.40 - 13.00	Discussion	
13.00 - 14.00	Lunch	
14.00 - 14.20	Results of the Survey	Mr. B. M. Pant, ERM
14.20 - 14.50	The Policy Making Process	Prof. N. Lucas, ERM
14.50 - 15.15	Discussion	
15.15 - 15.30	Tea	
15.30 - 15.55	Planning Model	Prof. N. Lucas, ERM
15.55 - 16.20	Discussion on Planning Model	
16.20 - 16.45	Open Discussion	
16.45 - 17.00	Chairman's Conclusion	Dr. J. Horberry

Environmental Issues in the Power Sector- Draft Programme on 30 July 1996

Chairman : Dr. J. Horberry

TIME		
9.30 - 11.00	Special Studies (Presentation & Discussions)	The Project Team
11.00 - 11.15	Tea	
11.15 - 12.00	Special Studies (Presentation & Discussions)	The Project Team
12.00 - 12.45	Open Discussion	
12.45 - 13.00	Chairman's Closing Remarks	Dr. J. Horberry
13.00 - 14.00	Lunch	

Afternoon

Meeting involving EMC, ERM, World Bank, ASCI, SCADA, APSEB, APSPCB, AP.Sec.Egy. and AP.Sec.Env., BSEB, BSPCB, B.Sec.Egy., B.Sec.Env. regarding detailed work programme and scope of work for ASCI and SCADA and the establishment of the State Level Steering Committee.

Annex D

Reconciliation of Loss Rates by Consumption Sectors

Reconciliation of loss rates by consumption sectors

Case I shows an energy reconciliation for the BSEB system for 1994-1995.

Column [1] shows the "sales" as recorded in the 1994/95 BSEB financial accounts. Customers are divided into three categories: LT assumed served at 0.4kV; MT, assumed served at 11Kv; and HT, assumed served at 33/66kV. In fact, most of the railway traction demand is supplied at its electrification voltage of 25kV. There are also some customers supplied at 132kV – but for this reconciliation all customers supplied at 25kV and above are simply treated as a single category of HT.

The BSEB consumer sales statistics differentiate between HT and LT, so some assumption is needed to identify the fraction of sales in the relevant category supplied at MT (11kV). For example, BSEB energy statistics indicate that about 56% of "HT Industrial" is supplied at 11kV, the rest as 33kV and above. The adjustment is shown in column [2].

Column [3] is for "adjustments" – as discussed below.

Column [4] shows "sales", equal to what is *recorded* as being metered. In this first case, we assume that this figure is as stated by BSEB, so the total in column [1] and [3], shown in row 40, are equal. At 6,387 GWh.

Column [5] shows the rate of non-technical loss – defined as the percentage of what is actually consumed in each customer class that is not recorded as metered. The values of the loss rates shown here are discussed below. In Column [6] is shown the non-technical loss in GWh, which is added to sales to equal the actual demand (consumption) in Column [7].

In Column [8] are shown the technical loss rates with respect to the energy requirement at each voltage. Column [9] is the corresponding quantity in GWh, and column [10] is the sum of consumption plus technical loss. For example, in row 13, we see the total in column [10] as 3,407 GWh.

In Column [10] we follow through the accounting balance. The total supplied (BSEB plus purchases), shown in row 42, is 8,407 GWh; the total in row 41 is 7,119 GWh, the difference being what is supplied from DVC (another power supplier and distribution in Bihar) at 33kV (shown in row 29).

Row 39 shows the difference between that calculated amount of the energy requirement: row 38 minus row 41: this is shown as 4 in this case. The BSEB and calculated loss rates, as % of supply, shown in rows 46 and 47, respectively, are shown here as almost equal.

Unfortunately for this reconciliation to balance (i.e. row 39=0), it is necessary to assume values for non-technical loss rates that are not very reliable. Clearly values in the range of 3 to 6%

appear to be very much on the lower side. It follows that the sales figures shown by BSEB might have been overstated (1).

What happens when the maximum possible rates for non-technical losses are used? In Case II, non-technical loss rates are shown in the range of 5% to 40%. These are based on the results of feeder studies conducted in other States. It may be noted that non-technical loss rate for agriculture is indicated as very low, namely 5%: is a consequence of the simple proposition that there is no incentive for theft if service to agriculture is neither metered; or, if metered, the application tariff is very close to zero. We have also increased the technical loss rates for the agricultural, domestic and commercial consumers, because the 14.5% rate is based on conditions in urban areas: in rural areas; with typically much longer LT lines, is seems reasonable to use somewhat higher rates.

However, as indicated, once we use plausible rates for non-technical losses, and combine them with BSEB's sales figures, the reconciliation does not balance – row 39 shows an error of 1,863 GWh.

Therefore, we need to adjust sales in such a manner as to again achieve balance. This is done in Case III: if we reduce agricultural sales by 1100GWh, we once again achieve balance (approximately).

These adjustments are subject to some uncertainty, insofar as there are an infinite number of possible such combinations of adjustment values that achieve reconciliation. However, it can be said that they are at least consistent.

The corresponding adjustment for 1993/94 is also shown. To achieve reconciliation, sales adjustments totalling 1,095 GWh are required: the expected loss rate is seen to be 33.4% rather than 19% as indicated by BSEB.

(1) BSEB is of course not the only SEB to have underestimated its loss rates by overstating agricultural consumption. Since the latter is rarely metered, it is calculated according to norms that defy verification. For example, in Haryana, it is estimated that in 1993/94, agricultural consumption was overstated by almost 40%.

RECONCILATION OF LOSSES 1994-95 Case: I

(As per BSEB sales figures)

Sl No	Item	Sales: Data as per BSEB	Sales: Less sold at M T	Sales: Adjustment	Sales: As per this reconcil	Non Tech Loss %	Non Tech Loss GWH	Actual Demand GWH	Tech Loss %	Tech Loss GWH	Total GHW	Remarks
		1	2	3	4	5	6	7	8	9	10	
1	LT consumption											
2	Domestic	726			726	6%	46	772	14.50%	131	903	
3	Commercial	418			418	6%	27	445	14.50%	75	520	
4	Agricultural	1365			1365	6%	87	1452	14.50%	246	1698	
5	Pub. lighting	28			28	6%	2	30	14.50%	5	35	
6	Pub. water works											
7	Bulk supply											
8	Inter state sale											
9	Free supply											
10	Industry (LT)	202			202	6%	13	215	14.50%	36	251	
11	Industry (HT)											
12	Railway / Tract											
13	Total LT	2739			2739		175	2914	14.50%	493	3407	
14	M.T. consumption supplied at 11 kV											
15	Domestic											
16	Commercial											
17	Agricultural											
18	Pub. lighting											
19	Pub. water works	156			156	5	8	164				
20	Bulk supply	93			93	5	5	98				
21	Inter state sale											
22	Free supply											
23	Industry (LT)											
24	Industry (HT)	2973	1305		1668	5	88	1756				
25	Railway / Tract	-										
26	Total M T	-			1917		101	2018			2018	
27	Losses in 11 kV system					Losses at 11 kV @4.6%					262	
28	Energy requirement at 11 kV (feeder requirement)										5687	
29	Less DVC input P(DVC)										(-)1268	
30	HT consumers	-										
31	HT industry	2973	1668		1305	5%	69	1374				
32	Railway / Tract	369			369			369				
33	Inter state sale	57			57			57				
34	Total HT				1731		69	1800			1800	
35	Trans. losses @33 kV				(Loss rate at 33kV) >5.3%						347	
36	Energy requirement at 33 kV										6546	
37	Trans losses at 132/220 kV				(Loss rate at 132/220 kV) >8.1%						577	
38	Energy requirement at 132 kV										7123	
39	Reconcilation error										4	
40	Energy as per this reconcilation	6387			6387							
41	Energy available as per BSEB (Excl. DVC at 33 kV)										7119	
42	Total energy as per BSEB (Incl. DVC @33 kV)										8407	
43	Total Losses										1990	
44	Tech. losses %of generation									19.90%	1674	
45	Non-tech. losses as %of generation									3.80%	316	
46	Total losses as % of generation as per BSEB									24		
47	Total losses as %of generation as per this reconcilation									23.7		

RECONCILATION OF LOSSES 1994-95 Case: II

(As per BSEB sales figures and possible loss rates)

Sl No	Item	Sales: Data as per BSEB	Sales: Less sold at M T	Sales: Adjustment	Sales: As per this reconcil	Non Tech Loss: %	Non Tech Loss: GWH	Actual Demand GWH	Tech Loss: %	Tech Loss: GWH	Total GHW	Remarks
		1	2	3	4	5	6	7	8	9	10	
1	LT consumption											
2	Domestic	726			726	40	484	1210	20 00%	303	1513	
3	Commercial	418			418	40	279	697	20 00%	174	871	
4	Agricultural	1365			1365	5	72	1437	25 00%	479	1916	
5	Pub lighting	28			28			28	14 50%	5	44	
6	Pub water works											
7	Bulk supply											
8	Inter state sale											
9	Free supply											
10	Industry (LT)	202			202	30	87	289	14.50%	49	338	
11	Industry (HT)											
12	Railway / Tract											
13	Total LT.				2739		922	3661		1010	4671	
14	M T. consumption											
	supplied at 11 kV											
15	Domestic											
16	Commercial											
17	Agricultural											
18	Pub lighting											
19	Pub water works	156			156			156				
20	Bulk supply	93			93	5	5	98				
21	Inter state sale											
22	Free supply											
23	Industry (LT)											
24	Industry (HT)	2973	1305		1668	15%	294	1962				
25	Railway / Tract											
26	Total M.T.				1917		299	2216			2216	
27	Losses in 11 kV system					Losses at 11 kV @4 6%					381	
28	Energy requirement at										7268	
	11 kV (feeder requirement)											
29	Less DVC input P(DVC)										(-)1288	
30	HT consumers											
31	HT Industry	2973	1668		1305	7 5%	106	1411				
32	Railway / Tract	369			369			369				
33	Inter state sale	57			57			57				
34	Total HT.						106	1837			1837	
35	Trans. losses @33 kV				(Loss rate at 33kV) 5 3%						437	
36	Energy requirement at 33 kV										8254	
37	Trans losses at 132/220 kV				(Loss rate at 132/220 kV) @8 1%						728	
38	Energy requirement at 132 kV										8982	
39	Reconcilation error										1863	
40	Energy as per this reconcilation	6387			6387							
41	Energy available as per										7119	
	BSEB (Excl DVC at 33 kV)											
42	Total energy as per BSEB										8407	
	(Incl DVC @33 kV)											
43	Total Losses								46 20%		3883	
44	Tech losses %of generation								30 40%		2556	
45	Non-tech losses as %of generation								15 80%		1327	
46	Total losses as % of								24%			
	generation as per BSEB											
47	Total losses as %of generation as per this reconcilation								46 20%			

RECONCILATION OF LOSSES 1994-95 Case: III

(Adjusted sales)

Sl No	Item	Sales: Data as per BSEB	Sales: Less sold at M T	Sales: Adjustment	Sales: As per this reconcil	Non Tech Loss %	Non Tech Loss GWH	Actual Demand GWH	Tech Loss %	Tech Loss GWH	Total GHW	Remarks
		1	2	3	4	5	6	7	8	9	10	
1	LT consumption											
2	Domestic	720			726	30%	311	1037	20 00%	259	1296	
3	Commercial	416			416	20%	185	523	14 50%	89	612	
4	Agricultural	1365		-1099	266	67%	53 2	798	25%	266	1064	
5	Pub lighting	28			28			28	14 50%	5	33	
6	Pub water works											
7	Bulk supply											
8	Inter state sale											
9	Free supply											
10	Industry (LT)	202			202	12	28	230	14.50%	39	269	
11	Industry (HT)											
12	Railway / Tract											
13	Total LT.	2739		-1099	1640		976	2616		658	3274	
14	M.T. consumption											
	supplied at 11 kV											
15	Domestic											
16	Commercial											
17	Agricultural											
18	Pub. lighting											
19	Pub. water works	156			156			156				
20	Bulk supply	93			93			93				
21	Inter state sale											
22	Free supply											
23	Industry (LT)											
24	Industry (HT)	2973	1305		1668	5%	88	1756				
25	Railway / Tract											
26	Total M.T						88	2005			2005	
27	Losses in 11 kV system					Losses at 11 kV @4.8%					255	
28	Energy requirement at										5534	
	11 kV (feeder requirement)											
29	Less DVC input P(DVC)										(-)1288	
30	HT consumers											
31	HT Industry	2973	1668		1305	5%	69	1374				
32	Railway / Tract	369			369			369				
33	Inter state sale	57			57			57				
34	Total HT.				1731		69	1800			1800	
35	Trans. losses @33 kV				(Loss rate at 33kV) @5.3%						338	
36	Energy requirement at 33 kV										6384	
37	Trans losses at 132/220 kV				(Loss rate at 132/220 kV) @8 1%						563	
38	Energy requirement at 132 kV										6947	
39	Reconcilation error										-172	
40	Energy as per this reconcilation											
41	Energy available as per										7119	
	BSEB (Excl DVC at 33 kV)											
42	Total energy as per BSEB										8407	
	(Incl DVC @33 kV)											
43	Total Losses										2947	
44	Tech losses %of generation									21.60%	1814	
45	Non-tech losses as %of generation									13.50%	1133	
46	Total losses as % of									35 10%		
	generation as per BSEB											
47	Total losses as %of generation as per this reconcilation											

Reconciliation of losses for 1993/94

	sales				non-tech.losses		actual	technical losses (at 11kV/LT/TX)			
	data per BSEB	less sold at MT	adjustment		%dem.	gwh	demand	as % of LT	gwh	total	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
LT consumption											
domestic	**604**		-245	359	**40.0%**	240	599	**20.0%**	150	749	
commercial	**344**		-150	194	**40.0%**	129	324	**20.0%**	81	405	
agricultural	**1360**		-700	660	**5.0%**	35	694	**25.0%**	231	926	
public lighting	**28**			28	**20.0%**	7	35	**14.5%**	6	41	
public waterworks	**114**	-57		57	**20.0%**	14	71	**14.5%**	12	83	
bulk supply	**73**	-37		37	**20.0%**	11	48	**14.5%**	8	56	
interstate	**19**	19						**14.5%**	-0	-0	
free supply											
industrialLT	**249**			249	**30.0%**	107	356	**14.5%**	60	416	
industrialHT											
railway traction											
total LT	2791	-113	1094	1584		513	2127		549	2675	<d(0.4kV)
MT consumption		frac at MT									
domestic											
commercial											
agricultural											
public lighting											
public waterworks		**0.50**		57	**10.0%**	6	63			63	
bulk supply		**0.50**		37	**10.0%**	4	41			41	
interstate		**1.00**		19			19			19	
free supply											
industrialLT											
Industry HT		**0.56**		1684	**15.0%**	297	1981			1981	
railway traction											
total MT				1797		308	2104			2104	
losses in 11kV system T(11kV)					(lossrate at 11Kv) >			**4.6%**		231	<T(11kV)
energy requirement at 11kV feeder input										5011	<d(11kV)=d(0.4kV)+T(11kV)+D(MT)
less DVC @ 33kV: P(DVC)										1413	<P(DVC)
HT consumption		sold at MT									
Industry HT	**3001**	-1684		1317	**7.5%**	107	1424			1424	
railway traction	**357**			357			357			357	
total HT	3358	-1684		1674		107	1781			1781	
transmission losses @66/33kV					(lossrate at 66/33Kv) >			**5.3%**		301	<T(66/33kV)
energy requirement at 66/33kV										5680	<d(33/66kV)=d(11kV)+T(66/33kV)+D(HT)-P(DVC)
transmission losses @220/132kV					(lossrate at 220/132Kv) >			**8.1%**		499	<T(220/132kV)
energy requirement @ 220/132kV										6179	<d(220/132kV)=d(33/66kV)+T(220/132kV)
reconciliation error									error >	-0	
energy per this reconciliation	6149			5055							
energy available per BSEB (D) (excludes DVC@33kV)										6179	
total energy per BSEB (incl.DVC @33kV)										7592	
total losses										2537	
tech. losses as% of generation									20.8%	1580	
non tech losses as % generation									12.6%	957	
total losses as % generation, per BSEB									19.0%		
total losses as % generation, this reconciliation									33.4%		

note: all BSEB figures from "BSEB 28th Annual Statement of Accounts: 1994/1995,Schedule 3"

Annex E

Reconciliation of Loss Rates by Consumption Sectors

1 INTRODUCTION

This report has been prepared by ERM India in September 1996 for the Energy and Infrastructure Operations Division of the World Bank as part of the project, "Environmental Issues in the Power Sector". It is designed to be a background paper on environmental stocktaking in India and covers the following main issues:

· the laws, regulations and practices relating to environmental control, mitigation and compensation in the power sector and related activities (such as coal mining); and

· loose policies, voluntary agreements and practices affecting the State Electricity Boards, the National Thermal Power Corporation and the National Hydro Power Corporation etc.

The report is split into the following main sections:

- Institutional and Legislative Framework
- Environmental Clearance Procedures for Power Plants.
- Environmental Stocktaking in the Power Sector.
- Environmental Stocktaking in the Coal Mining Sector.

2 *INSTITUTIONAL AND LEGISLATIVE FRAMEWORK*

2.1 *INSTITUTIONAL FRAMEWORK*

The Ministry of Environment and Forests (MoEF), constituted in 1985, is the nodal agency at the Central level for planning, promoting and coordinating environmental programmes, apart from policy formulation. A number of enforcement agencies assist the MoEF in executing the assigned responsibilities.

The Central Pollution Control Board (CPCB) was established in September 1974, for the purpose of implementing provisions of the Water (Prevention and Control of Pollution) Act, 1974 (Water Act, 1974). The executive responsibilities for the industrial pollution prevention and control are primarily executed by the CPCB at the Central level, which is a statutory authority, attached to the MoEF.

Subsequently, the State Pollution Control Boards (SPCBs) were constituted, to implement the Act in respective States of the Indian Union. Thereafter, the CPCB and SPCBs were also given the responsibility of implementing other specific enactments relating to the environment.

The specific functions of these institutions are as follows:

Ministry of Environment and Forests (at the National level)

- Environmental policy planning;
- Ensure effective implementation of legislation;
- Monitoring and control of pollution;
- Environmental Clearances for industrial and development projects;
- Promotion of environmental education, training and awareness; and
- Forest conservation, development and wildlife protection.

Central Pollution Control Board (at the National level)

- Promote cleanliness of streams and wells;
- Advise the Central Government on the matters concerning prevention, control and abatement of water and air pollution;
- Co-ordinate and provide technical and research assistance to SPCBs;
- Lay down, modify or annul the standards for a stream or well, and for air quality;
- Planning and execution of nation wide programmes for the prevention, control or abatement of Water and Air pollution; and
- Ensure compliance with the provisions of the EPA, 1986.

State Pollution Control Boards (at the State level)

- Planning and execution of state wide programmes for the prevention, control or abatement or Water and Air pollution;
- Advise the State Government on prevention, control and abatement of water and air pollution and siting of industries;
- Ensure compliance with the provisions of the relevant Acts;
- Lay down, modify or annul the effluent and emission standards;
- Ensure legal action against defaulters; and
- Evolve techno-economic methods for treatment, disposal and utilization of the effluent.

2.2 LEGISLATIVE FRAMEWORK

India has provided for the protection and improvement of the environment in its Constitution. Article 51-(g) of the Constitution states that "It shall be the duty of every citizen of India to protect and improve the natural environment including forest, lakes, rivers and wildlife and to have compassion for living creatures".

Primary legislation in India is in the form of Acts which provide a framework for control. These are all applicable at National level. Key Acts on environmental protection include the following.

- The Water (Prevention and Control of Pollution) Act, 1974, as amended upto 1988.
- The Water (Prevention and Control of Pollution) Cess Act, 1977 as amended upto 1991.
- The Air (Prevention and Control of Pollution) Act 1981, as amended upto 1987.
- The Environment (Protection) Act, 1986.
- The Public Liability Insurance Act, 1991.

Detailed requirements are set out in Rules which are made under the Acts. The list of Rules made under various environmental Acts is as follows.

- The Water (Prevention and Control of Pollution) Rules, 1975.
- The Water (Prevention and Control of Pollution) Cess Rules, 1978 as amended upto 1992.
- The Air (Prevention and Control of Pollution) Rules 1982 and 1983.
- The Environmental (Protection) Rules, 1986.
- The Hazardous Wastes (Management and Handling) Rules, 1989.
- Manufacture, Storage and Import of Hazardous Chemical Rules, 1989.

- Manufacture, Use, Import, Export and Storage of Hazardous Micro-Organisms, Genetically Engineered Micro-organisms or Cells Rules, 1989.

- The Public Liability Insurance Rules, 1991.

- Environmental (Protection) Rules, 1992 and 1993 "Environmental Statement".

- Environmental (Protection) Rules, 1993 - "Environmental Standards".

- Environmental (Protection) Rules, 1994 - "Environmental Clearance".

In addition, the following factors should be noted.

- Some environment, health and safety related aspects are also covered under the Indian Factories Act, 1948.

- The CPCB has stipulated MINAS (Minimal National Standards) for Water Effluents as well as Air Emissions for thermal power stations. These standards limit the concentration and volumes of the effluents and emissions released to the atmosphere. There are also emission standards for various types of boilers (based on the capacities and the fuel used). These standards could be made more stringent by the SPCBs based on the environmental sensitivity of a specific location.

- The project proponents are required to take Consents (for both air and water) and No Objection Certificates (NOCs) from the relevant SPCBs before initiating any activity.

- In addition to the above, CPCB has also specified Ambient Air Quality Standards (for Suspended Particulate Matter (SPM), SO_2 and NO_x) for the residential, commercial, industrial and sensitive zones for the country as a whole. All the major rivers of the country have also been classified based on the designated best use criteria (Five Designated Best Use Classes from A to E). It is the responsibility of the corresponding State Governments to ensure that the water quality criteria are met as per the specifications.

3 CLEARANCE PROCEDURES FOR POWER PLANTS

3.1 SITING CRITERIA

The proper siting of a thermal power plant not only reduces the cost of the pollution control measures but also prevents damage to the natural and human environment. Due to this the MoEF has issued guidelines for the siting criteria of a TPP.

· Location of TPP should be avoided within 25 km of the outer peripheries of the following:
  · metropolitan cities;
  · national parks and wildlife sanctuaries; and
  · ecologically sensitive areas like tropical forests, biosphere reserves, National Parks and Sanctuaries, important lakes and coastal areas rich in coral formations.

· In order to protect the coastal areas above 500 m of High Tide Line (HTL), a buffer zone of 5 km should be kept free of any TPP

· The stack should not fall within the approach funnel of the runaway of the nearest airport.

· The site should be at least 500 meters away from the Flood Plain of Riverine Systems.

· The site should be at least 500 m from highways.

· Location of TPP should be avoided in the vicinity (say 10 km) of places of archaeological, historical, cultural, religious or tourist importance and defence installations.

· The TPP should be surrounded by an exclusion zone of 1.6 km and located on the leeward side of the exclusion zone with respect to the predominant wind direction, Residential/commercial development should be regulated in the exclusion zone on the basis of strict landuse zoning.

· No forest or prime agricultural land should be utilized for setting up of TPP, or for ash disposal.

3.2 ENVIRONMENTAL CLEARANCE PROCEDURES

Under Rule 5 of the Environment (Protection) Rules, 1986 (as amended in 1994), all new projects being set up listed in the Schedules to the Rules must obtain an Environmental Clearance (permit) from the State or Central Government, as the case may be. For grant of this permit, an application is to be submitted to the MoEF (at the Centre) or Department of Environment (at the State level), with the following particulars:

· Filled in Application Form;
· NOC from the SPCB;

- Summary Project Report (one copy);
- EIA/EMP;
- Risk Analysis Report;
- Comprehensive Rehabilitation Plan - if more than 1,000 people are likely to be displaced, other wise only the summary plan;
- Commitment regarding availability of water and electricity from competent State authorities.

The EIA/EMP Reports should be prepared in accordance with the guidelines issued by MoEF. *For this specific purpose "Guidelines for the Industrial Projects" is to be used.*

The Impact Assessment Agency (IAA) at MoEF prepares a set of recommendations based on a technical assessment of the documents and data, furnished by the project authorities, supplemented by data collected during visits to sites or factories, if undertaken, and interaction with the affected population and environmental groups, if necessary. The IAA's procedures to project evaluation can be summarised as follows.

- The IAA, ie the MoEF or the Department of Environment, in consultation with a Committee of Experts of a specific composition, evaluates the requisite documents, and is required to convey their decision within four months from the date of receipt of the proposal. If no comments form the IAA are received within the specified time limit, the proposal would be deemed to have been granted as `Environmental Clearance' unconditionally.

- The IAA upon evaluation of the data would specify an insufficiency or inadequacy to the project proponent within 30 days from the date of submission of the proposal. The project would be reviewed as and when submitted along with the requisite data. It should be noted that submission of inadequate data for the second time would mean rejection of the project summarily.

- The IAA may also recommend the need for a public hearing within 30 days, from the date of receipt of the proposal. However, at least one month's notice, in at least two newspapers, would be required for such a public hearing.

The assessment is completed within a period of ninety days from the receipt of the requisite documents and data from the project authorities. The clearance granted is valid for a period of five years for commencement of construction or operation. No construction work, preliminary or otherwise, relating to the setting up of the project is allowed to be undertaken until the environmental clearance is obtained.

3.3 OTHER CLEARANCE PROCEDURES

Besides environmental clearance, many other clearances are required for setting up a project in the Electricity Sector. The following is the list of clearances required for setting up a TPP:

Table 3.3a Statutory Clearance

Statutory Clearance	Clearing Authority
1. Cost Estimate Section 29(1)	Central Electricity Authority
2. Techno-Economic Clearance	-do-
3. Publication/Section 29(2)	State Government
4. Water Availability	CWC/State Govt.
5. SEB Clearance	SEB/State Govt.
6. Pollution Clearance (Water and Air)	CPCB/SPCB
7. Forest Clearance	MOEF/State Govt.
8. Environment & Forest Clearance	-do-
9. Civil Aviation Clearance for Chimney height	National Airport Authority
10. Company Registration	Registrar of Companies
11. Rehabilitation and Resettlement of Displaced Families by Land Acquisition	MOEF/State Govt.
12. Hydro Projects	Ministry of Water Resources
13. Equipment Procurement	DGTD, Directorate of International Trade

Table 3.3b Non-Statutory Clearance

Non-Statutory Clearance	Clearing Authority
14. Land Availability	State Govt.
15. Fuel Linkage	Dept. of Coal, dept. of Petroleum Natural Gas
16. Financing	CEA/DOP/Dept of Economic Affairs/Financial Institutions
17. Transportation of Fuel	Depts of Coal/Petroleum & Natural Gas/Ministry of Railways. Shipping & Surface Transport

3.4 CONSENT TO ESTABLISH

The provision of `Consent to Establish' under the Water and Air Acts have been made obligatory after amendments to the Acts made in 1988 and 1987 respectively. Earlier, the SPCBs were issuing separate NOCs for siting an industry and for adequacy and appropriateness of the pollution control equipment and related measures. This requirement has now been replaced by the `Consent to Establish'. However, some SPCBs have not yet notified the amended rules. In such cases, the proponent is still required to obtain a NOC from the SPCB and not the `Consent to Establish'. For obtaining a NOC, an application is to be submitted to the SPCB with the following details.

- Application mentioning the purpose of NOC.
- Environment Impact Proforma specified by the SPCB, in quadruplicate.
- Feasibility report.

No application fee is required to be paid for obtaining a NOC for siting of industry.

Consent to establish for discharge of effluents under the Water Act, 1974

All industrial units (operation, process or any treatment and disposal system) which are likely to discharge sewage or trade effluents into a stream, sewer or on land, are required to obtain `Consent to Establish for discharge of Effluents under the Water Act, 1974 (amended in 1988). For obtaining this consent, an application is to be submitted to the concerned SPCB in the prescribed form along with the prescribed application fee.

Consent to establish for emission under the Air Act, 1981

All industrial units (operation or process) located in an Air Pollution Control Area (APCA) declared so by the concerned SPCB, and likely to emit air pollutants in the atmosphere, are required to obtain `Consent to Establish for Emission' under the Air Act, 1981 (amended in 1987). For obtaining this consent, an application is to be submitted to the concerned SPCB, in the prescribed form and along with the prescribed application fee.

3.5 FINALISATION OF CLEARANCE PROCEDURE

- After obtaining the `Consent to Establish', and then the `Environmental Clearance', the project proponents can begin work related to the setting up of the project.

- After this, the project proponent is required to submit a half yearly compliance report indicating effective implementation of the recommendations and connotations, subject to which the `Environmental Clearance' has been granted by the IAA.

3.6 PUBLIC CONSULTATION

In India, there is practically no public participation in the EIA process. Now some companies, as a matter of good practice, have started informing local population about the planned developments. This is actually done to assess people's attitude towards the developmental activity so that no problems are faced at later stages. In number of cases, in the past, developers had to abandon their activities midway due to the public pressure groups.

As far as the EIA is concerned, under Procedures for project evaluation, some public participation is involved but that is very rarely done. The environmental clearance procedures for setting up an TPP are represented in a graphical form in *Annex 1*.

4 ENVIRONMENTAL STOCKTAKING IN THE POWER SECTOR

4.1 HYDROPOWER

This is perhaps the most environmentally friendly mode of power generation and there are no direct environmental problems associated with the generation of electricity from hydropower. Indirect effects arise following the large-scale uprooting of communities necessitated by the dam construction; impaired replenishment of downstream aquifers; and nutrient deprivation of downstream water (as opposed to the benefits from irrigation). As far as regulations for effluent discharge are concerned, the General Wastewater Discharge Standards as laid down in the Environment Protection Act (EPA), 1986, are applicable.

4.2 NUCLEAR POWER

During normal operation, nuclear power plants have few environmental problems. The radioactive contamination of the environment and the resulting exposure to the members of the public are orders of magnitude less than exposures from natural background radiation. However, nuclear power plants do have the problem of safe disposal of high-level nuclear wastes and the risk of accidents. Nuclear Power Plants in India are administratively controlled by the Department of Atomic Energy and they are directly responsible for the safe operation of the plants.

4.3 THERMAL POWER

Indian TPPs use gas, oil, and coal as the fuels for generating power. The environmental problems associated with gas, oil, and coal are discussed separately in the following sections:

4.3.1 Gas-Based Generation

The gas based power plants are more environmentally friendly and have a relatively short gestation period. These are the major reasons for a shift towards gas based TPPs. The only problems associated with the gas based TPPs being emissions of oxides of Nitrogen and cooling tower discharges. The oxides of Nitrogen are regulated by the General Emission Standards under the Air Act, 1981 which restrict emissions to 50 ppm. The regulations for Cooling tower discharges are the same for gas as they are for coal-based TPPs.

4.3.2 Oil-Based Generation

Oil-based generation is relatively new in Indian. The government has given permission for oil based (mainly diesel) TPPs only for captive power generation. The environmental problems associated with and oil-based TPPs are the release of oxides of nitrogen, oxides of sulphur, carbon monoxide. Indian legislation regulates oxides of sulphur through stack height. The other parameters are regulated by the General Emission Standards under the Air Act, 1981. The minimum height of stack to be provided with each generator set is worked out by using the following formula:

$$H = h + 0.2*(KVA)^{1/2}$$

H = Total height of stack in metre
h = Height of the building in meters where the generator set is installed
KVA = Total generator capacity of the set in KVA

Based on the above formula, the following gives the minimum stack height to be provided with different range of generator sets.

Table 4.3a Diesel Generator Sets: Stack Height

Generator Sets	Total Stack Height in Meter
50 KVA	Height of the Building + 1.5 meter
50 - 100 KVA	Height of the Building + 2.0 meter
100 - 150 KVA	Height of the Building + 2.5 meter
200 - 250 KVA	Height of the Building + 3.0 meter
250 KVA	Height of the Building + 3.5 meter

Similarly, for higher KVA ratings, stack height can be worked out using the above formula.

4.3.3 Coal-Based Generation

Coal-based power generation has played an important role in India. Abundance of coal reserves and the short gestation periods has led to a large increase in the level of coal-based power generation. Installed capacity of coal-based TPPs increased from 17,124 MW (as on 31 March, 1981) to 49,147 MW by 31 March, 1994 (TEDDY, 1995-96, New Delhi). Coal-based TPPs are associated with the problems of gaseous and particulate matter emissions, liquid effluents and solid wastes which directly affect the eco-system. The environmental problems associated with the coal-based TPPs are discussed in the following sections under three broad categories, viz., Air Pollution, Water Pollution and Solid Wastes.

Air Pollution

Due to the release of gaseous and particulate matter, ambient air quality in and around TPP tends to be poor. The extent of dispersion depends upon several factors namely the stack height, temperature and velocity of exhaust gases, the meteorological conditions which include wind speed and direction, temperature and humidity and the surrounding terrain. The heavier particles

(> 50 microns) settle down in the immediate vicinity of the plant, blanketing the trees, houses and roads in a thick layer of ash. Adverse impacts include damage to vegetation, damage to water courses, possible damage to land, and a general nuisance to the local inhabitants. The finer particles may stay suspended in the atmosphere for long periods of time and over long distances, and increase the natural levels of dust in the air, cause a variety of health problems.

The Air Act (1981) has provided National Ambient Air Quality Standards (NAAQS). NAAQS have been provided for Sulphur Dioxide, Oxides of Nitrogen, Suspended Particulate Matter, Respirable Particulate Matter (size less than 10 micron-metre), Lead, and Carbon Monoxide. The NAAQS are very dependent on whether the area is industrial, residential, rural or particularly sensitive.

Table 4.3b gives the emission standards for power plants on the basis of its location, age and boiler size. As there were no regulations for the TPPs before 1981, the government had to relax the regulatory limit. The old TPPs did not have adequate space for installing Electrostatic Precipitators (ESPs) and also the older boilers were inefficient, so regulations would not be as strict as for the new ones.

Table 4.3b Emission Standards for TPPs

Boiler size	**Particulate conc., mg/Nm^3**		
	Protected area	**Other area**	
		Old (before 1979)	**New (after 1979)**
Less than 200 MW	150	600	350
200 MW & above	150	-	150

Depending upon the requirement of the local situation, such as protected area, the Pollution Control Boards and other implementing agencies may prescribe a limit of 150 mg/Nm^3, irrespective of generation capacity of the plant. Through Amendment rules in 1990, the emission standards for small-size boiler have been notified as given in *Table 4.3c*.

Table 4.3c Emission Standards for Varying Boiler Capacities

Capacity of Boiler	Control device	Coal consumption, MT/day	Particulate emission, mg/Nm^3
Less than 2t/hr	Cyclones	8-5	1,600
2-15 t/hr	Multicyclones	8.5-64	1,200
More than 15 t/hr	Bag filters	More than 64	150

Coal-based TPPs are also associated with the problems of sulphur dioxide emissions. SO_2 emission standards, based on pollution control equipment in TPPs have not been prescribed. However, MoEF have issued a few guidelines on the desulphurisation of coal, which are:

· all TPPs being built in sensitive areas (which is decided by MoEF), irrespective of their capacity, are required to have provisions for space and facilities for retrofitting Flue Gas Desulphurisation (FGD) system or any other device for SO_2 control;

· the TPPs of 500 MW and above, irrespective of their location are required to have provisions for space and facilities for retrofitting FGD system or any other alternative devices for SO_2 emission control.

In order to have better control of fly ash and sulphur dioxide emissions, MoEF has issued guidelines for coal washing. As per this guideline, TPPs of 500 MW and above are required to have provisions for coal washing, (ie a coal washery is to be provided for such units).

Since 1984, the MoEF has adopted stack height requirements for proper SO_2 emission dispersion to maintain desired ambient air quality. The stack height for different boiler capacities have been notified as given in *Table 4.3d.*

SO_2 emission standards in developed countries are not regulated through stack height, instead, concentration based standards are applied. The developed countries tend have high sulphur content in coals whereas Indian coals have low sulphur content (< 1 percent). Developed countries therefore have to use scrubbers to control the SO_2 emission whereas scrubbers are not required for Indian coal. Control of SO_2 through stack height for effective dilution of its concentration at ground level fulfils the objective.

Table 4.3d Stack Height Requirement in TPPs

Power generation capacity (1)	Stack height, metre (2)
Less than 200 MW/210 MW	$H=14(Q)^{0.3}$, where Q is emission rate of SO_2 in kg/hr, H is stack height in metre
200/210 MW to less than 500 MW	220
500 MW and above	275
Steam Generating Capacities of Boilers:	
Less than 2t/hr	2½ times the neighbouring building height or 9 metre whichever is more
2 - 5 t/hr	12
5 - 10 t/hr	15
10 - 15 t/hr	18
15 to 20 t/hr	21
20 - 25 t/hr	24
25 - 30 t/hr	27
> 30t/hr	30 or using formula $H=14\ (Q)^{0.3}$ (whichever is more where Q is emission rate of SO_2 in kg/hr and H is stack height in metre.

Water Pollution

The major sources of wastewater generation in TPPs are (a) cooling water from condensers, and (b) overflow from ash ponds. The minor sources are (i) boiler blow-down, (ii) cooling tower blow down, (iii) Due to regeneration of ion-exchange columns, (iv) Due to filter bag washing, and (v) oil pollution from oil handling yards.

Under the Water Act, 1974, CPCB has evolved MINAS for wastewater generated during process operations such as condenser cooling and boiler blow-down which are presented in *Tables 4.3e* through *4.3g*.

Table 4.3e MINAS for Condenser Cooling Water (Once through Cooling System)

Parameters	Max limiting Concentration
pH	6.5-8.5
Temperature	Not more than 5°C higher than the intake water temp
Free available Chlorine	0.5 mg/1

Table 4.3f MINAS for Boiler Blow-down

Parameters	Max limiting concentration (mg/l)
Suspended solids	100.0
Oil and grease	20.0
Copper (total)	1.0
Iron (Total)	1.0

Table 4.3g MINAS for Cooling Tower Blow-down

Parameters	Max limiting concentration (mg/l)
Free available chlorine	0.5
Zinc	1.0
Chromium (total)	0.2
Phosphate	5.0

The coal base TPPs generate huge quantities of fly ash (Management of fly ash is discussed under solid waste section). The fly ash collected is turned into slurry and conveyed to ash ponds. Overflow from ash ponds takes place if they are not operated properly. The CPCB has formulated standards for Ash pond effluent discharge which are reproduced in *Table 4.3h.*

Table 4.3h MINAS for Ash-pond Effluent

Parameters	Max limiting concentration
pH	6.5-8.5 preferably greater than 7.0
Suspended solids	100 mg/l
Oil & Grease	20 mg/l

The water used and wastewater generation in TPPs depends on the type of cooling system adopted. CPCB has formulated standards for water consumption and wastewater discharge in TPPs which are reproduced in *Table 4.3i.*

Table 4.3i Water Consumption and Wastewater Discharge in TPPs

Plant Capacity (MW)	Water Consumption (x1000 KLD)				Wastewater discharge (x1000 KLD)		
	Once-through cooling system		Cooling tower system		Once through Cooling System		Cooling tower blow-down
	Min	Max	Min	Max	Min	Max	
30	80	90	80	90	80	90	0.1 approx
110	125	175	125	175	125	175	0.4-0.5

Solid Waste

A major environmental problem associated with the TPP is the arrest of flyash discharged through the stack. Normally TPP use an ESP to arrest the fly ash. Theoretically an ESP can have a 99.99 % efficiency, although the working of an efficient ESP can still pose flyash problems. This is illustrated by the following example: Two units of 210 MW will burn 260 tons of coal and produce about 90 tons of ash, out of which 70 tons is fly ash. Even with a 99% efficiency, about 0.75 tons of fly ash is discharged into the atmosphere every hour. Based on these statistics, it can be estimated that for an annual national power generation of approximately 45,000 MW (CEA, 1991) nearly 70 million tonnes of fly ash is being produced per year. Storage and disposal of this enormous quantity of solid waste in an environmentally friendly manner is a great matter of concern. Fly ash causes extensive air pollution and also brings about significant changes in surface water and groundwater quality adversely affecting landuse practices and public health.

The flyash collected in ESP is normally sluiced with water to ash ponds for disposal. In theory, the ash settles down in the ash ponds and clean water is discharged into adjacent natural water bodies. In practice, however, at most power plants in India, the ash pond is not properly designed or operated. This results in large quantities of fly ash finding its way into reservoirs, streams and rivers, the turbidity increases causing changes in the aquatic ecosystem. Some of the ash settles down causing siltation.

A fraction of ash dissolves in the water, both in the ash pond and later in the natural water bodies, releasing trace quantities of several toxic elements. These substances cause degradation of natural water bodies, in some cases beyond permissible water quality standards. A portion of water from the ash pond leaches into the subsurface and mixes with the groundwater which also gets contaminated.

In the ash ponds, the ash is supposed to remain submerged under a layer of water. However, due to poor design and operations, areas of exposed ash are quite common. During dry periods, the wind blows away portions of exposed ash. Thus the ash pond in most cases becomes a source of air pollution as well as groundwater pollution. This is in addition to the large areas of land necessary to store the ash. This land is essentially lost to its original use. Large expenditure are necessary to reclaim this land after the disposal operations are over, and this is seldom done.

Fly ash has been found to have a binding property. Research studies have shown that fly ash can be utilised in making bricks, building blocks, hume pipes etc. Although the MoEF has not issued any standards for utilisation of fly ash, it has constituted the National Waste Management Council (NWMC) in 1991 to look into the menacing problem of waste disposal. The salient features of a recent NWMC report were:

- that fly-ash should be utilised by the TPPs to the extent of 25 percent by 1993, 50 percent by 1994 and 100 percent by 1995, and no fly-ash slurry will be permitted to be discharged on land with effect from 1st January, 1996; and

- the environmental clearance will not be awarded to TPPs of capacity 500 MW and above unless brick manufacturing plant is also being proposed.

However, these targets have not been met.

4.4 PRACTICES AFFECTING STATE ELECTRICITY BOARDS (SEBS), NTPC ETC

Most of the TPPs in India are managed by State Electricity Boards (SEBs) and the Public Sectors. The majority of power plants are relatively inefficient due to:

- inadequate financial resources;
- poor capacity utilisation;
- slow project implementation - time and cost overruns;
- management inefficiencies - overstaffing;
- cumbersome bureaucratic procedures; and
- poor and inadequate responses to protect consumer interests and lack of autonomy.

Indian TPPs normally do not comply with the environmental regulations. As TPPs are managed by government (either SEBs or Public Sectors), environmental compliance takes a secondary place. In some instances, power plants get away with environmental regulations by obliging SPCBs officials. Also, the power plants in the annual consent application to the SPCB ask for several years for complying with the environmental regulations. In some cases, public sectors enter into litigation with the SPCB on any compliance issue. The objective is to buy time as Indian courts take considerable time (sometimes more than 5 years) to decide on cases.

However, as regulations are getting stricter and SPCBs becoming more active, the trend is changing. The power plants are now keeping environmental compliance as a part of their business plans.

5 ENVIRONMENTAL STOCKTAKING IN THE COAL MINING SECTOR

5.1 INTRODUCTION

The mining industry in India has been growing at an annual rate of 4 to 5 % during last three decades. With private sector and joint venture participation in the mining sector the growth rate is expected to increase in the future. The first significant step by the Government of India (GoI) towards reducing the environmental damage caused by coal mining was the constitution of a Working Group on "Mining and the Environment" by the Department of Science and Technology. The group submitted its recommendations in 1981 which were later published by the Department of Environment (entitled "Environmental Management of Mining Operations"). Since this time, legislation related to mining development was amended to include provisions for environmental protection.

MoEF and Ministry of Mines are the nodal ministries of GoI responsible for creating and enforcing legislation designed to mitigate and control environmental pollution during mining operations. Different regulatory bodies exists both at the Central at State level. CPCB and SPCBs have been created for the control of water and air pollution; the Chief Conservator of Forests (Zonal Office of the Forest Department of Central Government) and the District Forest Officer (DFO) of the State Government are responsible for forest conservation; the Indian Bureau of Mines (IBM) is responsible for Mineral conservation and environmental protection and approval of mining plans in the mining sector; the State directorates of Geology and Mining are responsible for granting leases. The relevant legislation is discussed in the following sections.

5.2 MINES AND MINERALS (REGULATIONS AND DEVELOPMENT) ACT, 1957

In 1986, the Mines and Minerals (Regulation & Development) Act (MM (R&D)), 1957 was amended to include specific provisions relating to the protection of the environment around mines. The requirement of a "Mining Plan" for new applications or renewal of any mining lease was incorporated in the amended act. Salient features relating to mining environment are enumerated below.

Sec. 4A(1): Where the State Government, after consultation with the Central Government, is of the opinion that it is expedient in the interest of regulation for mines and mineral development, preservation of natural environment, control of floods, prevention of pollution or to avoid danger to public health and communications or to ensure safety of buildings, monuments or other structures or such other purposes as the State Government may deem fit, it may, by an order, in respect of any minor mineral, make premature termination of the prospecting licence or mining lease with respect to the area or any part thereof covered by such licence or lease.

Sec. 5(2): No mining lease shall be granted by the State Government unless it is satisfied that there is a mining plan duly approved by the Central Government for the development of mineral deposits in the area concerned.

Sec. 18(1): It shall be the duty of the Central Government to take all such steps as may be necessary for the conservation and systematic development of minerals in India and for the protection of the environment by preventing or controlling any pollution which may be caused by prospecting or mining operations and for such purposes the Central Government may, by notification in the Official Gazette, make such rules as it thinks fit.

5.3 MINERAL CONCESSION RULES (MCR), 1960

These rules are framed under the MM (R&D) Act, 1957 and require that the "Mining Plan" shall incorporate amongst others, a plan of the area showing the water courses, limits of reserved and other forest areas, density of trees, if any, and on assessment of the impact of mining activity on forest, land surface and environment including air and water pollution. The Mining Plan should also include details of schemes for the restoration of the area by afforestation, land reclamation, use of pollution control devices and such measures as may be directed by the Central or the State Government.

5.4 MINERAL CONSERVATION AND DEVELOPMENT RULES, 1988

These rules were also framed under the parent MM (R&D) Act. The rules at present provide for generation of environmental baseline data even before the commencement of prospecting operations. They also provide for the preparation of an EMP incorporating proposals for the prevention and control of air and water pollution, progressive reclamation and rehabilitation of the land disturbed by prospecting operations, a scheme of planting trees and such other measures as may be directed by the Central or State Government for minimising the adverse effect of prospecting operations on the environment.

5.5 RESTRICTIONS ON MINING OPERATIONS IN COASTAL REGULATION ZONE

The MoEF issued a notification No. SO 114(E) dated 19th February, 1991, under the Environment Protection Act and the Rules made thereunder. As per the notification, the coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action (in the landward side) upto 500 metres from the HTL and the land between Low Tide Line (LTL) and HTL has been declared as Coastal Regulation Zone (CRZ). Certain restrictions have been imposed on setting up and expansion of industries in the CRZ. Mining of sands, rocks and other substrata materials is also prohibited except for those rare minerals which are not available outside the CRZ areas. Dredging and underwater blasting in and around coral formations are also not permitted.

5.6 Prohibition of Mining Operations in Ecologically Fragile Areas

The GoI has identified a number of areas/eco-systems as ecologically fragile areas where mining cannot be generally recommended. In case, any person/company are desires to undertake any mining operations in the said areas then as per the notification, an application has to be submitted to the Secretary, MoEF, New Delhi, specifying *interalia*, the details of the area and the proposed process or operation duly supported by an Environmental Impact Statement (EIS) and EMP and such other information as may be required by the Central Government.

There are a few ecologically sensitive areas where mining has been prohibited either by the court's order or by a MoEF notification. Limestone mining in the ecologically fragile Doon valley in the State of Uttar Pradesh has been prohibited under orders from the Hon'ble Supreme Court, the apex court of the country. The Aravalli mountain range covering the northern States of Rajasthan and Haryana is another ecologically sensitive area where mining operations (including renewals of mining leases) have been prohibited under a notification No. S.O. 319(E) dated 7th May, 1992 issued by the MoEF. Mining operations in all areas of Sariska National Park and Sariska Sanctuary in the state of Rajasthan have been prohibited by the Central Government under the Wild Life (Protection) Act, 1972 as they pose a threat to the ecology of the area and to the wild life.

5.7 Consents/Permits Required for a New Mining Project

The following permits/consent are required for a new mining project.

- Consent from the SPCB for water and air pollution separately under the Water Act (1974) and Air Act (1981).

- Site clearance and environment clearances under the EPA, 1986.

- Forest clearance under Forest Acts and Rules if it is within the forest area.

- Approval of mining plan by the Central Government.

- Clearances for mining in the restricted area notified under the EPA.

In addition, statutory permission may have to be avoided from various other Central and State Government agencies depending upon the mine location.

5.8 ENVIRONMENTAL PROBLEMS ASSOCIATED WITH THE MINING SECTOR IN INDIA

India is endowed with a wide range of natural resources. Mining operations of approximately 65 minerals are being carried out from over 3,200 operating mines. A large majority of these mines are opencast and the rest are underground mines. The extent of the environmental damage caused by mining varies with a variety of factors including the scale of operation and nature of topography. The following sections discuss the environmental problems associated with the mining operations.

5.8.1 Land Degradation

Land damage is a major impact of an opencast mining project. The land can get damaged either by the excavations made for extracting minerals or for locating waste disposal sites and other allied operations. In addition, surface subsidence can occur due to large scale underground mining. This can sometimes lead to substantial damage to surface buildings and structures and to the surface drainage pattern. In some cases, the mill tailings generated during ore bonification, if disposed of over ground surface can also cause land degradation due to wind blowing, and silting of surface natural water courses.

5.8.2 Removal of Top Soil/Overburden

Top soil is often removed to open up a mineral deposit. The removed top soil is to be stockpiled separately with proper vegetation cover for future use in agriculture etc. The Indian mines do not give much importance to the storage of top soil, as a result, it gets eroded and degraded. In some cases, top soil has been used for covering waste dumps or outside for agricultural use.

5.8.3 Socio-Economic Impact

Socio-economic implications are always associated with mining projects. The positive impacts are in the form of new employment opportunities, the provision of drinking water and educational facilities, improved communication and health care. The major negative impact is the displacement of large numbers of people from the neighbourhood. This Rehabilitation and Resettlement (R&R) forms a major component of any new mining project.

5.8.4 Air Pollution

Air pollution can be caused by any of the following activities - drilling, blasting, loading and unloading of materials, mobile and fixed equipments (crushers, screens, conveyors etc). The general NAAQS apply to the mining projects.

5.8.5 Water Pollution

During mining operations, water pollution mainly occurs in the following forms:

- mine drainage;
- mine impoundments; and
- fouling of water sources.

Water pollution may be caused by direct discharge of mine water to the water streams and due to wash off from the waste dumps. The nature of water may be acidic or alkaline and it can be contaminated with dissolved chemicals and toxic substances or suspended solid particulates.

The most severe impacts of mine drainage on water regime are the degradation of surface and subsurface water quality, alteration of surface run off and stream flow.

The General Standards for discharge of environmental pollutants are applicable for mining operations.

5.8.6 Noise Pollution

Use of various equipment such as rotary drills, electric shovels, graders, locomotives, fixed and mobile plant installations etc cause noise pollution. Ambient Air Quality standards in respect of noise as laid down in EP Act apply for all the mining activities.

5.8.7 Solid Waste Management

Solid wastes are generated consequent to mining operations and consist of overburden/waste rock, subgrade ore and mineralised rejects. Proper disposal of the solid waste generated is important as it could result in serious environmental pollution and cause degradation of land.

IBM has evolved threshold values for 15 minerals in the country for their separate stacking for future utilisation. Rule 16 of the Mineral Conservation and Development Rules, 1988, prescribes the manner in which disposal of such non-saleable minerals should be done and guidelines for selection of sites for doing so.

The relevant provisions in the Mineral Conservation and Development Rules, 1988, have been reproduced below.

Rule 33(4): Wherever possible, the waste rock, overburden etc. shall be backfilled into the mine excavations with a view to restoring the land to its original use as far as possible.

Rule 33 (5): Wherever backfilling of waste rock in the area excavated during mining operations is not feasible, the waste dumps shall be suitably terraced and stabilised through vegetation or otherwise.

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
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
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
	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

Region/Country	***Activity/Report Title***	***Date***	***Number***
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
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
Mauritius	Energy Assessment (English)	12/81	3510-MAS
	Status Report (English)	10/83	008/83
	Power System Efficiency Audit (English)	05/87	070/87

Region/Country	*Activity/Report Title*	*Date*	*Number*
Mauritius	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	--
	Industrial Energy Efficiency Technical Assistance (English)	08/90	122/90

Region/Country	*Activity/Report Title*	*Date*	*Number*
Tanzania	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
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	--

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
	Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties (English)	06/96	183/96
Fiji	Energy Assessment (English)	06/83	4462-FIJ

Region/Country	*Activity/Report Title*	*Date*	*Number*
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
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
Western Samoa	Energy Assessment (English)	06/85	5497-WSO

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	--

Region/Country	Activity/Report Title	Date	Number
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
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)

Region/Country	Activity/Report Title	Date	Number
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
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 Pricing (English and Polish)	08/98	206/98
	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

MIDDLE EAST AND NORTH AFRICA (MNA)

Region/Country	Activity/Report Title	Date	Number
Arab Republic of Egypt	Energy Assessment (English)	10/96	189/96
Morocco	Energy Assessment (English and French)	03/84	4157-MOR

Region/Country	*Activity/Report Title*	*Date*	*Number*
Morocco	Status Report (English and French)	01/86	048/86
	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
	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
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
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

Region/Country	*Activity/Report Title*	*Date*	*Number*
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
	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
Saint Lucia	Energy Assessment (English)	09/84	5111-SLU
St. Vincent and the Grenadines	Energy Assessment (English)	09/84	5103-STV
Trinidad and Tobago	Energy Assessment (English)	12/85	5930-TR

GLOBAL

	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	--

Region/Country	Activity/Report Title	Date	Number
	GLOBAL (Continuation)		
	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

06/02/99

ESMAP

The World Bank

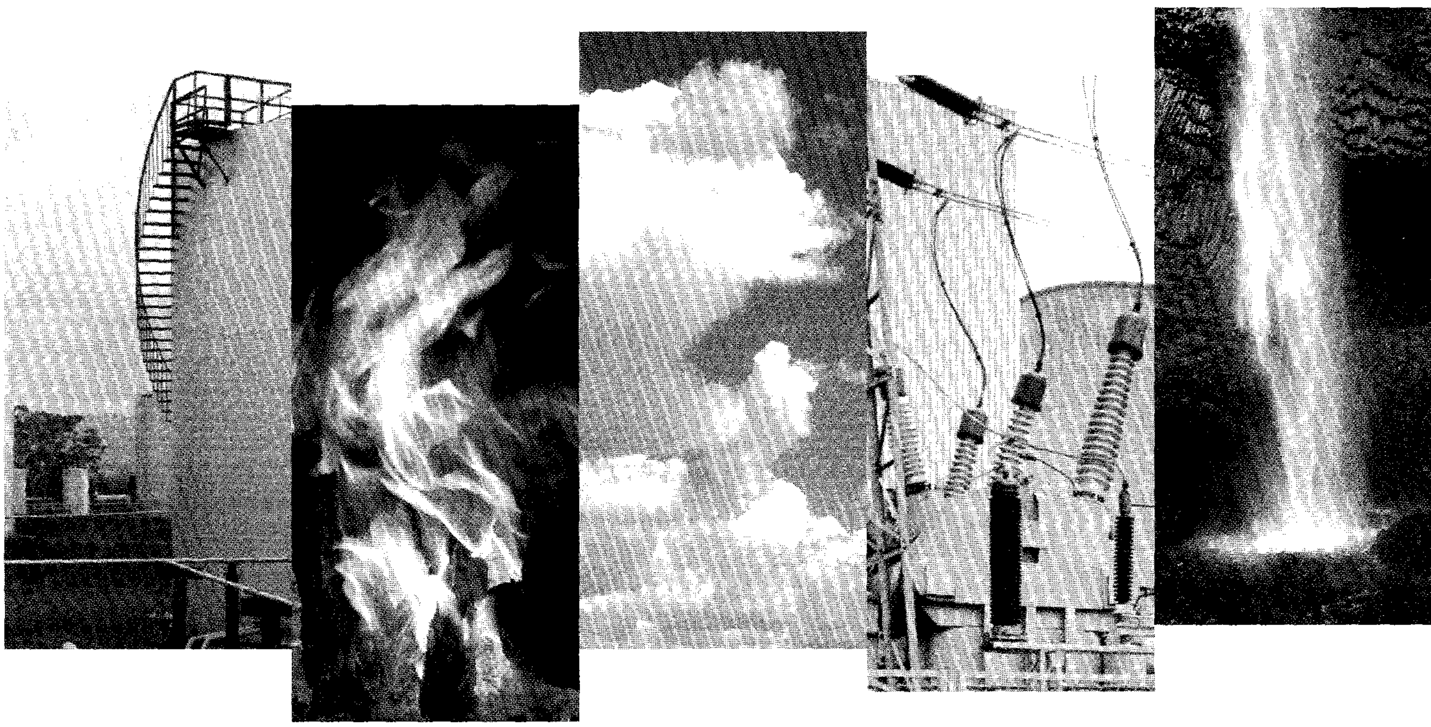
1818 H Street, NW

Washington, DC 20433 USA

Tel.: 1.202.458.2321 Fax.: 1.202.522.3018

Internet: www.worldbank.org/esmap

Email: esmap@worldbank.org



A joint UNDP/World Bank Programme