Grid-connect Electricity Supply in India

Documentation of Data and Methodology
India – Strategies for Low Carbon Growth

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Acronyms and Abbreviations

CEA	Central Electricity Authority
CO_2	Carbon dioxide
GDP	Gross domestic product
GHG	Greenhouse gases
GoI	Government of India
Gt	Gigatons or billion metric tons
GWh	Gigawatt-hour
HVAC	Heating Ventilation and Air Conditioning
IEA	International Energy Agency
IEP	Integrated Energy Policy
IRR	Internal Rate of Return
kWh	Kilowatt-hour
LCG	Low Carbon Growth
LDC	Load Duration Curve
MAC	Marginal Abatement Cost
MIT	Massachusetts Institute of Technology
MNRE	Ministry of New and Renewable Energy Sources
MPa	Megapascal
MoP	Ministry of Power
MW	Megawatt
NEP	National Electricity Policy
NPV	Net Present Value
O&M	Operation and maintenance
PPP	Purchasing Power Parity
R&M	Renovation and maintenance
Rs	Indian rupees
UMPP	Ultra Mega Power Plants

Grid-connect Electricity Supply in India - Documentation of Data and Methodology

Introduction

The World Bank was requested by the Government of India (GoI) to undertake a study, *Strategies for Low Carbon Growth.* The main objectives of this study are to help the GoI to:

- Articulate a cost-effective strategy for further lowering the carbon intensity of the economy at the macro and sectoral levels in ways to enhance national growth objectives by identifying synergies, barriers and potential trade-offs, and the financial needs to address the barriers and trade-offs
- Identify opportunities for and facilitate leveraging of financial resources, including external finance (such as carbon finance) to support of a low-carbon growth strategy, as well as explore the possible need for new financing instruments; and
- Raise national awareness and facilitate informed consensus on India's efforts to address global climate change.

As part of this study, the World Bank is developing a model to analyze the main components of India's future GHG emission projections and assess the costs and benefits of alternative growth strategies with different GHG emissions outcomes. The purpose of this bottom-up model is to examine alternative scenarios and produce a refined and expanded set of assumptions, scenarios and outputs that contribute to the assessment of available GHG projections, mitigation potential and associated costs.

This paper describes the methodology, data and key assumptions used for the power sector supply-side module of the *India Low Carbon Growth* study and presents preliminary results. The module is used to project the required growth in grid-connected electricity supply in India to fiscal 2031–32 under different scenarios and using diverse technology. Other scenarios and sensitivity analysis will be described in a future version of this paper. Unless indicated otherwise, all sources for tables and figures in this paper are World Bank staff calculations.

General description of the Model

Modeling Objectives

The model is being initially developed by the World Bank for this project, with the clear intention of transferring ownership and use to institutions selected by GOI for its future maintenance and upkeep. The model is multi-sector – of which electricity supply is one – and contemplates GHG emissions from combustion and other processes.

It has been agreed that the model shall:

- Include households, non-residential (commercial and public buildings), industrial, power, transport, and agriculture sectors

- Be developed using Visual Basic in Microsoft Excel to ensure that it is user-friendly and can be run, and modified, without complex equipment or training by institutions and researchers in India.
- Have all assumptions and input data clearly visible (with no “black-box” calculations)
- Be capable of testing a number of divergent scenarios in all sectors
- Allow the user to select how to apportion demand to distinct supply options.

Specific objectives for the modeling work include:
- The calculation of future demand based on exogenous variables within the model
- The calculation of GHG emissions throughout the supply chain, and from consumption
- The optional inclusion of upstream and downstream full life cycle GHG emissions released during manufacturing of equipment and construction of plants, and during the disposal of equipment and dismantling of plants
- The calculation of the change in investments and operating costs needed to reduce GHG emissions
- The calculation of the net present value of future expenditures on reducing GHG emissions, with NPV minimization as one objective function
- The evaluation of the emissions of local pollutants in specific, critical, sectors

Model Structure

The model is being developed using a series of linked workbooks as illustrated in Figure 1 that allow an unlimited number of paired-analyses between two distinct scenarios (usually a LCG scenario compared to a reference case).

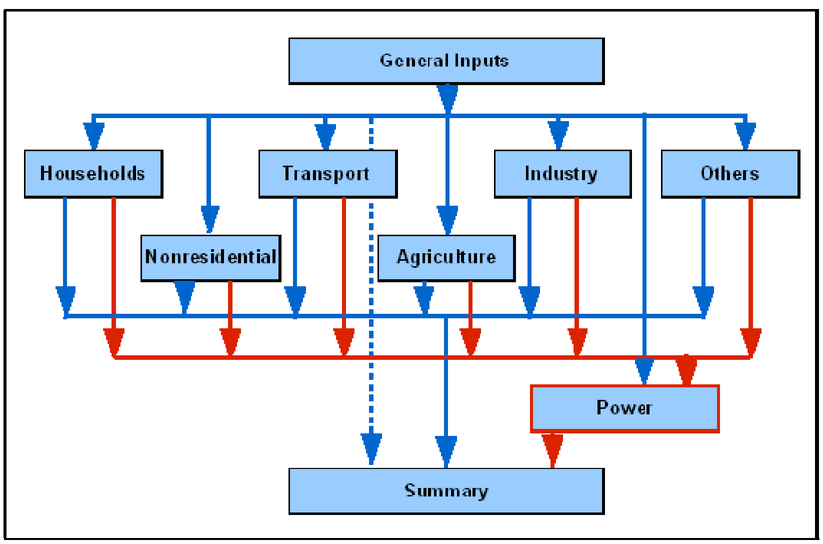


Figure 1 – Model Structure

The timeframe of the model covers the period to 2031/2 on a year-by-year analytical basis but can be easily extended, as required, to longer periods. It is being developed in Microsoft Excel version 2003 to facilitate its use by a wide audience. It is structured to allow an unlimited number of variables where the yearly data points can be entered as separate exogenous data, calculations or complete linked additional spreadsheets. A custom menu interface facilitates navigation and calculation within the model.

Model Outline

The general outline of the model is shown in Figure 2.

Sectors	Themes
Households	• Appliance ownership, demand and energy efficiency • Electricity demand • Other fuels / fuel substitution
Non-residential (Commercial / Institutional)	• Lighting, HVAC, appliances and energy efficiency • Electricity demand • Other fuels / fuel substitution
Transport	• On-road passenger and freight transport • National navigation • Passenger and freight rail • Domestic aviation
Agriculture	• Irrigation – diesel and electricity • Other energy use • Methane emissions from rice and other crops
Industry	• Energy (electric and other fuels) o Grid demand / captive generation o Process heat o Fuel substitution • Process-related GHG emissions
Power	• Electricity Demand • Captive power and grid demand • Transmission and distribution • Grid supply • Required installed capacity (hydro, thermal, renewable, nuclear)
General	• Contains all data and assumptions that are used in more than one sector
Summary	• Combines output from all sectors

Figure 2 – Model Outline

Installation and use of the model

The model is provided in a compressed (zip) file.

Requirements

The model is designed to operate in a Microsoft Windows operating system using XP SP2 or later or any version of Vista. It requires Microsoft Excel version 2003 or later.

The performance of the model will depend on the processor and memory installed in the computer and on the additional applications and processes that are simultaneously run.

As a guide, acceptable performance should be achievable when using a 1.6 GHz or faster Pentium 4 processor and at least 2 GB of RAM for XP or 4GB of RAM for Vista. The use of a separate graphics processor is highly recommended.

If at any time the model appears to stall, or the hard drive access light turns-on during calculations, either (i) shutdown unneeded applications and/or (ii) install additional random access memory.
It is expected that only one sector module (apart from Summary and General) will be open when calculations are performed. If it is desired to keep all open simultaneously, more RAM will be required.

Installation

1) Give a double click on the "India_LCG.zip" file (as attached to this email)
2) Select Open (as required) to access the contents of the zip file.
3) Copy the enclosed "India LCG" folder to anywhere on your hard drive
4) This folder should contain an Excel file "START_LCG_Model.xls" and a folder "Templates". It is important to maintain the integrity of this file structure and to not *mix-and-match* individual files with previous versions since the different workbooks are linked and will not successfully run if these links are damaged.
5) The "Templates" folder will contain each of the modules (currently 4: General, Households, Power and Summary)

Configuration

This model uses Visual Basic extensively and Excel must be setup to allow the macros to run. To do this:

1) Start Excel
2) Select from the menu Tools -> Options -> Security tab -> Macro Security button -> Security Level tab -> Select low
3) Close all dialogs by selecting "OK" twice
4) Close Excel

This only has to be done once.

Running the model

1) To start the model open the "START_LCG_Model.xls" file.
2) The model asks you to select a scenario that already exists or create a new one. Either type a name for the new scenario in the box (for example "Run1") or select an existing scenario from the drop-down list.
3) If you typed a new name in (2) above, the model will then ask if you want to create this new scenario. Select "Yes". The model will ask which existing scenario you want to use as a template for the new scenario. You can either select any existing scenario as a basis for this new scenario or leave "blank sheets" in the box to generate a new one from scratch. Select "OK". This will copy the files in the template into your new scenario.
4) If, in (2) above you selected an existing scenario, the model will open this scenario.
5) The model will ask if you want to use short menus. This option is included only whilst the model is in development. The final user-version will use short menus but

long menus are required during development to make changes to the model. You can use either.

6) Note that each module has its own custom Excel menu.
   Sectors: Allows you to navigate between modules in this program
   Summary: Allows you to navigate within the sheets of this module. This heading and contents change for each different module
   Analysis: Runs any analytical scripts for the module that has been activated.

Model design conventions

The principal design conventions for the user interface in the workbooks are as follows:

For all sector worksheets

- All rows with blue titles (in columns "B" to "E") contain data and calculations specific to the workbook.
- Rows with green titles (in columns "B" to "E") copy data from other workbooks.
- The main year-by-year calculation area in the worksheets is from column “K” to column “AK”. Within this area, all cells where data may be manually entered should be colored light blue. This color convention is not respected in those sheets that contain tables with other than year-by-year data to allow flexibility in identifying different data types.
- Input data and assumptions that are used in more than one sector should be managed in the “General.xls” workbook.
- Output or calculated data from one workbook (blue titles) can be linked as input data to another workbook (green titles) **provided this only happens in the direction of the arrows** shown in Figure 1. Data links that does not meet this rule should only occur via the “General.xls” workbook. Two examples illustrate this point:
  - i) The results of calculations in the “Households” workbook (blue titles) can be linked to the “Power.xls” workbook where they will appear with green titles
  - ii) The results of calculations in the “Households” workbook (blue titles) ***cannot be linked*** to the “Nonresidential.xls” workbook. This should be avoided wherever possible by placing the source data or calculation in the “General.xls” workbook and linking to both “Households.xls” and “Nonresidential.xls”.
    However, a macro can be set up to ***copy*** data from “Households” to the “Nonresidential.xls” workbook
- No data should be linked between workbooks other than via the above process.
- Many sheets contain two sets of input data or calculations in scenarios controlled by a drop-down combo box in cell B9. These are easily identified with turquoise and yellow title boxes in the “A4 to G9” cell area
- Rows with a Yellow box in column "H" have their data in one of the two scenarios. Scenario 1 currently starts in column "BF" and Scenario 2 in column "CZ". Which of these two is currently in use is chosen by the combo box in cell B9 on the same page.
- Many sections of data are compacted. Each section can be opened/closed by clicking in the "+" box on the left hand edge of the spreadsheet. All such sections on that page can

be compacted by clicking in the “1” box and expanded by clicking in the “2” box at the top of the left-hand edge.

- Those sections that contain rows that collect data from one of the two scenarios are indicated by a bottle-green box in column "H".
- Data in rows marked with a "@" in column "A" are collected into a Run Report on the "PrintSummaryByYear" sheet after the data. This is an important record of the scenarios and options selected for that run. A "@" can be inserted in column "A" in any row of any sheet in the workbook.
- All rows and columns marked with a variable name that starts with "#" are used by Visual Basic to locate the data it needs. **Do not delete**.
- All text in Red is used by Visual Basic. Do not use red text for other purposes.
- All calculations currently extend to 2031/2 but can easily be extended to 2051/2 as required.
- The baseline year and currency are controlled by a control panel in the “General.xls” workbook.

Current Status

Data collection has been initiated in all sectors and modules will be released as the required data is made available. All sectors should be available during calendar 2008.

The power sector – supply side is the most advanced. Its key assumptions are presented in the following section.

Power Sector Module

The power sector module consists of the sheets shown in Table 1:

Table 1 - Power Sector Module

Index
Demand
TransDist
Supply
LDC
NewPlants
UnitEfficiency
Units
LoadDisp
Output
Scenario_Analysis
MAC_Analysis
Tables
Tables2
Results
PrintSummarybyYear
PrintSummary_5Year (2005-30)
PrintSummary_5Year (2006-32)
Message

Power Sector module operation

The sequence of operation is as follows:

- The "Demand" sheet defines the demand for grid-supplied electricity. This is based on GDP growth adjusted by the change in demand due to Energy Efficiency and other measures in each sector module. This sheet also allows the impact of modifying the amount of captive supply to be evaluated.
- The "TransDist" sheet takes the total energy supplied by the grid from the previous sheet and analyzes transmission and distribution losses to determine the amount of energy that needs to be generated to supply the grid.
- The "Supply" sheet takes this figure and adds shortages and spinning reserves. It receives the year-by-year available capacity included in the model considering already installed plants plus those yet to be built (slippage from the 10^{th} plan and programmed units in the 11^{th} plan) from the "Units" and "LoadDisp" sheets. It calculates how much additional capacity in new plants needs to be built by the model over the modeling period and assigns this on a scenario-basis to Hydro, Wind, Biomass, Solar and Nuclear. The remaining new plants are built as coal and gas according to a plant type mix defined on this sheet.
- The "LDC" sheet contains the Load Duration curve and allows the shape of the curve to be changed between Scenarios.
- The "NewPlants" sheet defines the specifications of the new plant types to be built by the model. It currently contains 22 plant specifications and can be easily expanded to add more.
- The "UnitEfficiency" sheet contains two lookup tables that define heat rate data for existing plants and those in the 11th plan. For the 12th plan onwards this data is found in the "NewPlants" sheet.
- The "Units" sheet gives the expected characteristics of each existing and new plant in the (modifiable) target year shown in cell C8. This sheet is run individually for every year of the model's timeframe. The units are in five color coded groups:
  - Those plants in operation at the end of the 10th plan (green)
  - New plants that were originally programmed in the 10th plan but because of slippage are now programmed to be completed in the 11th plan (purple)
  - New plants that are now programmed to be built in the 11th plan (blue)
  - Renewables and adjustments taken from the 11th plan working group report that are expected to be built during the 12^{th} and 13^{th} plans (up to 2021) (yellow)
  - New units built by the model to meet the required demand in the modeling timeframe (brown).
- On a year by year basis, data from the "Units" sheet is copied into the "LoadDisp" sheet and dispatched on a merit-order variable cost basis. First, Wind, Biomass, Solar, and Nuclear are run. Then the position of Hydro in the load demand curve is located to give a weighted average load factor for Hydro of 50%. The remaining units are then dispatched on a merit-order variable cost basis between the "always-run" and the start of hydro, all Hydro is then dispatched and then remaining thermal is finally dispatched above hydro to complete the load demand supply. Note that if cell "C1" on the "LoadDisp" sheet

contains 0, all formulae are turned off for speed; you can put 1 in this cell to see the calculations.

- This dispatch is performed on a year-by-year basis and the output data from these calculations is copied to the "Output" sheet. Here additional calculations are performed in all those data-blocks that are not identified by a "#" variable name in column "A".
- The "Scenario_Analysis" sheet contains a Scenario Calculator that enables comparison of any two scenarios and determines the breakeven price of carbon between the two.
- The "MAC_Analysis" sheet contains a Marginal Abatement Cost, Carbon Price and IRR Calculator that enables comparison of any two plant technologies and determines the breakeven price of carbon and the marginal abatement cost between the two.
- The "Results" sheet contains a summarized copy of "Output" with further processing.
- The "PrintSummarybyYear", "PrintSummary_5Year (2005-30)", and "PrintSummary_5Year (2006-32)" are outputs for reporting purposes. It is important to mention that the "PrintSummarybyYear" sheet contains the record of data and assumptions used in the most recent run (as marked by "@" in all sheets).
- The "Tables" sheet contains a series of look-up tables including plant life and payment schedules.
- The "Tables2" sheet contains a series of lookup tables with year-by-year data together with linked data from the General.xls workbook.
- The "Message" sheet contains an indicator that is used by Visual Basic to show the progress made in scripted calculations.

After each run, the model generates a results file (identified by date and time of run) to allow a comparison to be made between different runs.

General Key Assumptions

Inflation

The model is developed in constant Rupees. Currently the base year is 2005.

GDP Annual Growth Rate

Table 2 - GDP Annual Growth Rate

Year	%
2006/7	9.6%
2007/8	9.0%
2008/9	7.6%
2009/0	7.1%
2010/1 - 2021/2	8.0%
2022/3 - 2026/7	7.5%
2028/9- 2031/2	7.0%

2006/7 as shown in Press Information Bureau, Government of India, Advance estimates of national income, 2007-08 Dated 7 February, 2008. Economist Intelligence Unit projection June 19th 2007/8 to 2009/0, GoI target to 2021/2 and assumption of 7.5% 2022/3 - 2026/7 and 7.0% 2028/9- 2031/2

Population Annual Growth Rate and Urban Migration

Table 3 - Population Growth and Urban split

Fiscal Year	Population Growth Rate	Percent Urban
2006/7	1.50%	27.5%
2007/8	1.47%	27.7%
2008/9	1.44%	27.9%
2009/0	1.40%	28.1%
2010/1	1.37%	28.4%
2011/2	1.34%	28.6%
2012/3	1.31%	28.8%
2013/4	1.28%	29.0%
2014/5	1.25%	29.2%
2015/6	1.22%	29.5%
2016/7	1.19%	29.7%
2017/8	1.15%	29.9%
2018/9	1.12%	30.1%
2019/0	1.09%	30.4%
2020/1	1.06%	30.6%
2021/2	1.02%	30.8%
2022/3	0.98%	31.0%
2023/4	0.93%	31.2%
2024/5	0.89%	31.5%
2025/6	0.84%	31.7%
2026/7	0.79%	31.9%
2027/8	0.73%	32.1%
2028/9	0.68%	32.4%
2029/0	0.63%	32.6%
2030/1	0.58%	32.8%
2031/2	0.53%	33.0%

Source: Census of India, Population Projection for India and States 2001-2026, Dec 2006 (projection as on 1st March 2006) extended to 2031 and corrected to 1st October

Discount Rate

The model allows different discount rates to be use for financial analysis and for accruing carbon reduction and both may vary on a year-to-year basis.

This study can optionally use a fixed rate such as 10% or use the Ramsey equation,

$$r = \delta + \eta g \qquad \text{(Equation 1)}$$

where r is the interest rate (used to discount consumption), δ is the rate of pure time preference (set to 0.1 percent), η is the elasticity of marginal utility (set to 2), and g is the per capita growth rate of consumption.

The results of using the Ramsey formula are shown in Table 4. These were used to generate the results in this report.

Table 4 - GDP, MPCE and Discount rate

Fiscal Year	Mean per Capita Expenditure Growth	Discount Rate
2006/7	7.8%	15.7%
2007/8	7.3%	14.6%
2008/9	5.9%	11.9%
2009/0	5.5%	11.0%
2010/1	6.4%	12.8%
2011/2	6.4%	12.9%
2012/3	6.4%	13.0%
2013/4	6.5%	13.0%
2014/5	6.5%	13.1%
2015/6	6.5%	13.2%
2016/7	6.6%	13.2%
2017/8	6.6%	13.3%
2018/9	6.6%	13.4%
2019/0	6.7%	13.4%
2020/1	6.7%	13.5%
2021/2	6.7%	13.6%
2022/3	6.3%	12.7%
2023/4	6.3%	12.8%
2024/5	6.4%	12.9%
2025/6	6.4%	13.0%
2026/7	6.5%	13.1%
2027/8	6.1%	12.2%
2028/9	6.1%	12.3%
2029/0	6.2%	12.4%
2030/1	6.2%	12.5%
2031/2	6.3%	12.6%

Marginal Abatement Cost

Marginal abatement costs are calculated in this study as the present values of costs for avoiding a one-tonne increase in the stock of carbon dioxide equivalent (CO_2e) in the atmosphere as of the end of fiscal 2031/2.

Breakeven Price of Carbon

The breakeven price of carbon is calculated in this study as the price of carbon that makes the choice between the two alternatives financially neutral, that is to say that the present value of for each pair of alternatives is the same.

Power Sector Key Assumptions

The assumptions contained in this section are used in two scenarios (**Scenario 1** and **Scenario 2**) whose results are shown. Those assumptions that do not differentiate between **Scenario 1** and **Scenario 2** are used for both. The model structure allows multiple other scenarios to be run and compared and it is expected that may other options will be looked at after consultation.

Long Run Demand Income Elasticity for Electricity

Table 5 - Long Run Demand Elasticity

Year	%
2006/7 – 2011/2	1.00
2012/3 – 2016/7	0.90
2017/8 – 2021/2	0.85
2022/3 – 2026/7	0.80
2027/8 – 2031/2	0.75

Report on Seventeenth Electric Power Survey of India for 11th plan, Report of the Working Group on Power for the Eleventh Plan (2007–12) deviation for the 12th plan and continuing improvement thereafter

Captive Generation

73,639.7 GWh in 2005/6 growing 131,000 GWh in 2011/2 and constant thereafter

In line with the Report of the Working Group on Power for the Eleventh Plan (2007–12). No future increase in captive signifies that all growth in electricity generation is captured within the model

Transmission and Distribution losses (technical)

Scenario 1

29.03% in 2005/6 linearly reducing to 15.05% in 2025/6 and constant thereafter

In line with the Report of the Working Group on Power for the Eleventh Plan (2007–12).

Scenario 2

Evaluates the impact of a slower improvement in Transmission and Distribution loss reduction, taking an additional 5 years to reach 15.05%.

Load Duration Curve

Scenario 1

A national system-wide Load Duration Curve (LDC) that maintains the 2005 values constant at 79.2% with a curve shape as shown in Table 6.

Table 6 - Power duration curve

Time (%)	Power (%)	Area
0	100.00	
5	92.95	4.8%
10	89.51	4.6%
15	87.66	4.4%
20	86.23	4.3%
25	85.28	4.3%
30	83.90	4.2%
35	82.99	4.2%
40	81.56	4.1%
45	80.71	4.1%
50	79.62	4.0%
55	78.97	4.0%
60	77.59	3.9%
65	76.67	3.9%
70	75.55	3.8%
75	74.05	3.7%
80	72.15	3.7%
85	70.30	3.6%
90	67.92	3.5%
95	62.02	3.2%
100	55.99	3.0%
		79.2%

All India 2005 average calculated from 2005 monthly data from all the Regional Load Dispatch Centers. The All India 2005 load-demand curve shape was computed from a weighted average of the load-demand curves from each of the five Regional Load Dispatch Centers.

Scenario 2

Other middle income economies have peakier LDC curves than India currently has, possibly due to having higher disposable income among other factors. **Error! Reference source not found.** shows in comparison with India (Scenario 1) the curves for Thailand (2002) and three regions of Malaysia (2005). The areas under these curves and the GDP per capita, PPP (constant 2005 international $) for each are shown in Table 7.

Figure 3 Load Duration Curves of other middle income countries

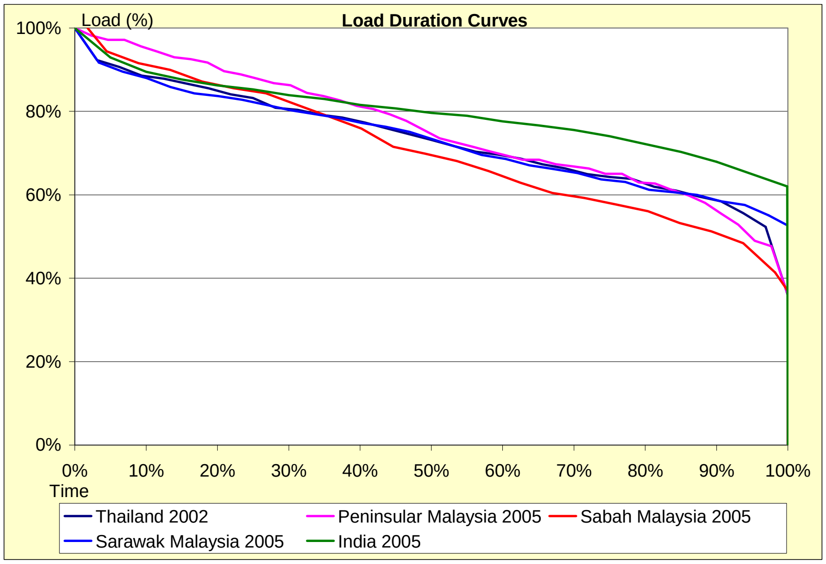


Table 7 - Load Duration Curve areas

Country	Year	GDP per capita, PPP (constant 2005 international $)	LDC area (%)
India	2005	$2,222	79.2%
Thailand	2002	$6,063	73.2%
Malaysia	2005	$11,678	
Peninsular			75.5%
Sabah			68.8%
Sarawak			72.8%

Scenario 2 evaluates the impact of the Indian LDC changing from its historic (2005) shape to that of Thailand (2002) by 2021/2 when GDP per capita PPP will be approximately comparable.

The Load Duration Curves used in scenario 2 change gradually from the India Historic 2005 LDC to that of Thailand 2002 as shown in Table 8.

Table 8 - LDC Areas used in Scenario 2

Year	LDC area (%)
2005/6 – 2006/7	79.2%
2007/8 – 2011/2	77.7%
2012/3 – 2016/7	76.2%
2017/8 – 2021/2	74.7%
2022/3 – 2031/2	73.2%

Transmission and Distribution loss reduction investment

Investment required 24.0 Rs million/MW

As shown in the Annual Report 2004-05 of SRPC (http://www.srpc.kar.nic.in).
In line with the Report of the Working Group on Power for the Eleventh Plan (2007–12).

Supply Shortage / Spinning Reserves

Total energy shortage of 9.8% of supplied demand in 2005/6 is eliminated by 2009/0 and a 5% spinning reserve is achieved in 2011/2 and maintained thereafter.

In line with the Report of the Working Group on Power for the Eleventh Plan (2007–12).

Additional reserve capacity

No additional reserve capacity is currently considered.

In line with the Report of the Working Group on Power for the Eleventh Plan (2007–12).

Plants built by the model

Scenario 1

The model builds plants to meet the growing demand for electricity starting in 2013.
In this scenario, the model builds the following capacity on a scenario basis between 2013 and 2031/2:

- Hydro: 76,000 MW
- Wind: 41,600 MW
- Biomass: 10,410 MW
- Nuclear: 7,600 MW

The remaining additional plants are Thermal (365,240 MW) of which 95% are coal and the rest gas.

This gives an installed capacity at the end of each plan as shown in Table 9

Table 9 - Installed capacity at the end of each plan

End of Plan	11th Plan	12th Plan	13th Plan	14th Plan	15th Plan
Year	2011/2	2016/7	2021/2	2026/7	2031/2
Hydro	57,238	77,164	98,734	118,734	138,734
Thermal	141,877	171,041	247,511	344,471	478,512
Nuclear	6,420	7,920	9,720	11,280	13,060
Renewable	25,070	45,501	70,843	85,893	100,243
Total	230,605	301,627	426,808	560,378	730,549

In line with the Report of the Working Group on Power for the Eleventh Plan (2007–12).

Seventy percent of new Hydro built by the model is considered to be Run of River.

For Coal-fired plants, 10 percent are assumed to use imported coal. The rate of adoption of higher temperatures and pressures that is considered in this scenario is shown in Table 10.

Table 10 – Coal Plant Build mix assumed in Scenario 1

	12th Plan	13th Plan	14th Plan	15th Plan
Year	**To 2016/7**	**To 2021/2**	**To 2026/7**	**To 2031/2**
National Coal (90% of total)				
Subcritical	50%	30%	10%	10%
Low Supercritical	50%	50% to 20%	20%	
High Supercritical		20% to 50%	70%	70%
Ultracritical				20%
Imported Coal (10% of total)				
Subcritical				
Low Supercritical	100%	50%		
High Supercritical		50%	100%	50%
Ultracritical				50%

Scenario 2

This scenario evaluates the impact of building less Hydro and Renewables.
In this scenario, the model builds the following capacity on a scenario basis between 2013 and 2031/2:

- Hydro: 38,000 MW
- Wind: 20,800 MW
- Biomass: 5,205 MW
- Nuclear: 7,600 MW

The remaining additional plants are Thermal (445,240 MW) of which 95% are coal and the rest gas.

This gives an installed capacity at the end of each plan as shown in Table 11.

Table 11 - Installed capacity at the end of each plan

End of Plan	11th Plan	12th Plan	13th Plan	14th Plan	15th Plan
Year	**2011/2**	**2016/7**	**2021/2**	**2026/7**	**2031/2**
Hydro	57,238	69,164	80,734	90,734	100,734
Thermal	143,127	200,011	297,021	418,061	558,512
Nuclear	6,420	7,920	9,720	11,280	13,060
Renewable	25,070	42,001	61,388	68,913	76,088
Total	231,855	319,097	448,863	588,988	748,394

As in Scenario 1, seventy percent of new Hydro built by the model is considered to be Run of River.

For Coal-fired plants, 10 percent are assumed to use imported coal. A slower rate of adoption of higher temperatures and pressures that is considered in this scenario is shown in Table 12.

Table 12 – Coal Plant Build mix assumed in Scenario 1

	12th Plan	13th Plan	14th Plan	15th Plan
Year	**To 2016/7**	**To 2021/2**	**To 2026/7**	**To 2031/2**
National Coal (90% of total)				
Subcritical	60%	50%	30%	10%
Low Supercritical	40%	30% to 20%	30%	20%
High Supercritical		20% to 30%	40%	70%
Ultracritical				
Imported Coal (10% of total)				
Subcritical				
Low Supercritical	100%	80%	40%	20%
High Supercritical		20%	60%	50%
Ultracritical				30%

Plant renovation and end of life

Calculated from date of commission of individual units based on the following table:

Table 13 - Plant renovation and end of life

Years	Planned Life	Extension	End of Life
Hydro	50	35	85
Nuclear	40	-	40
Thermal	25	15	40

Plant renovation cost considered at 30% of initial investment.

Assumptions discussed in meeting on Aug 1, 2007.

Plant and unit level data

A. For existing grid-supply Plants (commissioned prior to the 11th Plan)

Baseline data on existing plants is taken from the CEA CO_2 Baseline Database for the Indian Power Sector version 3 for 2006/7. This includes:

- Plant name
- Unit no
- Date of commission
- Capacity in MW
- Region
- State
- Sector
- System
- Type
- Fuel 1

- Fuel 2
- Net Generation GWh
- Absolute Emissions t CO_2

Where specific plant and unit level data is not available, the station-level and unit-level assumptions in Appendix 2 of this document were used.

B. For units to be built during the 11th Plan

Specific plant identification data was obtained from the 11th plan wherever available. !0th plan plants that were not commissioned during the 10th plan and slipped into the 11th plan were identified from the CEAs All India Electricity Statistics General Review 2007 together with the CEAs National Electricity Plan Volume 1 – Generation (April 2007).

C. Renewables

No specific plant identification was found for the grid interactive renewables to be built during the 11th, 12th and 13th plans as programmed by the Ministry of New & Renewable Energy (MNRE).

D. For units to be built by the model

No specific plant identification or localization was assigned to these units.

Plant Efficiency

A. For existing grid-supply Plants (commissioned prior to the 11th Plan)

For existing plants, energy consumption is calculated for each unit from CO_2 emissions as per CEA CO_2 Baseline Database for the Indian Power Sector version 3 for 2006/7.
After 10 years of use, post 2005, energy consumption per MW is increased at a rate of 0.2%/yr and for a standard life extension renovation (R&M) 90% of this change in energy consumption is recouped.

Based on 1% change in heat rate in 5 years from the MIT "Future of Coal" paper and calculations based on the CEA CO_2 Baseline Database for the Indian Power Sector version 2 for 2005/6

B. For units to be built during the 11th Plan

Energy consumption is calculated from Appendix B of the CEA CO_2 Baseline Database for the Indian Power Sector version 3 for 2006/7.

Table 14 - Energy consumption

	Capacity		Gross Heat Rate	Auxiliary Power Consumption	Net Heat Rate	
	From	to	kcal /kWh	%	kcal /kWh	MJ/KWh
Coal - SubCrit	Up to	99.9	2,753	12.0%	3,128	13.1
	100	199.9	2,317	9.0%	2,546	10.7
	200	299.9	2,317	9.0%	2,546	10.7
	300	599.9	2,255	7.5%	2,438	10.2
	600	on	2,255	5.0%	2,374	9.9
Coal - SuperCrit	Up to	299.9	2,135	9.0%	2,346	9.8
	300	599.9	2,078	7.5%	2,246	9.4
	600	on	2,078	5.0%	2,187	9.2
Lignite	Up to	99.9	2,750	12.0%	3,125	13.1
	100	199.9	2,560	12.0%	2,909	12.2
	200	on	2,713	10.0%	3,014	12.6
Gas	Up to	49.9	1,950	3.0%	2,010	8.4
	50	99.9	1,910	3.0%	1,969	8.2
	100	199.9	1,970	3.0%	2,031	8.5
	200	299.9	1,970	3.0%	2,031	8.5
	300	on	1,970	3.0%	2,031	8.5
Diesel	Up to	0.99	2,350	3.5%	2,435	10.2
	1	2.99	2,250	3.5%	2,332	9.8
	3	9.99	2,100	3.5%	2,176	9.1
	10	on	1,975	3.5%	2,047	8.6
Naphtha	All		2,117	3.5%	2,193	9.2
Hydro	All		0	1.0%	77	0.3
RunofRiver	All			1.0%	77	0.3
Storage	All			1.0%	77	0.3
Pumped	All			1.0%		28.0

Energy consumption is projected to deteriorate at the following rate where year 0 refers to the year of commissioning and to the year of major R&M

Table 15 - Heat Rate Degradation

Year	Heat Rate Degradation %
0	0.00%
1	1.56%
2	2.40%
3	2.79%
4 to 8	2.94%
9	0.90%
10	1.80%
11	2.40%
12	2.70%
13 to 17	3.00%
18	1.20%
19	1.80%
20	2.40%
21	2.70%
22 on	3.00%

Based on data from the UMPP risk analysis report by Mott MacDonald (April 2007) but using three times the degradation rate according to local experience.

C. For units to be built by the model

Energy consumption for coal fired plants is based on data from the UMPP risk analysis report by Mott MacDonald (April 2007). Carbon Capture and Storage is shown with an energy consumption 28% higher than the equivalent Ultra-critical plant in line with the MIT "Future of Coal" paper. An option for Carbon Capture and Storage consumes 28% more energy than the Ultra-Critical plants shown as per the MIT "Future of Coal" paper.

Table 16 - Energy consumption for coal fired plants

Type	Capacity (MW)	MJ/kWh
Indian coal		
Subcritical	500	9.95
Subcritical	250	9.95
Low Supercritical	660	9.64
High Supercritical	800	9.38
UltraCritical	1000	8.97
Imported Coal		
Subcritical	500	9.36
Subcritical	250	9.36
Low Supercritical	660	9.07
High Supercritical	800	8.83
UltraCritical	1000	8.44

Energy consumption is projected to deteriorate at the rates shown in Table 15 in (B) above.

Planned Outages

For existing plants and for those built during the 11th plan, 3% is considered for all plants except where the generation of individual plants in the CEA CO_2 Baseline Database is substantially lower than that given by calculation. For these, a unit by unit review was conducted and percent planned outage individually assigned in each case.

For plants built by the model, 3% is considered for hydro and nuclear, 4.1% for thermal in line with the UMPP risk analysis report by Mott MacDonald (April 2007) and 10% for biomass.

Based on personal communication with Mr R.K. Jain

Probabilistic Forced Outages

For existing plants and for those built during the 11th plan, the figures in Table 17 are assumed:

Table 17 - Forced Outages existing and 11th plan plants

Plant type	% Outages Existing plants	% Outages 11th plan plants
Thermal up to 220 MW	13.5%	6.8%
Thermal over 220 MW Within 10 years of commissioning or R&M After more than 10 years from commissioning or R&M	 8.0% 10.0%	 4.0% 5.0%
Others	6.0%	3.0%

Based on personal communication with Mr R.K. Jain

For plants built by the model, 3.8% is considered for all plants in line with the UMPP risk analysis report by Mott MacDonald (April 2007).

Plant Operations and Maintenance costs (O&M)

For existing plants and for those built during the 11th plan fixed and variable O&M costs were calculated from the Planning Commission Annual Report (2001-02) on The Working of State Electricity Boards & Electricity Departments and indexed to the 2005 baseline.

For thermal plants built by the model, fixed and variable O&M costs were calculated in line with the UMPP risk analysis report by Mott MacDonald (April 2007). For others, fixed and variable O&M costs were used as for 11th plan plants.

Auxiliary Load

For existing plants this is already included in the energy consumption per MW as calculated from the CO_2 emissions reported in the CEA CO_2 Baseline Database.

For plants built in the 11th plan, the auxiliary load data was obtained from Appendix B of the CEA CO_2 Baseline Database for the Indian Power Sector version 2 for 2005/6.

For thermal plants built by the model, auxiliary load data was obtained from the UMPP risk analysis report by Mott MacDonald (April 2007). For others, fixed and variable O&M costs were used as for 11th plan plants.

Investment in New Plant Equipment

For plants built in the 11th plan and by the model, plant equipment costs are taken from the Report of the Working Group on Power for the Eleventh Plan (2007–12), appendix 10.3.

Table 18 - New Plant Equipment

Plant type	On-going projects (crore per MW)	New projects (crore per MW)
Thermal generation		
Coal based		4.0
Gas based		3.0
Hydro generation		
Run of the river	4.5	5.0
Storage	5.5	6.0
Pump Storage		5.0
Nuclear Generation		6.5

The figure of 4 crore per MW cited for coal-based is taken for Subcritical 500 MW units. The relative plant equipment investment costs for other types of coal-fired plant are taken from the UMPP risk analysis report by Mott MacDonald (April 2007) as shown in Table 19

Table 19 - Coal-fired plant equipment

Type	Capacity (MW)	Crore per MW
Indian coal		
Subcritical	500	4.00
Subcritical	250	4.21
Low Supercritical	660	4.28
High Supercritical	800	4.39
UltraCritical	1000	4.72
Imported Coal		
Subcritical	500	3.82
Subcritical	250	4.03
Low Supercritical	660	4.12
High Supercritical	800	4.27
UltraCritical	1000	4.46

Phasing of expenditure of generation projects

For plants built in the 11th plan and by the model, the phasing of expenditure of generation projects is taken from the Report of the Working Group on Power for the Eleventh Plan (2007–12), appendix 10.3 for Thermal and for Hydro. It is assumed that Nuclear would have a similar expenditure cycle to Hydro and that Renewables would have a similar expenditure cycle to Thermal.

For R&M it is assumed that the expenditure flow occurs over a 2 year period with 60% in the first year. The investment in Transmission and Distribution loss reduction is assumed to occur over a 3 year period as shown in Table 20.

Table 20 - Phasing of expenditure

Years before Commission date	0	1	2	3	4	5
Payment Schedule for new plants (% of total cost)						
Hydro	10%	25%	20%	20%	15%	10%
Thermal	30%	30%	25%	15%		
Nuclear	10%	25%	20%	20%	15%	10%
Renew	30%	30%	25%	15%		
Payment Schedule for Rehabilitation (% of total cost)						
Hydro	40%	60%				
Thermal	40%	60%				
Nuclear	40%	60%				
Renew	40%	60%				
T&D loss reduction	30%	30%	40%			

Hydro Utilization

The length of the dry season is considered to be 273 days per year in all regions except for the Northern and North-Eastern Regions where it is considered as 182.
Average wet season effective utilization % of max generation capacity is set to 100%.
Average dry season effective daily utilization % of max generation capacity is set to 32% to give average all-year utilization over the 11th plan period of 50%.

Assumptions discussed in meeting on Aug 1, 2007.

Coal Transport Distances

For existing plants and for those built during the 11th plan, coal transport distances were determined using Google Earth between each plant and the nearest identifiable coal field.

The model does not select sites for the plants it builds. For thermal plants built by the model an average rail transport distance of 500 km was assumed based on:

a) Almost two-thirds of the coal mined in India is transported across distances beyond 500 km according to the International Energy Agency (IEA), 2000, Coal in the Energy Supply of India, Paris, France.
b) However, it is expected that several new plants will be located at the pit-head, but it is understood that land availability issues would not allow this to be the case for the majority of plants.
c) Some plants, using principally imported coal will be located at ports.
d) For the imported coal, it is assumed that the transport cost is included in the fuel price.

Coal Transport Costs

For all plants the cost of rail transport of coal is assumed to be as in Table 21 that is based on Indian Railways Freight Rate Adjustments effective from April 1, 2005.

Table 21 - Coal Transport costs

Distance (km)	Rs/t-km
0	0.8995
200	0.8995
300	0.8380
500	0.7888
800	0.7611
1000	0.7519
1200	0.7458
1500	0.7396
1800	0.7138
2000	0.6880

For Imported coal, it is assumed that the coal price includes all transport costs to the plant.

Beneficiated coal

The model allows coal beneficiation of National coal to be specified for any of the coal fired plants. The assumptions used for the beneficiation process are shown in Table 22.

Table 22 - Beneficiated coal

Volume Reduction	Investment	Expected Life	O&M Variable	Levelized cost (per ton of output)
%	Rs /t annual capacity	years	Rupees /t	Rupees /t
24%	600	35	20	195

http://www.teri.res.in/teriin/news/terivsn/issue5/analysis.htm Note: The cost of beneficiation of coal was considered as Rs.125 per Tonne, in the Report of the Expert committee on Fuels for Power Generation, CEA Planning Wing, February 2004

LCA Lifecycle Emissions (new and retrofit)

The model allows upstream emissions to be specified for all new plants and for all R&M activities. These should include the life-cycle-analysis carbon emissions resulting from the manufacture of all components used, raw materials and construction and repair activities.
Currently the model does not contain values, these will be included as data collection allows.

Fuel costs

A long run pit-head coal price of 571 Rs/tonne is currently considered in the model.

Grade "F" BCCL, CCL, SECL as per http://www.coalindia.nic.in/pricing.htm Note: The cost of national coal was considered as Rs.517 per Tonne including Basic cost, royalty, Taxes and Duties, and Handling charges in the Report of the Expert committee on Fuels for Power Generation, CEA Planning Wing, February 2004

A pit-head estimated price for Lignite Rajasthan deposits of 800 Rs/ton is considered.

Imported coal is currently priced in the model at US$60/tonne.

Based on data from the UMPP risk analysis report by Mott MacDonald (April 2007)

Nuclear is currently priced in the model at Rs 50988 / TJ.

Using the calculator at http://www.wise-uranium.org/nfcc.html with an Apr 28, 2008 price of Natural Uranium of US$65/ lb.

The prevailing cost of Naphtha has been taken as Rs. 17,400/tonne (including handling charges of Rs 100 per Tonne at port).

The Report of the Expert committee on Fuels for Power Generation, CEA Planning Wing, February 2004

Fuel calorific values

Indian values taken from CEA documents. Imported coal taken from the UMPP risk analysis report by Mott MacDonald (April 2007)

"All India Electricity Statistics, General Review 2007." Ministry of Power Government of India, New Delhi CO2 emissions

Results

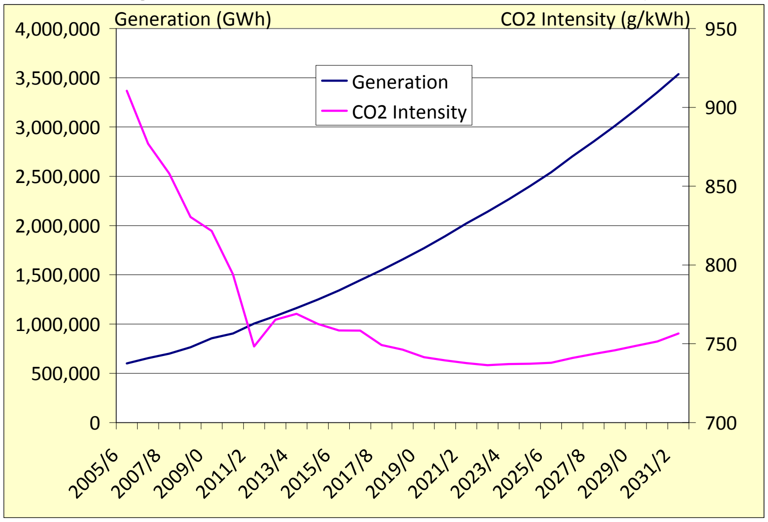
The power sector module is a tool kit that allows an infinite number of scenarios to be investigated and run. To demonstrate its operation, two scenarios have been selected. One (Scenario 1) is based on the goals and commitments laid out in the 11th Plan and associated working group reports. The other (Scenario 2) evaluates slight changes to this plan and how these might affect CO_2 emissions, plant investment and operation.

Scenario 1

The initial grid supply condition in the model shows a shortfall at the end of the 10th Plan (2006–07) of 10.9 percent. The forecast assumes that all the system expansion and generation, transmission and distribution improvements contemplated in the 11th plan occur on time and that, as stated by the Working Group Report captive power generation increases from 78,000 GWh in 2006/7 to 131,000 GWh in 2011/2. Since one important goal of the 11th plan is to achieve a spinning reserve of 5 percent on an average annual energy basis by 2011/2, captive power generation is held constant in the model after this date with the rest of electricity being supplied by the grid.

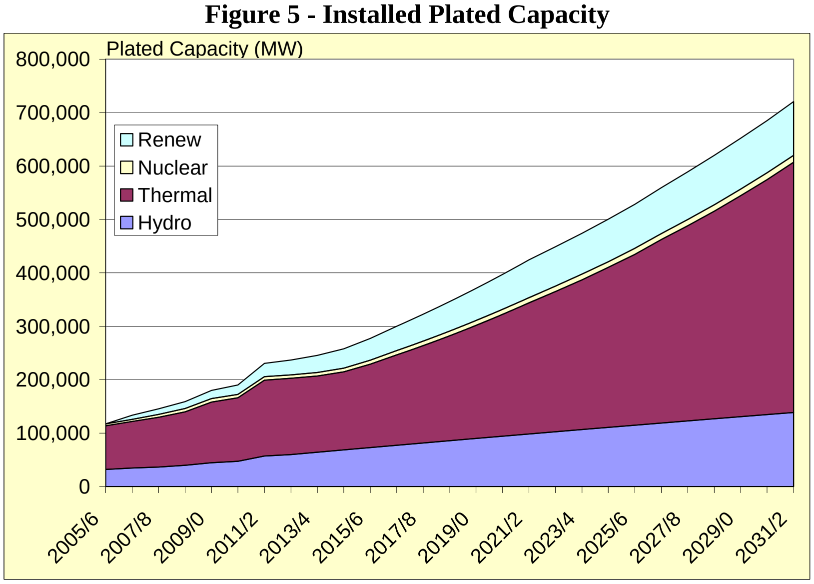
Under this scenario, and based on all the Scenario 1 assumptions shown above, the expected combined sum of power supplied to the grid and captive power generated by users increases at an average annual rate of 6.7 percent from 732,000 GWh in 2006/7 to 3,670,000 GWh in 2031/2 as shown in Figure 4.

Figure 4 - Power Generation and CO2 Intensity



Installed plated capacity grows from 133,600 MW in 2006/7 to 720,000 MW in 2031/2 at an average annual rate of 7 percent as shown in Figure 5. Over this period, Thermal grows at an annual average rate of 7.0%, Hydro at 5.7% whilst Nuclear maintains an average of 5.0% per year and Renewables 10.8% per year.

Figure 5 - Installed Plated Capacity



To achieve this rate of growth, considerable investment is required. The model builds plants from 2013/4 on, after the completion of those in the 11th Plan. Covering this period, the investment requirement (based on year of start of operation of each plant) increases from Rs 444 [E+09] in 2013/4 to Rs 1900 [E+09] in 2031/2 of which a cumulative 64% is for

Thermal followed by 17% for Hydro and 14.3% for Renewables. R&M accounts for less than 3% of the accumulative total. Figure 6 illustrates this requirement whilst Figure 7 shows the required investment on an expenditure flow basis.

Figure 6 - Investment required (Year of Operation)

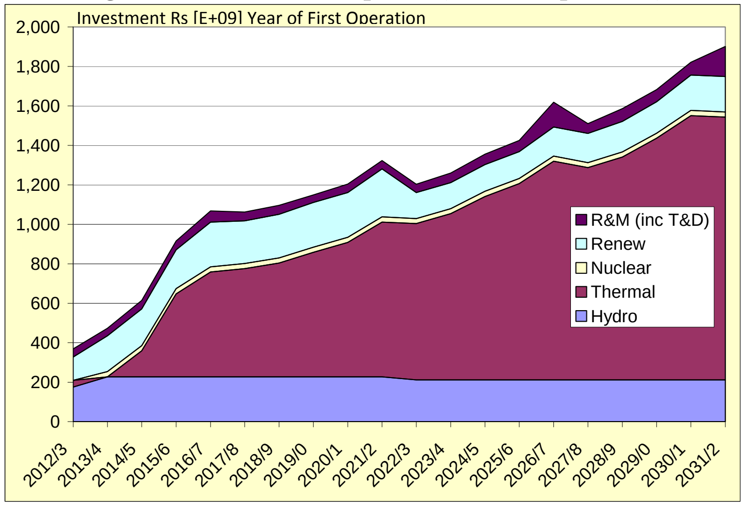
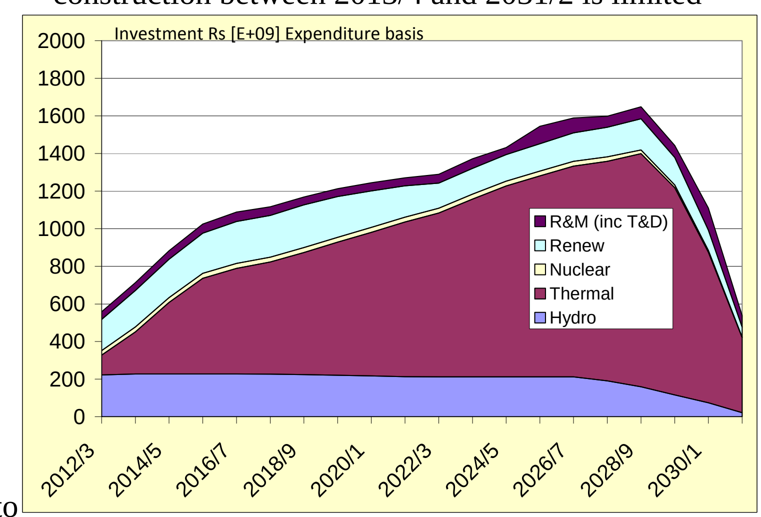


Figure 7 - Investment required (Expenditure Flow Basis)

1. A slower improvement in Transmission and Distribution loss reduction, taking an additional 5 years to reach 15.05%.
2. **LDC**: A slow change in the shape of the Load Duration curve, changing from its historic (2005) shape to that of Thailand (2002) by 2021/2 when GDP per capita PPP will be roughly comparable.

Supply: A slower build-rate for new Hydro and Renewable plants. In scenario 2, the model builds half the new capacity included in scenario 1 of Hydro, Wind and Biomass. New plant construction between 2013/4 and 2031/2 is limited



to

Scenario 2

Scenario 2 contains 3 measures that are compared to Scenario 1, namely:

3. **T&D**:

- Hydro: 38,000 MW
- Wind: 20,800 MW
- Biomass: 5,205 MW

The impact of these measures is discussed below. Table 25 in appendix A shows the values that important variables assume under scenario 1, scenario 2 and each of the three components of scenario 2 (T&D, Supply and LDC). Table 23 shows the percentage change of each of these options against scenario 1.

Total generation

In scenario 2, the total generation required into the grid to deliver the same energy supply to end users increases by 3.4% from 48.6 to 50.3 million GWh (48.6 to 50.3 PWh) over the 26 year period. This is principally because of the slower reduction of Transmission and Distribution (T&D) losses although the change in the shape of the load duration curve and its impact on dispatch also had a minor implication.

Table 23 - Scenario 2 percent change against Scenario 1

		Percent change vs Scenario 1			
		+T&D	+ Supply	+ LDC	Scenario 2
Total Generation (undiscounted)	GWh	3.1%	0.0%	0.3%	3.4%
Total Generation (Discounted at Financial Analysis rate)	GWh	3.7%	0.0%	0.2%	3.9%
Direct Expenditure					
New Plant Investment	Rs (E+09)	0.0%	-7.3%	7.4%	-0.3%
Cost of Renovation or Retrofit	Rs (E+09)	24.2%	-2.5%	2.3%	26.4%
Residual Value of new plant	Rs (E+09)	-2.0%	-8.7%	7.6%	-3.9%
Residual Value of renovated plant	Rs (E+09)	0.0%	0.0%	0.0%	0.0%
O&M (Fixed + Variable)	Rs (E+09)	1.9%	0.3%	2.6%	5.0%
Total fuel cost at Plant	Rs (E+09)	4.4%	3.9%	-3.6%	4.6%
Total Expenditure	Rs (E+09)	3.8%	0.9%	0.5%	5.5%
NPV in year 2005 (Discounted expenditure flow)					
New Plant Investment	Rs (E+09)	2.5%	-5.4%	4.9%	2.4%
Cost of Renovation or Retrofit	Rs (E+09)	-16.0%	-0.5%	2.4%	-13.8%
Residual Value of new plant	Rs (E+09)	-2.0%	-8.7%	7.6%	-3.9%
Residual Value of renovated plant	Rs (E+09)	0.0%	0.0%	0.0%	0.0%
O&M (Fixed + Variable)	Rs (E+09)	1.6%	0.1%	1.2%	3.0%
Total fuel cost at Plant	Rs (E+09)	6.2%	1.6%	-2.3%	5.0%
Total Expenditure	Rs (E+09)	3.3%	-1.3%	1.3%	3.3%
CO2e Emissions (undiscounted)					
Total CO2e emissions from both fuels	Gg	4.1%	4.8%	-0.3%	8.7%
Total CO2e Emissions	Gg	4.1%	4.8%	-0.3%	8.7%
CO2e Emissions (Discounted at Financial Analysis rate)	Gg	4.9%	2.3%	-0.2%	6.9%

New Plant Investment

In scenario 2, the total investment required for new plants over the complete period remained effectively unchanged (-0.3%) because the reduction of 7.3% in investment due to ***Supply*** was offset by an increase of 7.4% due to ***LDC***.
It can be seen, though, in the discounted expenditure flow (to 2005) that the timing of the investments differed between the two scenarios with ***T&D*** requiring more investment early on (whilst the losses were higher) resulting in a discounted investment 2.3% higher than scenario 1.

Plant Renovation and Retrofit

The total investment in plant renovation and retrofit (R&M) including that required for T&D losses in scenario 2 is higher than the Rs 1.5 [E+12] in scenario 1 by 26.4 % principally because the lag in reducing ***T&D*** losses allows the problem is grow and then requires a larger investment at a later date. This time phasing is clearly seen by reviewing the discounted expenditure cash flow where it can be seen that the discounted (to 2005) cost of this line item is lower for scenario 2 than for scenario 1 by 13.3%.

Plant Operations and Maintenance

The total cost of plant operations and maintenance in scenario 2 is 5% higher than the Rs 4.2 [E+12] in scenario 1. This is caused by an increase of 1.9% and 2.6% due to ***T&D*** and ***LDC*** respectively plus an additional slight increase (0.3%) due to ***Supply***.

Cost of Fuel

The cost of fuel also increases by 4.6% overall from Rs 6 [E+12] in scenario 1. This increase is due to 4.4% caused by ***T&D***, 3.9% caused by ***Supply*** offset by an improved utilization of Hydro with the peakier ***LDC*** of 3.6%.

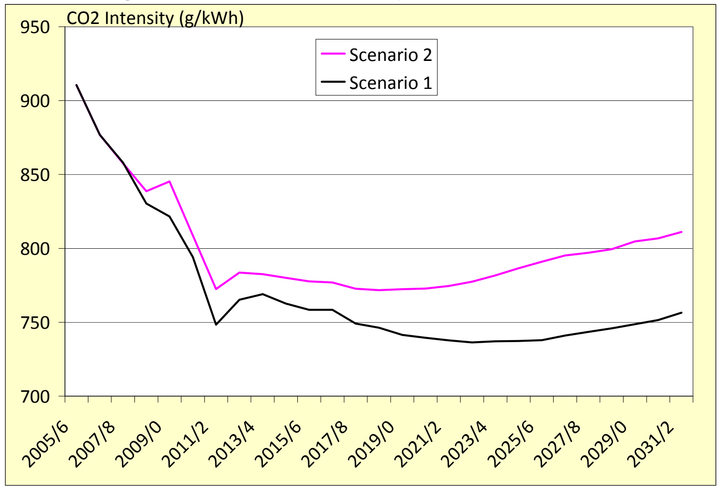
Total Expenditure

In direct expenditure over the 26 years in the model, scenario 2 shows an increase of 5.5% when compared to scenario 1. The greatest contributing factor to this difference is ***T&D***. On a discounted expenditure flow basis, scenario 2 requires an increase of 3.4% when compared to scenario 1.

CO_2 Emissions

The total CO_2 emissions over the 26 year period increased in scenario 2 by 8.8% from the 36.7 thousand million metric tons (36.7 [E+06] Gg) in scenario 1. This increase of 3.2 thousand million metric tons (3.2 [E+06] Gg) derives in similar proportions from ***T&D*** and ***Supply.*** Figure 8 shows the difference in carbon intensity of the two scenarios.

Figure 8 - Carbon Intensity of Scenarios 1 & 2



Comparison of Scenario 2 vs Scenario 1

Scenario 2 has a higher total discounted expenditure than scenario 1 by Rs 301 [E+09] or 3.4%. Scenario 2 also has higher CO_2 emissions than scenario 1 by 8.8% or 3.2 thousand million metric tons (3.2 [E+06] Gg). Thus the breakeven price of carbon is negative (US$-30.4/t).

The impact of each of the components of scenario 2 is as follows:

1. **T&D**:
   The 5-year slippage in meeting the Transmission and Distribution loss reduction targets increases the emission of CO_2 into the atmosphere by 1,500 million tonnes and increases the overall discounted expenditure flow by Rs 560 [E+09].

2. **LDC:**
   The slow change in the shape of the Load Duration curve increases the emission of CO_2 into the atmosphere by 92 million tonnes and increases the overall discounted expenditure flow by Rs 213 [E+09].

3. **Supply:**
   The slower build-rate for new Hydro and Renewable plants increases the emission of CO_2 into the atmosphere by 1,760 million tonnes but reduces the overall discounted expenditure flow by Rs 213 [E+09].
   The breakeven price of carbon of going from this to scenario 1 which is a more costly but cleaner option is US$33.4 /t.

Pair-wise comparison of Technologies

Table 24 presents a comparison of distinct technology options against a baseline. In this case the chosen baseline consists of a 500 MW Subcritical coal fired plant using national coal however the model allows any paired comparison to be made.

Table 24 - Comparison of Technologies

Plant Type		Coal Source	Capacity MW	CO2 Emissions		IRR @ US 10c /kWh	Breakeven Price of Carbon vs Baseline		Marginal Abatement Cost vs Baseline	
				Total Variable	Difference vs Baseline					
			MW	kg/kWh	kg/kWh	%	Rs (E+06)/Gg	USD /tCO2	Rs (E+06)/Gg	USD /tCO2
Coal	SubCritical	National	500	0.925	Baseline	31.5 %	Baseline			
	SubCritical	National	250	0.933	-0.009	29.7 %	-13.6	-340.7	-2.5	-63.3
	Low Supercritical	National	660	0.896	0.029	30.2 %	1.4	34.5	0.3	6.4
	High Supercritical	National	800	0.872	0.053	29.8 %	1.0	26.2	0.2	4.9
	Ultracritical	National	1000	0.834	0.091	28.6 %	1.0	26.1	0.2	4.9
	Ultracritical with CCS	National	1000	0.160	0.765	19.3 %	1.3	31.6	0.2	5.9
	SubCritical	Imported	500	0.908	0.016	29.9 %	18.8	469.2	3.5	87.2
	SubCritical	Imported	250	0.917	0.008	28.8 %	42.4	1060.2	7.9	196.9
	Low Supercritical	Imported	660	0.880	0.045	28.9 %	6.7	167.7	1.2	31.2
	High Supercritical	Imported	800	0.857	0.068	28.4 %	4.6	116.2	0.9	21.6
	Ultracritical	Imported	1000	0.819	0.106	28.0 %	2.9	72.8	0.5	13.5
	Ultracritical with CCS	Imported	1000	0.157	0.768	18.2 %	1.6	40.2	0.3	7.5
Gas			500	0.489	0.436	2.9%	5.9	148.4	1.1	27.6
			250	0.489	0.436	2.9%	5.9	148.4	1.1	27.6
Wind				0.000	0.925	15.1 %	1.5	36.5	0.3	6.8
Solar				0.000	0.925	2.7%	14.9	372.9	2.8	69.3
Hydro	Storage			0.000	0.925	18.5 %	0.6	15.9	0.1	1.4
	RunofRiver			0.000	0.925	21.1 %	0.2	5.8	0.0	0.5
Nuclear				0.000	0.925	22.0 %	0.3	8.2	0.1	1.5

The calculations in this table consider a coal cost at the plant of Rs 911.4 (US$22.8) per tonne for indigenous coal and Rs 2400 (US$60) per tonne for imported coal including transport.

Internal Rates of return (IRR) are calculated based on income from the sale of electricity at an average price of US$0.10/kWh.

The breakeven price of carbon shown (in millions of Rupees per gigagram and in Dollars per tonne of carbon dioxide) is the price that should be achieved from the sale of CO_2 over the lifetime of the plant to give same net discounted cash flow to that technology when compared with the chosen baseline. In this calculation both income from the sale of carbon and expenditures are discounted using mid-year values of the annual discount rates shown in Table 4. Since the cash flow is discounted to the start of plant operation – which increases the impact of all payments made prior to and during plant construction – and high discount rates minimize the cash-flow impact of long-term emissions savings, the resultant numbers often seem higher than expected.

The marginal abatement cost (MAC) shown in the table (in millions of Rupees per gigagram and in Dollars per tonne of carbon dioxide) is the discounted expenditure difference between the selected technology and the baseline divided by the undiscounted CO_2 emissions difference between the two. It is apparent that the MAC evaluates the marginal cost of not adding additional tonnes of CO_2 to the atmospheric emissions stock where this marginal cost is implicit in having selected a cleaner but more expensive technology than the chosen baseline. In this calculation expenditures are discounted using mid-year values of the annual discount rates shown in Table 4. Here a high discount rate has the tendency to reduce the resultant numbers and pairs with small emissions differences (such as subcritical 500MW and 250 MW plants) can generate large numbers.

All of the results shown in Table 24 are sensitive to fuel prices, discount rates, and other factors. Figure 9 shows how the Internal Rate of Return varies with coal prices. The horizontal axis shows the price of coal and the vertical axis the IRR of the plant.

Figure 9 - IRR sensitivity with coal price

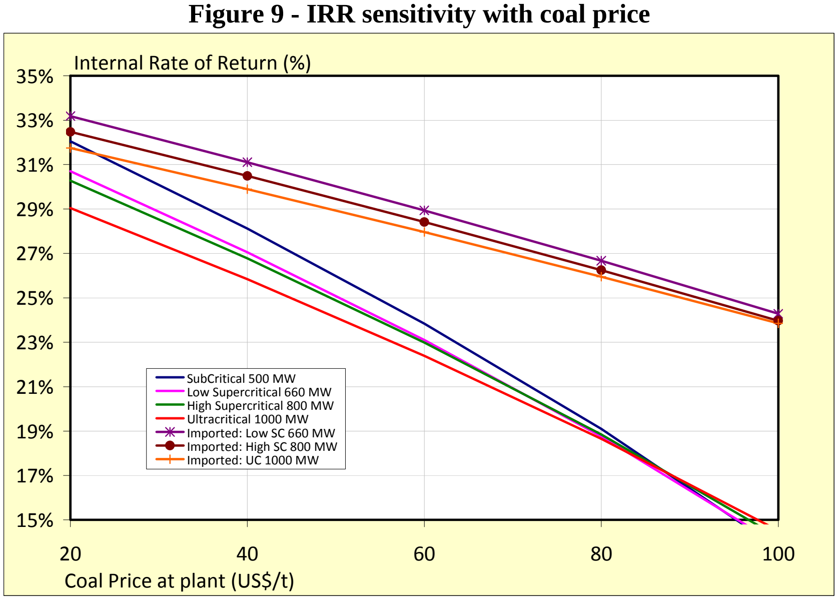


Figure 10 shows how the Breakeven price of carbon varies with coal prices. The horizontal axis shows the price of indigenous coal and for those plants that use imported coal (lines with markers) a price of US$40 above indigenous coal is used. Thus a breakeven price of zero is found for a low supercritical 660 MW plant using imported coal at US$92/t when compared to a subcritical 500 MW plant using national coal at US$52/t.

Figure 10 - Breakeven price of carbon sensitivity with coal price

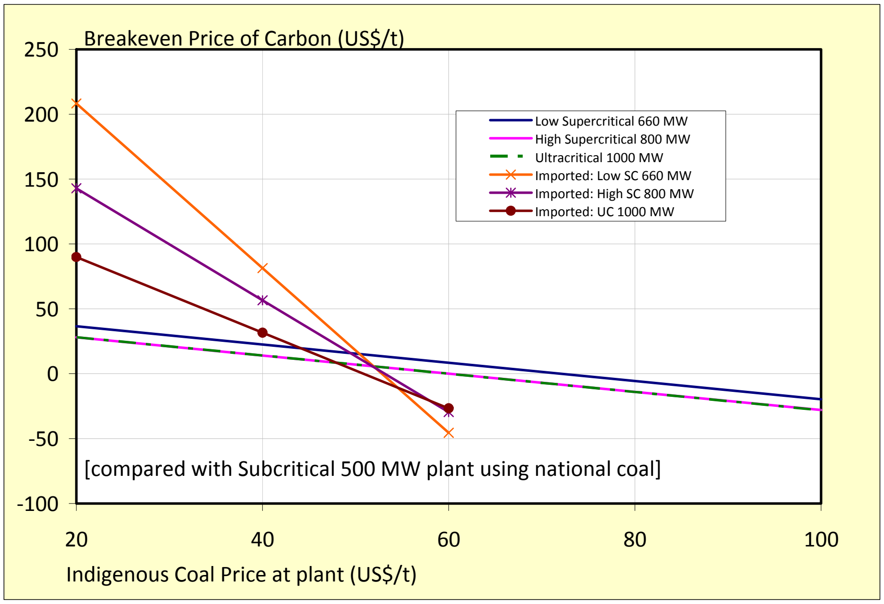
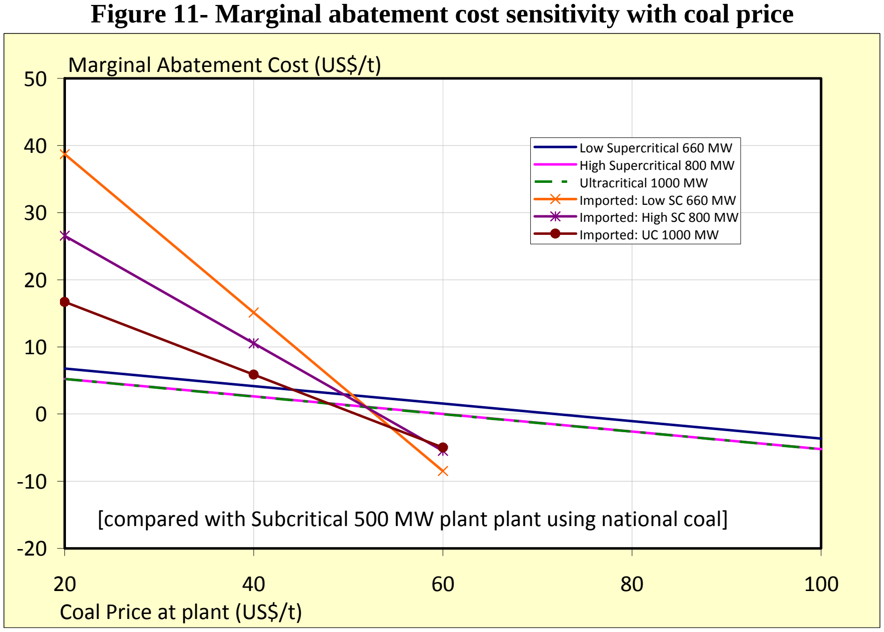


Figure 11 shows the same effect for the Marginal Abatement cost. The horizontal axis shows the price of indigenous coal and for those plants that use imported coal (lines with markers) a price of US$40 above indigenous coal is used. It can be seen that as coal prices rise, it becomes increasingly attractive to use a more efficient plant that consumes less coal and emits less CO_2 even though its up-front investment is greater.

Figure 11- Marginal abatement cost sensitivity with coal price



Appendix 1

Table 25 - Comparison of Scenarios 1 & 2

		Scenario 1	Scenario 1 +T&D	Scenario 1 + Supply	Scenario 1 + LDC	Scenario 2
Total Generation (undiscounted)	GWh	48,630,567	50,145,870	48,630,086	48,788,333	50,307,706
Total Generation (Discounted at Financial Analysis rate)	GWh	8,658,545	8,975,522	8,658,485	8,676,767	8,994,390
Direct Sumation						
New Plant Investment	Rs (E+09)	29,009	28,998	26,898	31,161	28,936
Cost of Renovation or Retrofit	Rs (E+09)	1,490	1,850	1,453	1,525	1,884
Residual Value of new plant	Rs (E+09)	(17,754)	(17,397)	(16,206)	(19,103)	(17,059)
Residual Value of renovated plant	Rs (E+09)	(446)	(446)	(446)	(446)	(446)
O&M (Fixed + Variable)	Rs (E+09)	19,962	20,344	20,017	20,482	20,958
Total fuel cost at Plant	Rs (E+09)	28,673	29,923	29,793	27,650	30,005
Total Expenditure	Rs (E+09)	60,934	63,271	61,509	61,268	64,277
NPV in year 2005 (Discounted expenditure flow)						
New Plant Investment	Rs (E+09)	7,099	7,269	6,718	7,449	7,263
Cost of Renovation or Retrofit	Rs (E+09)	383	324	381	392	332
Residual Value of new plant	Rs (E+09)	(765)	(750)	(698)	(823)	(735)
Residual Value of renovated plant	Rs (E+09)	(19)	(19)	(19)	(19)	(19)
O&M (Fixed + Variable)	Rs (E+09)	4,232	4,299	4,237	4,283	4,361
Total fuel cost at Plant	Rs (E+09)	6,006	6,374	6,105	5,868	6,307
Total Expenditure	Rs (E+09)	16,937	17,497	16,724	17,149	17,510
CO2e Emissions (undiscounted)						
Total CO2e emissions from both fuels	Gg	36,749,719	38,277,816	38,506,800	36,658,037	39,971,119
Total CO2e Emissions	Gg	36,749,719	38,277,816	38,506,800	36,658,037	39,971,119
CO2e Emissions (Discounted at Financial Analysis rate)	Gg	6,793,603	7,124,038	6,952,935	6,778,736	7,265,591

Table 26 - Scenario 1 Results

India: Low Carbon Growth Study		Scenario 1 - Data is for last yearof each Plan						
Power sector results			Data show n for one year (ie: 2005 = fiscal 2005-06)					
	Units	*2005/6*	*2006/7*	*2011/2*	*2016/7*	*2021/2*	*2026/7*	*2031/2*
Maximum Plated Capacity								
Total Hydro	MW	31,970	34,684	57,238	77,164	98,734	118,734	138,734
Total Thermal	MW	81,828	87,255	141,877	169,541	245,181	343,571	468,312
Total Nuclear	MW	3,360	3,900	6,420	7,920	9,720	11,280	13,060
Total Renew	MW	0	7,760	25,070	45,501	70,843	85,893	100,243
Total Maximum Plated Capacity	MW	117,158	133,598	230,605	300,127	424,478	559,478	720,349
Generation								
Total Hydro	GWh	83,579	90,681	150,312	201,859	259,841	310,831	360,227
Total Thermal	GWh	490,807	511,755	736,498	1,057,383	1,488,404	2,062,877	2,789,405
Total Nuclear	GWh	26,743	30,976	51,748	62,306	74,931	85,750	98,327
Total Renew	GWh	0	20,790	66,308	124,520	197,494	242,680	288,595
Total Generation	GWh	601,129	654,202	1,004,866	1,446,068	2,020,670	2,702,138	3,536,553
Unit Energy Consumption								
Total Hydro	MJ/kWh	2.01	2.23	2.63	2.35	1.98	1.71	1.49
Total Thermal	MJ/kWh	12.62	12.63	11.32	11.53	11.08	10.71	10.59
Total Nuclear	MJ/kWh	10.70	10.70	10.70	10.99	11.26	11.43	11.57
Total Renew	MJ/kWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Unit Energy Consumption	MJ/kWh	11.06	10.69	9.24	9.23	8.84	8.73	8.83
Total Energy Consumption								
Total Hydro	PJ	168	203	396	475	515	530	536
Total Thermal	PJ	6,192	6,463	8,340	12,186	16,495	22,090	29,538
Total Nuclear	PJ	286	331	554	684	844	980	1,138
Total Renew	PJ	0	0	0	0	0	0	0
Total Total Energy Consumption	PJ	6,647	6,996	9,289	13,346	17,854	23,600	31,212
Unit Variable CO2e Emissions per GWh								
Total Hydro	g/kWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Thermal	g/kWh	1,115.14	1,120.92	1,021.00	1,037.21	1,001.54	970.64	959.19
Total Nuclear	g/kWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Renew	g/kWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Unit Variable CO2e Emissions per GWh	g/kWh	910.49	876.85	748.33	758.42	737.72	741.01	756.54
Total Variable CO2e Emissions								
Total Hydro	Gg	0	0	0	0	0	0	0
Total Thermal	Gg	547,321	573,635	751,967	1,096,726	1,490,693	2,002,314	2,675,559
Total Nuclear	Gg	0	0	0	0	0	0	0
Total Renew	Gg	0	0	0	0	0	0	0
Total Total Variable CO2e Emissions	Gg	547,321	573,635	751,967	1,096,726	1,490,693	2,002,314	2,675,559
Investment Cash Flow in New								
Total Hydro	Rupees (E+09)	363.69	228.78	247.64	227.70	213.57	212.00	21.20
Total Thermal	Rupees (E+09)	148.55	222.32	294.36	561.99	822.31	1,120.63	399.51
Total Nuclear	Rupees (E+09)	99.78	45.57	18.33	26.00	26.00	26.00	2.60
Total Renew	Rupees (E+09)	305.03	181.93	207.55	222.06	165.83	150.85	53.74
Total Investment Cash Flow in New	Rupees (E+09)	917.04	678.60	767.88	1,037.74	1,227.71	1,509.48	477.04
Investment Cash Flow in Renovation								
Total Hydro	Rupees (E+09)	0.00	2.34	9.59	15.64	3.22	13.95	2.55
Total Thermal	Rupees (E+09)	0.00	2.46	4.01	4.32	2.36	3.28	9.04
Total Nuclear	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Renew	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	62.91	49.70
		36.24	46.83	33.51	30.60	37.78	0.00	0.00
Total Investment Cash Flow in Renovation	Rupees (E+09)	36.24	51.62	47.11	50.56	43.37	80.15	61.28

Table 27 - Scenario 1 Results

India: Low Carbon Growth Study — **Scenario 1 - Data is for last yearof each Plan**

Power sector results — Data shown for one year (ie: 2005 = fiscal 2005-06)

		Units	2005/6	2006/7	2011/2	2016/7	2021/2	2026/7	2031/2
Total Capital Cost (New)	Amounts in Year of Operation								
	Total Hydro	Rupees (E+09)	0.00	128.39	558.12	227.70	227.70	212.00	212.00
	Total Thermal	Rupees (E+09)	0.00	35.29	881.54	530.39	783.91	1,107.67	1,331.69
	Total Nuclear	Rupees (E+09)	0.00	0.00	14.30	26.00	26.00	26.00	26.00
	Total Renew	Rupees (E+09)	0.00	344.64	328.65	226.68	243.46	147.44	179.12
Total Investment in New		Rupees (E+09)	0.00	508.31	1,782.60	1,010.77	1,281.06	1,493.11	1,748.81
Plant & Equipment (New)	Amounts in Year of Operation								
	Total Hydro	Rupees (E+09)	0.00	128.39	558.12	227.70	227.70	212.00	212.00
	Total Thermal	Rupees (E+09)	0.00	35.29	881.54	530.39	783.91	1,107.67	1,331.69
	Total Nuclear	Rupees (E+09)	0.00	0.00	14.30	26.00	26.00	26.00	26.00
	Total Renew	Rupees (E+09)	0.00	344.64	328.65	226.68	243.46	147.44	179.12
Total Plant & Equipment (New)		Rupees (E+09)	0.00	508.31	1,782.60	1,010.77	1,281.06	1,493.11	1,748.81
Investment in Renovation	Amounts in Year of Operation								
	Total Hydro	Rupees (E+09)	2.10	2.49	10.23	17.76	5.50	19.04	6.36
	Total Thermal	Rupees (E+09)	1.86	1.77	4.33	3.44	2.11	2.86	22.60
	Total Nuclear	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Renew	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	103.54	124.25
			0.00	0.00	44.11	36.02	35.05	0.00	0.00
Total Investment in Renovation		Rupees (E+09)	3.97	4.26	58.67	57.22	42.67	125.44	153.20
O&M (Fixed + Variable)									
	Total Hydro	Rupees (E+09)	23.29	24.87	40.48	60.10	81.60	99.60	117.60
	Total Thermal	Rupees (E+09)	347.22	365.72	510.05	574.72	698.97	837.49	1,007.16
	Total Nuclear	Rupees (E+09)	2.45	2.85	4.69	4.61	4.47	4.15	3.99
	Total Renew	Rupees (E+09)	0.00	2.10	9.80	18.83	29.29	33.66	37.80
Total O&M (Fixed + Variable)		Rupees (E+09)	372.96	395.54	565.01	658.26	814.33	974.89	1,166.55
Fuel Cost									
	Total Hydro	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Thermal	Rupees (E+09)	636.25	632.09	550.82	905.13	1,095.11	1,385.54	1,788.34
	Total Nuclear	Rupees (E+09)	14.59	16.90	28.24	34.90	43.04	49.97	58.02
	Total Renew	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Fuel Cost		Rupees (E+09)	650.85	648.98	579.06	940.03	1,138.15	1,435.51	1,846.37

Table 28 - Scenario 1 Results

India: Low Carbon Growth Study **Scenario 1 - Data is for each complete Plan**

Power sector results

Data shown for each five-year plan

Rupees (E+09)	*0*	*Units*	*2005 - 2032*	*2007 - 2012*	*2012 - 2017*	*2017 - 2022*	*2022 - 2027*	*2027 - 2032*
Generation								
	Total Hydro	GWh	5,999,018	590,550	897,223	1,184,382	1,452,219	1,700,385
	Total Thermal	GWh	36,763,821	3,170,542	4,608,625	6,511,030	9,065,389	12,405,672
	Total Nuclear	GWh	1,822,903	249,901	283,948	352,549	410,579	468,206
	Total Renew	GWh	4,044,825	220,220	490,927	837,642	1,120,884	1,354,363
Total Generation		GWh	48,630,567	4,231,213	6,280,724	8,885,603	12,049,071	15,928,625
Total Energy Consumption								
	Total Hydro	PJ	11,904	1,504	2,226	2,509	2,626	2,668
	Total Thermal	PJ	406,986	37,991	53,281	73,088	98,198	131,774
	Total Nuclear	PJ	20,370	2,670	3,085	3,935	4,667	5,395
	Total Renew	PJ	0	0	0	0	0	0
Total Total Energy Consumption		PJ	439,260	42,166	58,592	79,532	105,491	139,837
Total Variable CO2e Emissions								
	Total Hydro	Gg	5	0	1	1	1	2
	Total Thermal	Gg	36,749,715	3,410,158	4,788,594	6,596,965	8,893,139	11,939,902
	Total Nuclear	Gg	0	0	0	0	0	0
	Total Renew	Gg	0	0	0	0	0	0
Total Total Variable CO2e Emissions		Gg	36,749,719	3,410,159	4,788,594	6,596,966	8,893,140	11,939,904
Investment Cash Flow in New								
	Total Hydro	Rupees (E+09)	5,869	1,420	1,133	1,102	1,060	562
	Total Thermal	Rupees (E+09)	17,766	2,342	1,781	3,540	5,021	4,711
	Total Nuclear	Rupees (E+09)	714	112	127	130	130	69
	Total Renew	Rupees (E+09)	4,660	810	1,001	1,025	706	630
Total Investment Cash Flow in New		Rupees (E+09)	29,009	4,684	4,042	5,797	6,918	5,972
Investment Cash Flow in Renovation								
	Total Hydro	Rupees (E+09)	196	27	45	30	44	48
	Total Thermal	Rupees (E+09)	114	19	23	19	19	33
	Total Nuclear	Rupees (E+09)	0	0	0	0	0	0
	Total Renew	Rupees (E+09)	410	0	0	0	125	285
Total Investment Cash Flow in Renovation		Rupees (E+09)	1,484	278	226	218	309	366
O&M (Fixed + Variable)								
	Total Hydro	Rupees (E+09)	1,850	165	257	365	462	552
	Total Thermal	Rupees (E+09)	17,422	2,202	2,708	3,233	3,891	4,676
	Total Nuclear	Rupees (E+09)	116	23	23	23	22	20
	Total Renew	Rupees (E+09)	575	32	75	125	159	181
Total O&M (Fixed + Variable)		Rupees (E+09)	19,962	2,422	3,063	3,746	4,534	5,430
Fuel Cost								
	Total Hydro	Rupees (E+09)	0	0	0	0	0	0
	Total Thermal	Rupees (E+09)	27,634	2,994	3,990	5,035	6,268	8,078
	Total Nuclear	Rupees (E+09)	1,039	136	157	201	238	275
	Total Renew	Rupees (E+09)	0	0	0	0	0	0
Total Fuel Cost		Rupees (E+09)	28,673	3,130	4,148	5,236	6,506	8,353

Table 29 - Scenario 2 Results

India: Low Carbon Growth Study

Power sector results

Scenario 2 - Data is for last yearof each Plan

Data shown for one year (ie: 2005 = fiscal 2005-06)

	Units	*2005/6*	*2006/7*	*2011/2*	*2016/7*	*2021/2*	*2026/7*	*2031/2*
Maximum Plated Capacity								
Total Hydro	MW	31,970	34,684	57,238	69,164	80,734	90,734	100,734
Total Thermal	MW	81,828	87,255	142,377	198,351	294,701	416,951	547,572
Total Nuclear	MW	3,360	3,900	6,420	7,920	9,720	11,280	13,060
Total Renew	MW	0	7,760	25,070	42,001	61,388	68,913	76,088
Total Maximum Plated Capacity	MW	117,158	133,598	231,105	317,437	446,543	587,878	737,454
Generation								
Total Hydro	GWh	83,579	90,681	149,483	182,320	211,070	238,476	255,293
Total Thermal	GWh	490,807	511,755	794,792	1,170,073	1,659,993	2,273,526	2,982,404
Total Nuclear	GWh	26,743	30,976	51,761	62,345	74,999	85,839	98,430
Total Renew	GWh	0	20,790	66,314	114,097	169,270	191,907	214,898
Total Generation	GWh	601,129	654,202	1,062,350	1,528,835	2,115,331	2,789,748	3,551,026
Unit Energy Consumption								
Total Hydro	MJ/kWh	2.01	2.23	2.51	2.20	1.95	1.75	1.62
Total Thermal	MJ/kWh	12.62	12.63	11.46	11.25	10.91	10.78	10.66
Total Nuclear	MJ/kWh	10.70	10.70	10.70	10.99	11.26	11.43	11.57
Total Renew	MJ/kWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Unit Energy Consumption	MJ/kWh	11.06	10.69	9.45	9.32	9.15	9.28	9.39
Total Energy Consumption								
Total Hydro	PJ	168	203	375	401	411	418	412
Total Thermal	PJ	6,192	6,463	9,112	13,163	18,106	24,498	31,796
Total Nuclear	PJ	286	331	554	685	845	981	1,139
Total Renew	PJ	0	0	0	0	0	0	0
Total Total Energy Consumption	PJ	6,647	6,996	10,040	14,250	19,362	25,897	33,348
Unit Variable CO2e Emissions per GWh								
Total Hydro	g/kWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Thermal	g/kWh	1,115.14	1,120.92	1,032.59	1,015.14	987.10	975.80	965.78
Total Nuclear	g/kWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Renew	g/kWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Unit Variable CO2e Emissions per GWh	g/kWh	910.49	876.85	772.53	776.92	774.62	795.24	811.13
Total Variable CO2e Emissions								
Total Hydro	Gg	0	0	0	0	0	1	1
Total Thermal	Gg	547,321	573,635	820,694	1,187,784	1,638,579	2,218,507	2,880,350
Total Nuclear	Gg	0	0	0	0	0	0	0
Total Renew	Gg	0	0	0	0	0	0	0
Total Total Variable CO2e Emissions	Gg	547,321	573,635	820,694	1,187,784	1,638,579	2,218,507	2,880,350
Investment Cash Flow in New								
Total Hydro	Rupees (E+09)	363.69	228.78	178.74	121.70	107.57	106.00	10.60
Total Thermal	Rupees (E+09)	151.55	227.32	469.93	742.78	1,056.06	1,162.07	441.82
Total Nuclear	Rupees (E+09)	99.78	45.57	18.33	26.00	26.00	26.00	2.60
Total Renew	Rupees (E+09)	305.03	181.93	194.62	170.38	100.72	75.42	26.87
Total Investment Cash Flow in New	Rupees (E+09)	920.04	683.60	861.62	1,060.86	1,290.35	1,369.50	481.88
Investment Cash Flow in Renovation								
Total Hydro	Rupees (E+09)	0.00	2.34	9.59	15.64	3.22	13.95	2.55
Total Thermal	Rupees (E+09)	0.00	2.46	4.01	4.32	2.36	3.28	9.04
Total Nuclear	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Renew	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	62.91	44.57
		9.33	16.83	31.46	43.80	58.83	74.48	0.00
Total Investment Cash Flow in Renovation	Rupees (E+09)	9.33	21.63	45.07	63.76	64.41	154.63	56.15

Table 30 - Scenario 2 Results

India: Low Carbon Growth Study

Power sector results

Scenario 2 - Data is for last yearof each Plan

Data shown for one year (ie: 2005 = fiscal 2005-06)

		Units	*2005/6*	*2006/7*	*2011/2*	*2016/7*	*2021/2*	*2026/7*	*2031/2*
Total Capital Cost (New)	Amounts in Year of Operation								
	Total Hydro	Rupees (E+09)	0.00	128.39	558.12	121.70	121.70	106.00	106.00
	Total Thermal	Rupees (E+09)	0.00	35.29	881.54	657.89	926.82	1,172.50	1,472.72
	Total Nuclear	Rupees (E+09)	0.00	0.00	14.30	26.00	26.00	26.00	26.00
	Total Renew	Rupees (E+09)	0.00	344.64	328.65	172.69	181.08	73.72	89.56
Total Investment in New		Rupees (E+09)	0.00	508.31	1,782.60	978.28	1,255.59	1,378.22	1,694.28
Plant & Equipment (New)	Amounts in Year of Operation								
	Total Hydro	Rupees (E+09)	0.00	128.39	558.12	121.70	121.70	106.00	106.00
	Total Thermal	Rupees (E+09)	0.00	35.29	881.54	657.89	926.82	1,172.50	1,472.72
	Total Nuclear	Rupees (E+09)	0.00	0.00	14.30	26.00	26.00	26.00	26.00
	Total Renew	Rupees (E+09)	0.00	344.64	328.65	172.69	181.08	73.72	89.56
Total Plant & Equipment (New)		Rupees (E+09)	0.00	508.31	1,782.60	978.28	1,255.59	1,378.22	1,694.28
Site Accomodation and Lan	Amounts in Year of Operation								
	Total Hydro	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Thermal	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Nuclear	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Renew	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Site Accomodation and Land		Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mgment, Insurance, Spares	Amounts in Year of Operation								
	Total Hydro	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Thermal	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Nuclear	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Renew	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Mgment, Insurance, Spares		Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment in Renovation	Amounts in Year of Operation								
	Total Hydro	Rupees (E+09)	2.10	2.49	10.23	17.76	5.50	19.04	6.36
	Total Thermal	Rupees (E+09)	1.86	1.77	4.33	3.44	2.11	2.86	22.60
	Total Nuclear	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Renew	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	103.54	111.42
			0.00	0.00	28.84	40.47	54.95	71.24	0.00
Total Investment in Renovation		Rupees (E+09)	3.97	4.26	43.41	61.68	62.56	196.68	140.38
O&M (Fixed + Variable)									
	Total Hydro	Rupees (E+09)	23.29	24.87	40.48	52.90	65.40	74.40	83.40
	Total Thermal	Rupees (E+09)	347.22	365.72	516.84	617.49	768.32	933.08	1,109.05
	Total Nuclear	Rupees (E+09)	2.45	2.85	4.69	4.61	4.47	4.15	3.99
	Total Renew	Rupees (E+09)	0.00	2.10	9.80	17.82	26.54	28.73	30.80
Total O&M (Fixed + Variable)		Rupees (E+09)	372.96	395.54	571.80	692.82	864.73	1,040.35	1,227.24
Fuel Cost									
	Total Hydro	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Thermal	Rupees (E+09)	636.25	632.09	628.92	894.59	1,138.41	1,471.90	1,888.92
	Total Nuclear	Rupees (E+09)	14.59	16.90	28.25	34.92	43.08	50.02	58.08
	Total Renew	Rupees (E+09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Fuel Cost		Rupees (E+09)	650.85	648.98	657.17	929.52	1,181.49	1,521.92	1,947.00

Table 31 - Scenario 2 Results

India: Low Carbon Growth Study — **Scenario 2 - Data is for each complete Plan**

Power sector results — ***Data shown for each five-year plan***

	Units	2005 - 2032	2007 - 2012	2012 - 2017	2017 - 2022	2022 - 2027	2027 - 2032
Generation							
Total Hydro	GWh	4,992,223	590,753	846,438	997,228	1,136,445	1,247,099
Total Thermal	GWh	40,105,615	3,356,875	5,044,730	7,254,480	10,074,697	13,372,272
Total Nuclear	GWh	1,824,223	249,941	284,065	352,825	410,979	468,694
Total Renew	GWh	3,385,645	220,231	467,280	734,047	913,180	1,030,116
Total Generation	GWh	50,307,706	4,417,800	6,642,513	9,338,580	12,535,301	16,118,182
Total Energy Consumption							
Total Hydro	PJ	9,967	1,499	1,937	2,019	2,057	2,083
Total Thermal	PJ	442,519	40,493	57,500	79,810	108,968	143,094
Total Nuclear	PJ	20,385	2,671	3,086	3,938	4,672	5,401
Total Renew	PJ	0	0	0	0	0	0
Total Total Energy Consumption	PJ	472,871	44,663	62,524	85,767	115,697	150,578
Total Variable CO2e Emissions							
Total Hydro	Gg	9	1	1	2	3	3
Total Thermal	Gg	39,971,110	3,625,797	5,180,700	7,217,906	9,863,925	12,961,825
Total Nuclear	Gg	0	0	0	0	0	0
Total Renew	Gg	0	0	0	0	0	0
Total Total Variable CO2e Emissions	Gg	39,971,119	3,625,798	5,180,701	7,217,908	9,863,928	12,961,828
Investment Cash Flow in New							
Total Hydro	Rupees (E+09)	3,855	1,266	614	572	530	281
Total Thermal	Rupees (E+09)	20,887	2,599	2,967	4,460	5,617	4,865
Total Nuclear	Rupees (E+09)	714	112	127	130	130	69
Total Renew	Rupees (E+09)	3,480	792	797	735	353	315
Total Investment Cash Flow in New	Rupees (E+09)	28,936	4,770	4,505	5,897	6,631	5,530
Investment Cash Flow in Renovation							
Total Hydro	Rupees (E+09)	196	27	45	30	44	48
Total Thermal	Rupees (E+09)	114	19	23	19	19	33
Total Nuclear	Rupees (E+09)	0	0	0	0	0	0
Total Renew	Rupees (E+09)	372	0	0	0	125	247
Total Investment Cash Flow in Renovation	Rupees (E+09)	1,877	184	261	312	529	560
O&M (Fixed + Variable)							
Total Hydro	Rupees (E+09)	1,508	165	239	302	354	399
Total Thermal	Rupees (E+09)	18,823	2,224	2,848	3,535	4,337	5,165
Total Nuclear	Rupees (E+09)	116	23	23	23	22	20
Total Renew	Rupees (E+09)	511	32	72	115	139	150
Total O&M (Fixed + Variable)	Rupees (E+09)	20,958	2,444	3,183	3,975	4,852	5,735
Fuel Cost							
Total Hydro	Rupees (E+09)	0	0	0	0	0	0
Total Thermal	Rupees (E+09)	28,966	3,352	4,075	5,127	6,614	8,529
Total Nuclear	Rupees (E+09)	1,039	136	157	201	238	275
Total Renew	Rupees (E+09)	0	0	0	0	0	0
Total Fuel Cost	Rupees (E+09)	30,005	3,489	4,233	5,327	6,852	8,805