Future Climate

Engineering Solutions

TECHONOLOGICAL SOLUTIONS

AND

CLIMATE PLAN FOR INDIA

CENTRE FOR CLIMATE CHANGE

Engineering Staff College of India

An Autonomous organ of The Institution of Engineers (India)

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PREFACE

Climate Change due to the global warming is the biggest challenge of the day and threat to all living beings on earth and human society today. There is an over whelming need to reduce greenhouse gas emissions (GHG) for the sustainable development. Over coming climate changes is a biggest challenge for the society in the 21st century.

The purpose of the project "Future Climate – Engineering Solutions" project is to develop the technology based climate plan for India and present sustainable and clean / green technologies & measures and the requirements to develop these technologies & measures. This project also details about the implementation of environment friendly technologies in India. This project includes the National Action Plan for Climate Change and national goals for climate change mitigation or adaptation.

"Future Climate - Engineering Solutions: Climate Plan for India" is a technology based climate plan for India. This project compiled by The Institution of Engineers – India (IEI) in partnership with The Danish Society of Engineers, (IDA) Copenhagen, Denmark. Other partners working on same project for their country are :

1. The Norwegian Society of Engineers (NITO), Norway
2. Institution of Mechanical Engineers, United Kingdom
3. Verein Deutscher Ingenieure e.V. (VDI), Germany
4. Sveriges Ingenjorer, Stockholm
5. The Finnish Association of Graduate Engineers TEK, Finland
6. The Association of Nordic Engineers, ANE, Denmark

This Climate Plan for India includes Qualitative and Quantitative description and technology based sustainable climate scenario for Power sector, Transport sector, Agriculture sector, Construction sector and economic viabilities for year 2020, 2030, 2050. It also provides the details and scenario for sustainable food production, innovation requirements, business potential, socio-economic development and job creation possibilities.

Detailed study on Indian power sector is provided. Indian power sector is witnessing major changes. Switch on to non-conventional energy sources is the best option to meeting the energy crises in environment friendly manner. As per IPCC report and other researches on Climate Change, it is clear that the developed countries now need to stabilize the GHG emissions within the next couple of years and subsequently reduce GHG emission of by above average levels to 50-85% in 2050. But Climate Change is GLOBAL CHALLALANGE and GHG reductions are mandatory in all regions of the world.

Keeping this in view The Institution of Engineers (India) associated with The Danish

Society of Engineers (IDA), Denmark for formulating the Climate Plan for India and for working further for CLIMATE CHANGE ABATEMENT AND SUSTAINABLE DEVELOPMENT.

ACKNOWLEDGEMENT

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A vision upto year 2031 is provided by The Government of India therefore the stress is on studies upto 2031. A comparative analysis and key results across all the scenarios are presented in summary. It also provides a deeper insight into the variations in the final energy and end-use consumption mix under alternative sets of assumptions.

1. Inter-scenario comparisons

Table 0.1 presents the variations in commercial energy consumption. Year 2001 is assumed as baseline year and projections for years at the difference of 5 years are given.

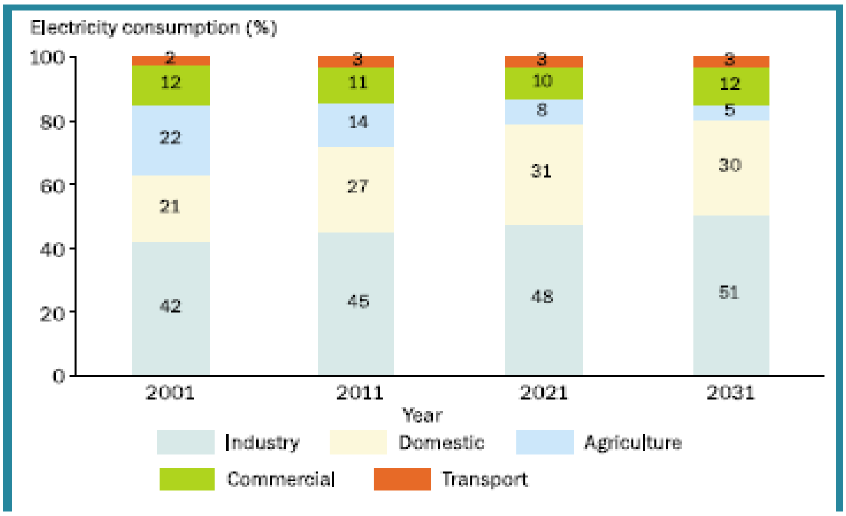
Table 0.1 Variations in commercial energy consumption across various scenarios (in Mtoe)

Scenario	2001/02	2006/07	2011/12	2016/17	2021/22	2026/27	2031/32	2050
LG	285	361	456	605	816	1134	1579	
BAU	285	391	527	749	1046	1497	2123	
REN	285	391	524	740	1033	1479	2097	
NUC	285	391	527	749	1030	1455	2061	
EFF	285	379	479	623	838	1131	1542	
HG	285	435	638	962	1438	2186	3351	

LG – low growth; BAU – business-as-usual; REN – aggressive renewable energy; NUC – high nuclear capacity; EFF – high efficiency; HG – high growth; Mtoe – million tonnes of oil equivalent

Trends in percentage distribution of electricity consumption in the business-as-usual scenario is shown in the below figure 0.1.

Figure 0.1 Trends in percentage distribution of electricity consumption in the business-as-usual scenario



1.2 Total and fuel-wise energy requirements across different scenarios

The difference in energy consumption between the EFF scenario and the BAU scenario in 2031 is 581 Mtoe (the saving in energy consumption in the EFF scenario is twice the consumption in 2031). This difference is mainly on account of the reduction in consumption of coal by 337 Mtoe and that of oil by 244 Mtoe for the period 2001–31. This reduction in consumption of coal and oil can be attributed to the adoption of energy- efficient technologies by the power, industrial, and transport sectors.

These are pictorially represented in Figure 1.2. In the BAU scenario, the total commercial energy consumption increases by 6.9% during the period 2001–31. However, it increases by 5.9% and 8.6% in the LG and HG scenarios, respectively. It has been observed that in the EFF scenario, characterized by the most probable growth rate (8% GDP), the total commercial energy consumption increases only by 5.8%.

Figure 0.2 Total commercial energy consumption across various scenarios

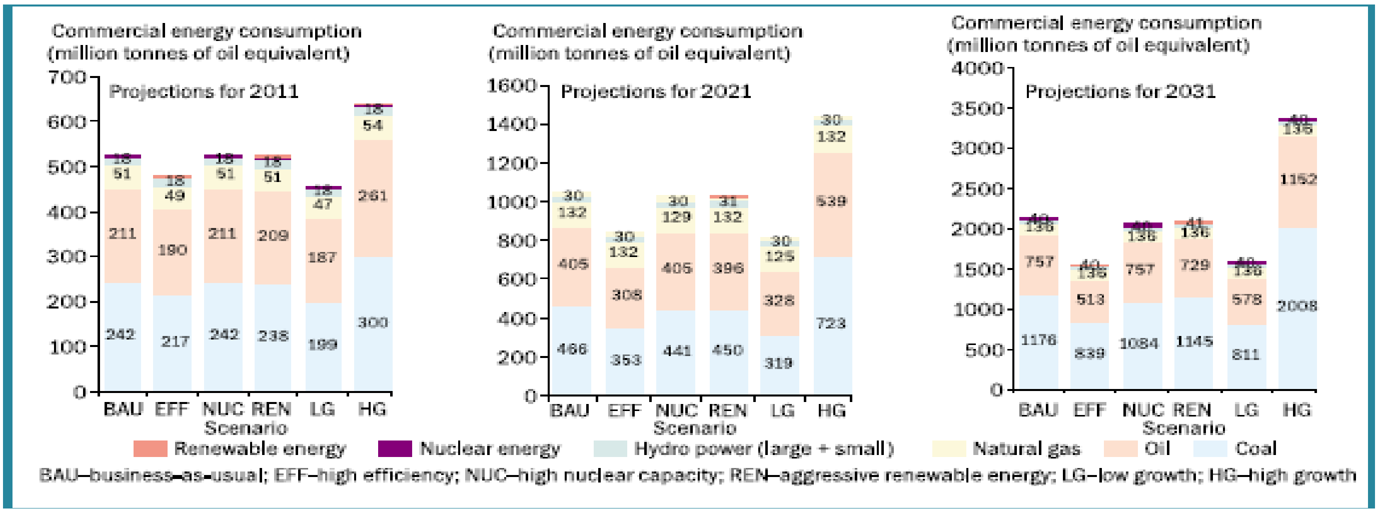
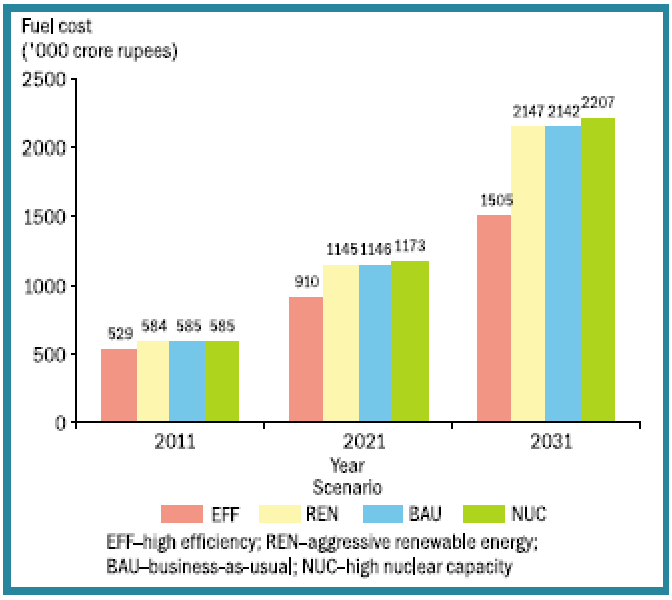


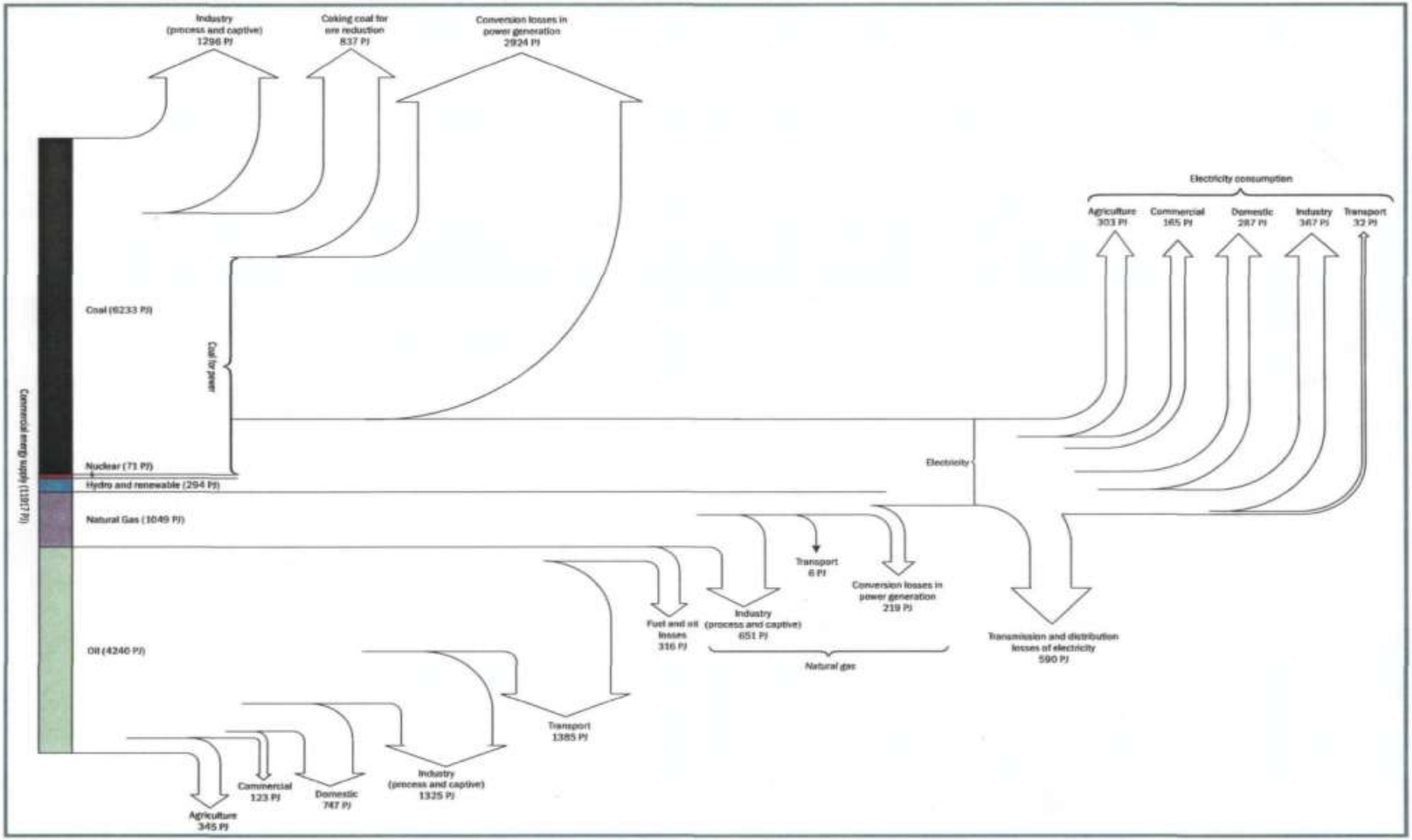
Figure 0.3 provides a comparison of the fuel costs across various scenarios. It can be observed that the cost reduces by 30% in the EFF scenario as compared to that in the BAU in 2031. In the REN scenario, although consumption of coal and oil reduces by 31 and 28 Mtoe, respectively, in 2031 as compared to the BAU, the fuel cost increases marginally by 5000 crore rupees due to the higher cost of bio-diesel. In the NUC scenario, the fuel cost is marginally higher when compared to the BAU scenario.

Figure 0.3 Average annual fuel cost across various scenarios



The diagrammatic representation of the detailed energy balance across various scenarios for 2001 and 2031 is provided through the Sankey diagrams.

Figure 0.4 Sankey diagram for the business-as-usual scenario (2001)



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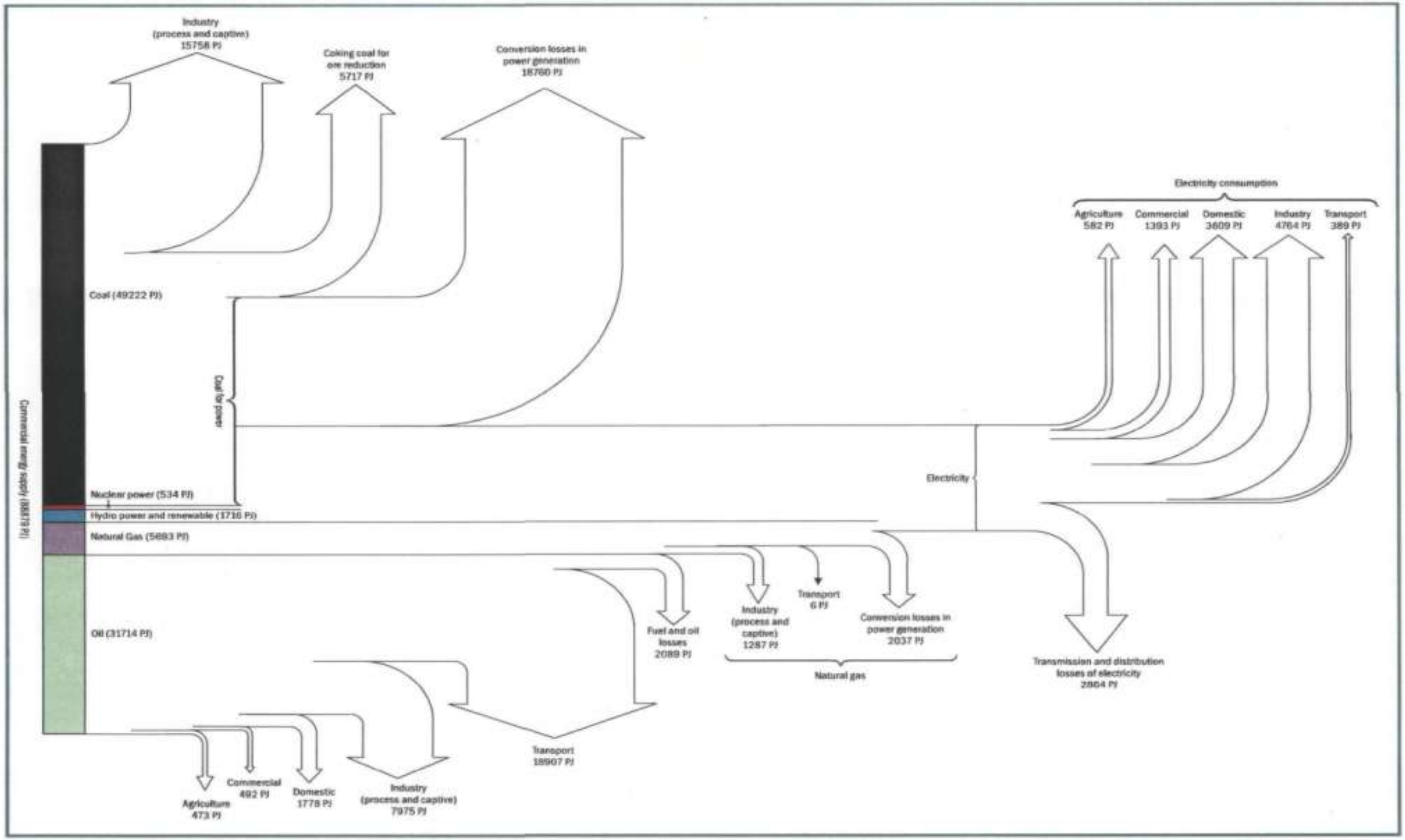


Figure 0.6 Sankey diagram for low-growth scenario (2031)

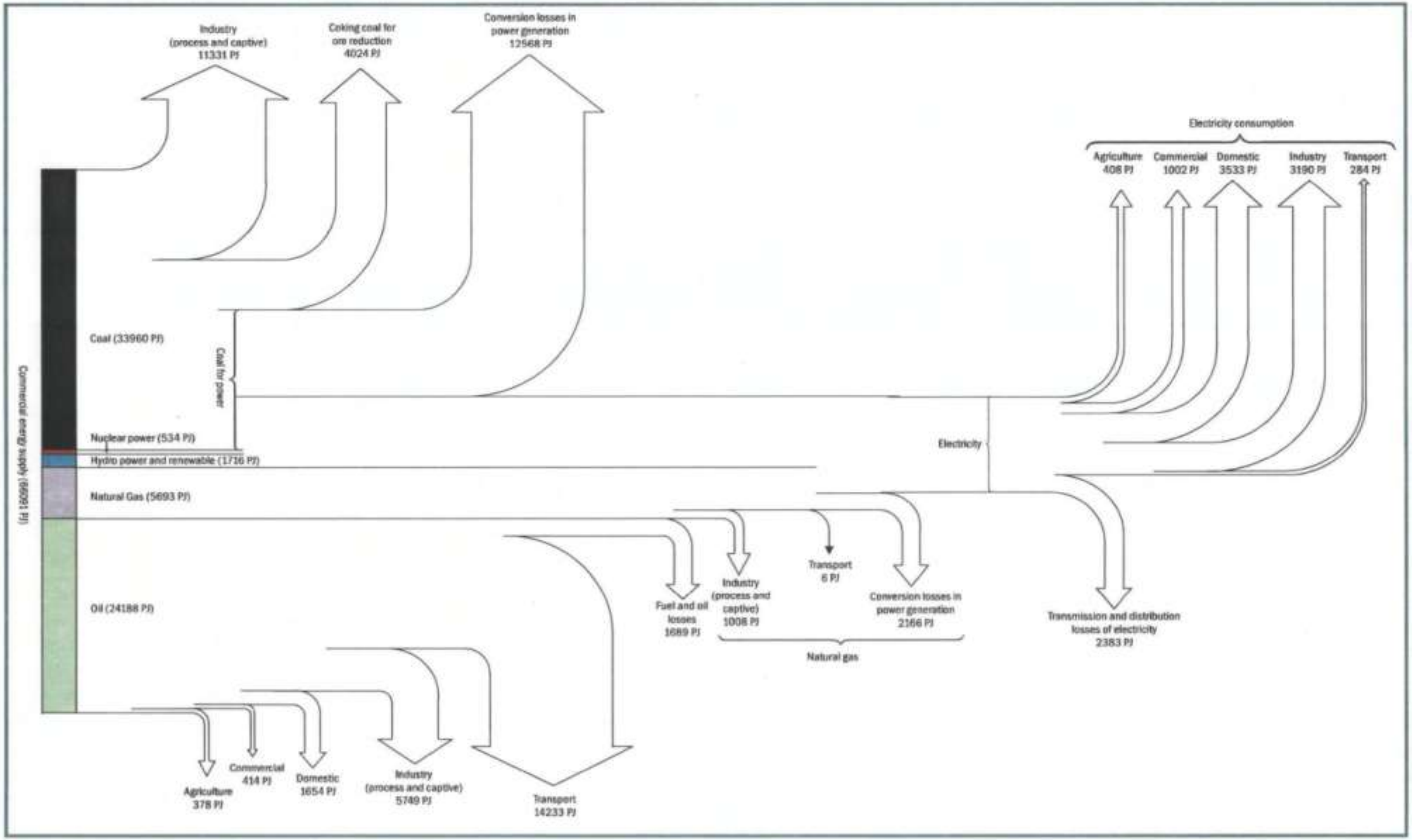


Figure 0.7 Sankey diagram for the high-growth scenario (2031)

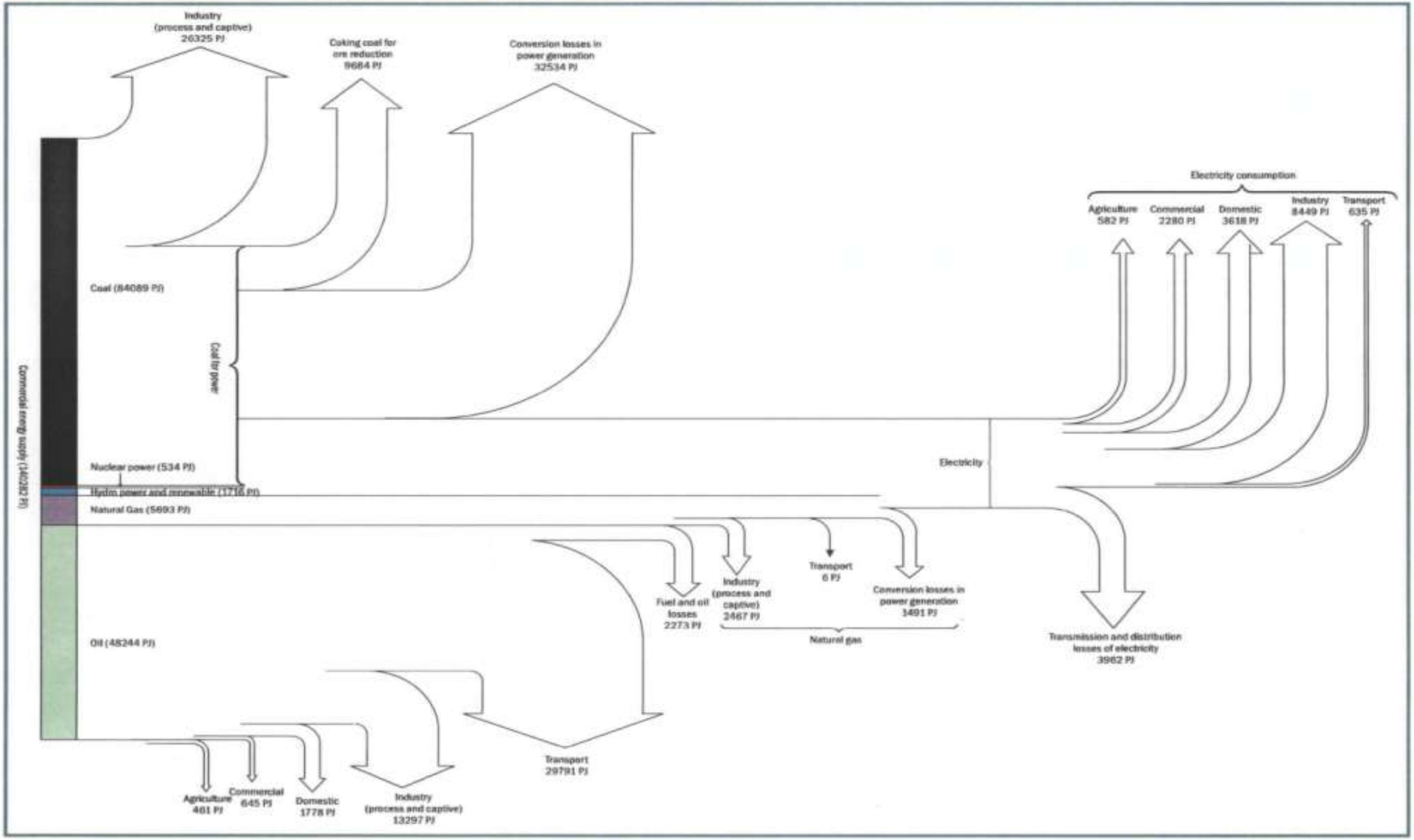


Figure 0.8 Sankey diagram for high energy efficiency scenario (2031)

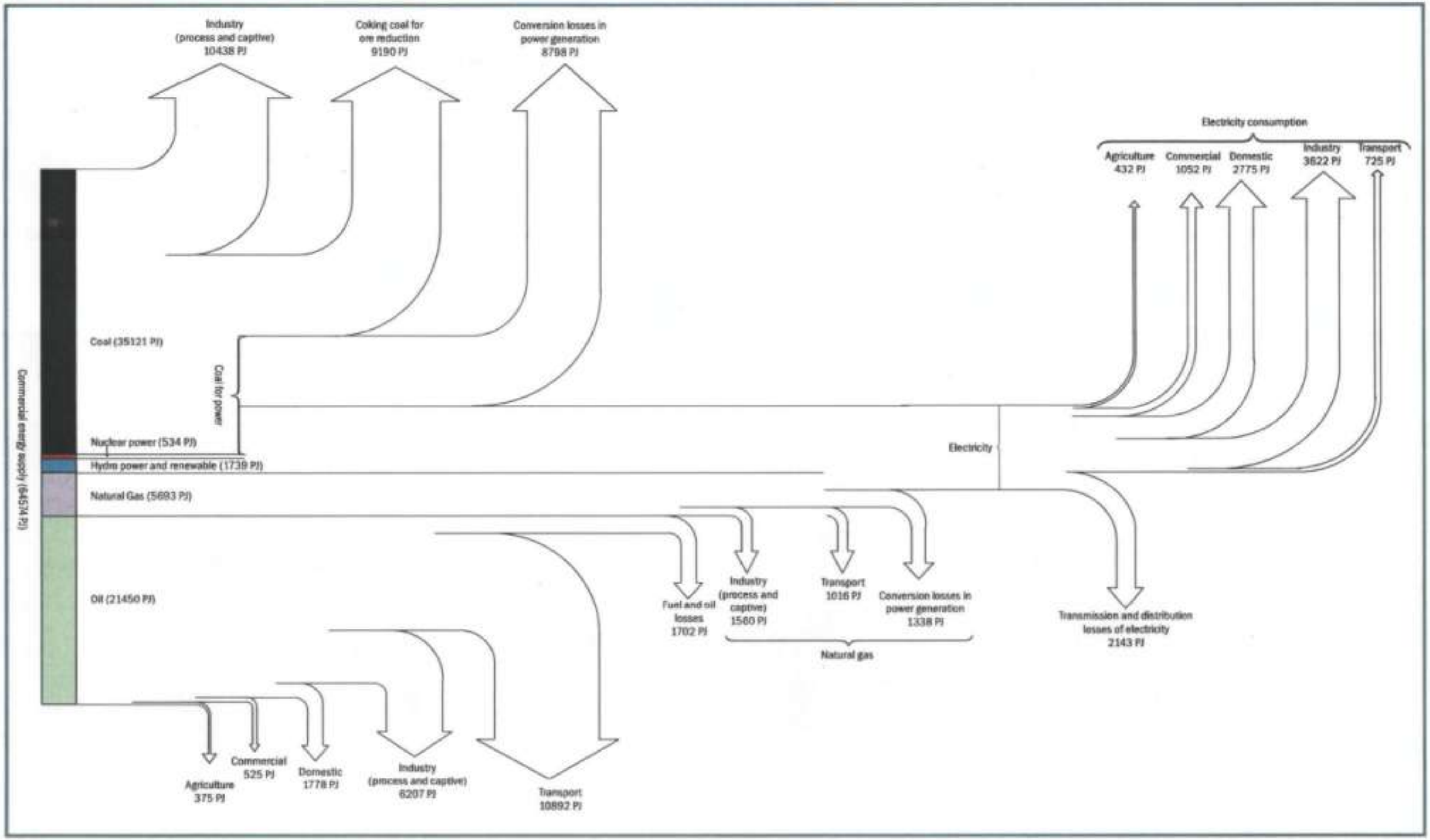
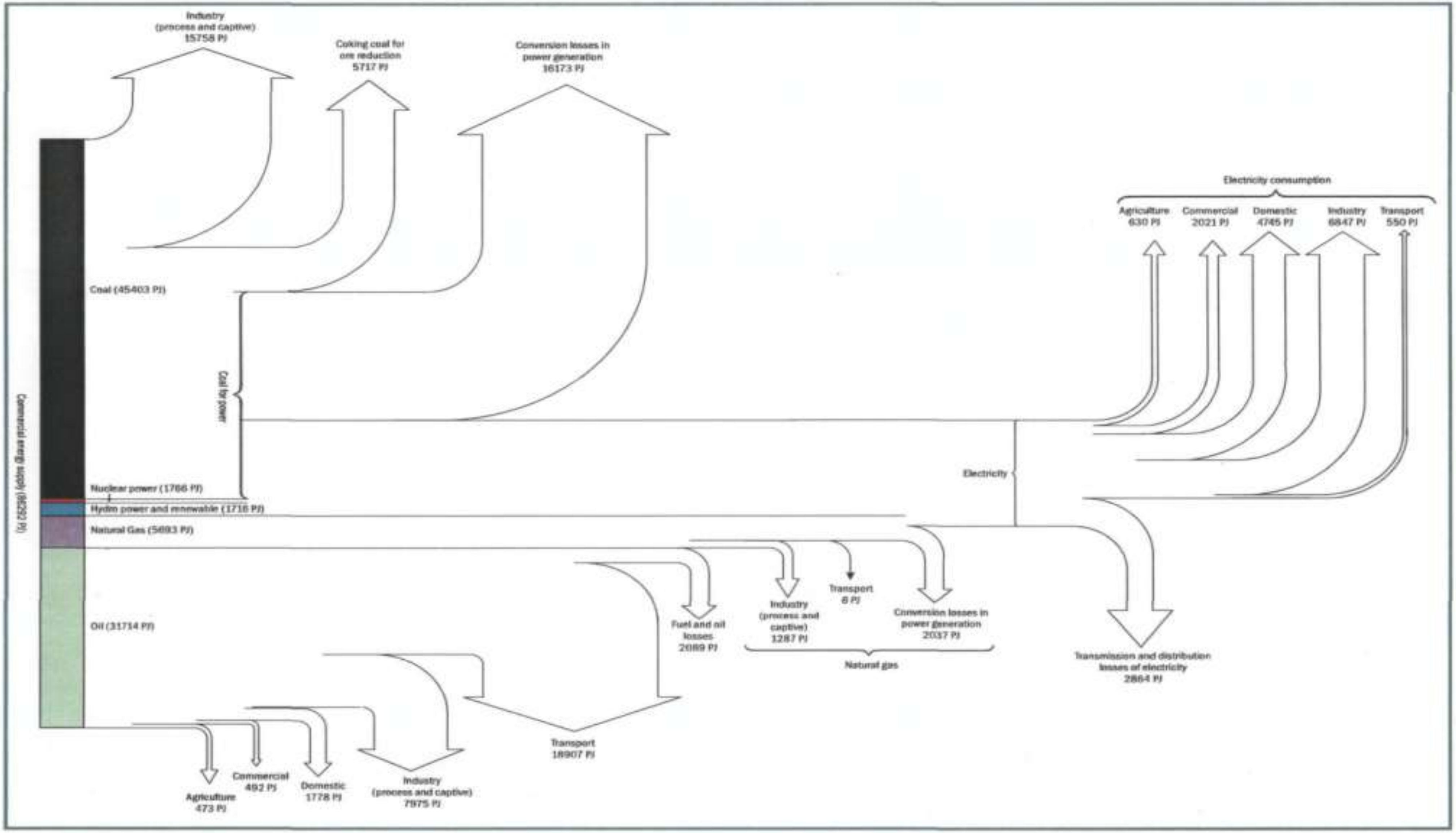


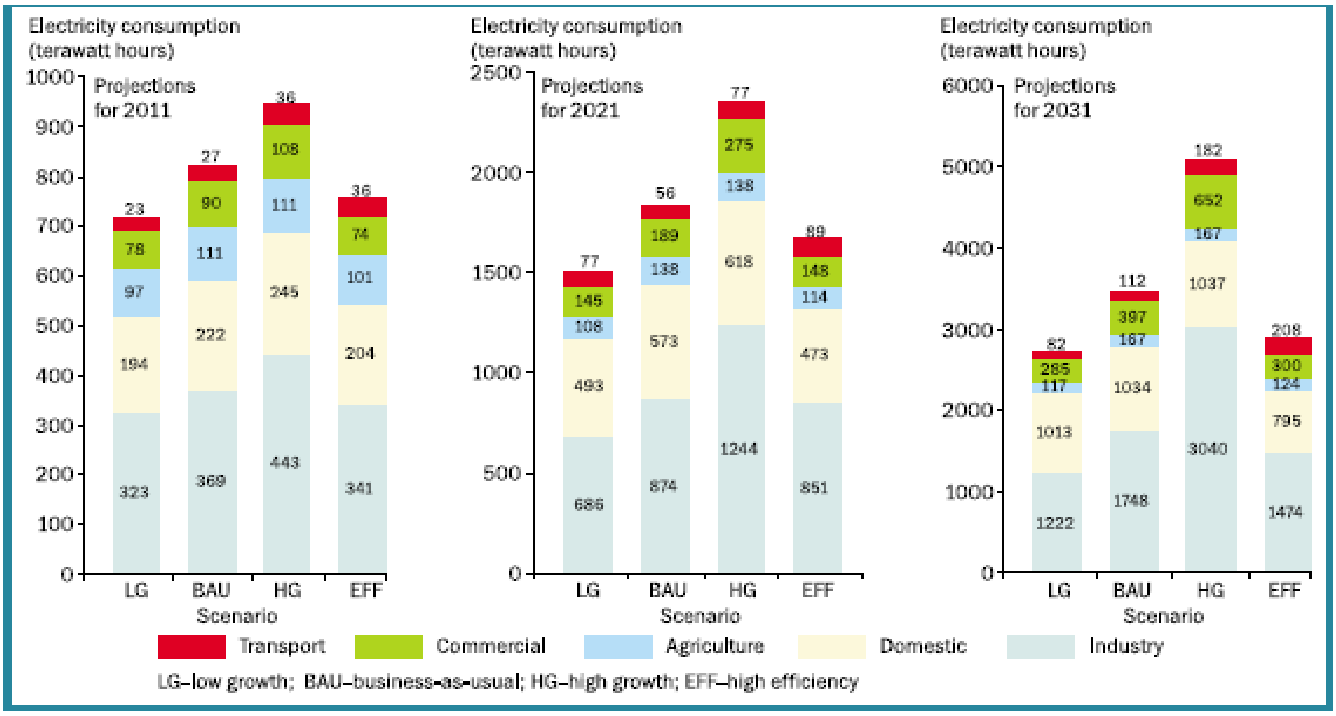
Figure 0.9 Sankey diagram for high nuclear capacity scenario (2031)



1.3 Electricity requirement across different scenarios

In the BAU (8% GDP growth), electricity consumption increases at an average growth ate of 7.6% over the period 2001–31, while the rate of growth is 6.8%, 9.1%, and 6.9%, respectively, in the LG (6.7% GDP), HG (10% GDP), and EFF scenarios (Figure 0.10).

Figure 0.10 Comparison of electricity consumption across various scenarios



Power Generation and Power use in Industrial sector

In the industrial sector, the growth rate of electricity consumption comes down from 8.2% in the BAU scenario to 7.6% in the high efficiency (EFF) scenario. This reduction is primarily due to the adoption of energy- efficient technologies in the various industrial sub-sectors. Suggested technologies for deployment in power sector are:

Power Generation Technologies

Hydro power generation

Supercritical boilers/ultra-supercritical boilers

Advanced gas turbines (for example, H-frame turbine)

Refinery-residue-based IGCC

Demonstration of commercial scale IGCC

Plants using indigenous and imported coals

Fast breeder nuclear reactor

End-use technologies

Cogeneration

Use of waste recovery in industrial processes

Lighting technologies: CFL, LED

Energy-efficient white goods: refrigerators, Alternating current

T&D loss reduction: HVDC, HVAC, and amorphous core transformer

R&D in exploration and production of fuels

Natural gas from gas hydrates

In-situ coal gasification

Deep-sea natural gas

CBM

Mining of coal from seams greater than 300 metres

CBM – coal bed methane; CFL – compact fluorescent lamp; LED – light emitting diode;

HVDC – high voltage direct current; HVAC – high voltage alternating current;

IGCC – integrated gasification combined cycle; T&D – transmission and distribution;

R&D – research and development

Technologies employed by power sector are given below.

<u>Commercial Technologies</u>

1. Thin Film Solar Sheets Technology
2. Best Practices in Compressed Air Systems
3. Improvement of Boiler Efficiency
4. Using Electro Chlorinators
5. Methane Drive:
6. Introduction of Powered Ventilators
7. Selective Catalytic Reduction
8. Co. Gasification
9. Chemical Looping Combustion
10. Capture the acid gases and CO_2 from flue gas
11. Fuel Cell Technology
12. Carbon Dioxide Capture and Storage:

i) Post combustion ii) Pre combustion iii) Oxy fuel combustion iv) Chemical looping

13. Fast breeder reactors

<u>R&D in Progress for the Technologies given below:</u>

1. Reversing CO_2 Emissions
2. Electro Chemical Separation.
3. Electrolysis and Pre Treatment Methods
4. Medical Technique adapted to Study Mobility of CO_2 in Coal:
5. Recovery of Coal bed Methane by using Nitrogen Technology
6. Cement Plugs will resist Degradation by CO_2

Construction

The electricity consumption increases by 8.8% in the residential sector in the BAU scenario during the 30-year period. However, in the EFF scenario, it reduces by 7.9%, with a reduction by 23% in absolute levels in 2031. This is primarily due to the adoption of efficient lighting systems, refrigerators, air conditioners, and other appliances. Technologies that can be employed in Construction sector are given below:

Commercial

1. Electricity from Plastic Waste

R&D

2. Roads from Plastic Waste.

Power in Transportation

Electricity consumption in the transport sector in the BAU scenario exhibits a growth rate of 8.7% over the 30-year period, while in the EFF scenario it exhibits a growth rate of 10.9% over the same time period. This is on account of the increase in the share of rail-based movement for passengers and freight as well as higher electrification of rail. Technologies employed and that can be further used by Transport sector are given below.

Commercial

Hybrid Propulsion System:

R&D

1. Solar Taxi

2. Methane Drive

3. Hydrogen Pellets for Vehicles 4. Fuel from Food Waste.

6. Hydrogen for Fuel cells from Formic Acid

Commercial

1. Waste to Fuel Technology

2. Introduction of new Braking and Duct System in Trains

Power and Agriculture

In the agriculture sector, electricity consumption increases by about 2.2% over the 30-year period in the BAU scenario. However, the EFF scenario indicates that electricity consumption increases only by 1.2% during the same period on account of efficient pump sets and judicious water utilization as well as the water table remaining nearly constant. Technologies that may be employed by Transport sector are given below:

Commercial

1. Oil from Algae:

R&D

1. Running Cars on Hydrogen made from Starch

2. Rhizofiltaration

3. Paddy Fields as Carbon Sinks

4. Biogas Production from Rice Straw

5. Hydrogen Production from Carbonaceous Solid Wastes by Steam Reforming

6. Bio Methanol Production from Organic Waste Materials

7. Conversion of Corn Stover to Chemical and Fuels

8. Bio Diesel Production from Vegetable Oils & Animal Fats

i) Pyrolysis ii) Blending iii) Emulsification iv)Transesterification.

1.3.1 Projected generation capacity across scenarios

Figure 0.11 presents a comparison of electricity generation capacity mix across various scenarios. In the BAU scenario, the total generating capacity increases from 125 GW in 2001 to 795 GW in 2031 (6.3 times). The coal-based capacity decreases from 466 GW in 2031 in the BAU scenario to 349 GW in the EFF scenario. Gas-based capacity increases from 137 GW in the BAU scenario in 2031 to 141 GW in the EFF scenario.

The total power generating capacity remains almost constant in the BAU, NUC, and REN scenarios. However, there exists variation in the technology deployment for power generation across various scenarios. In the NUC scenario, the nuclear power generation replaces coal-based generation. Same happens in the REN scenario in which renewable-energy-based generation replaces gas-based generation that is already at its maximum because of the non-availability of infrastructure to import additional gas.

Figure 0.11 Comparison of power generation capacity mix (including decentralized) across 2030 - 2031 scenarios

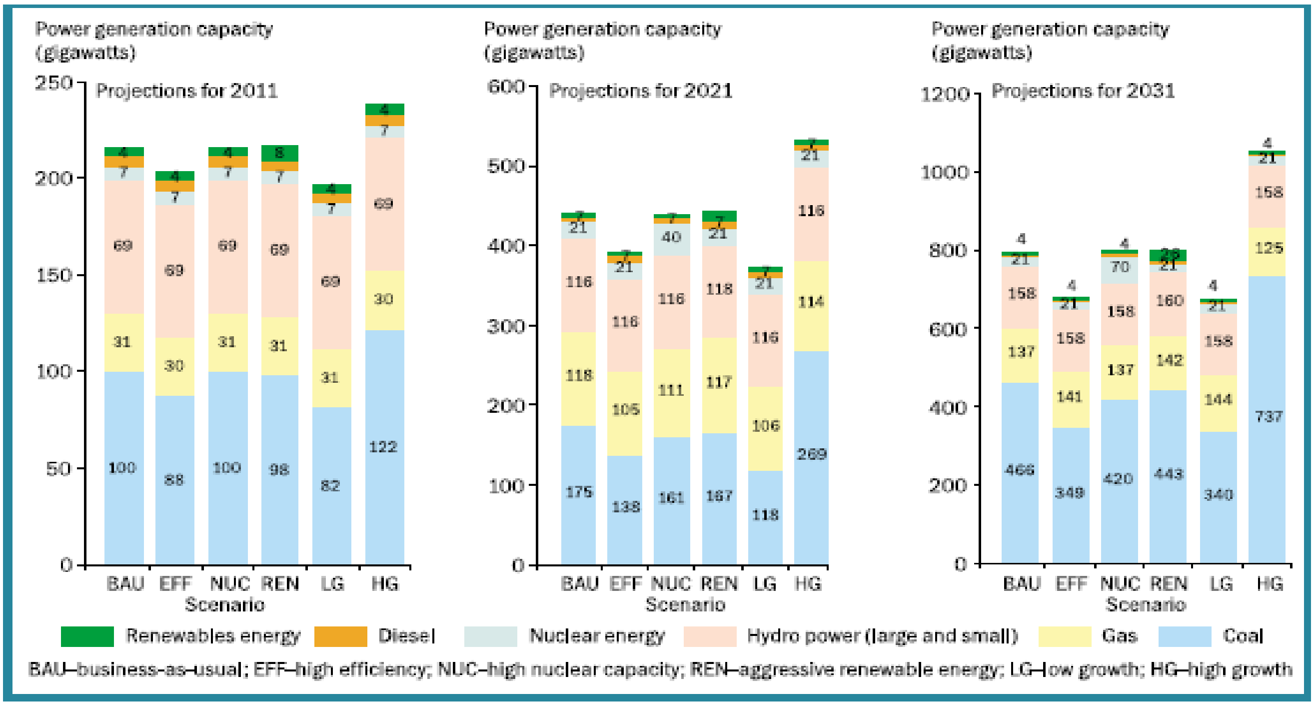
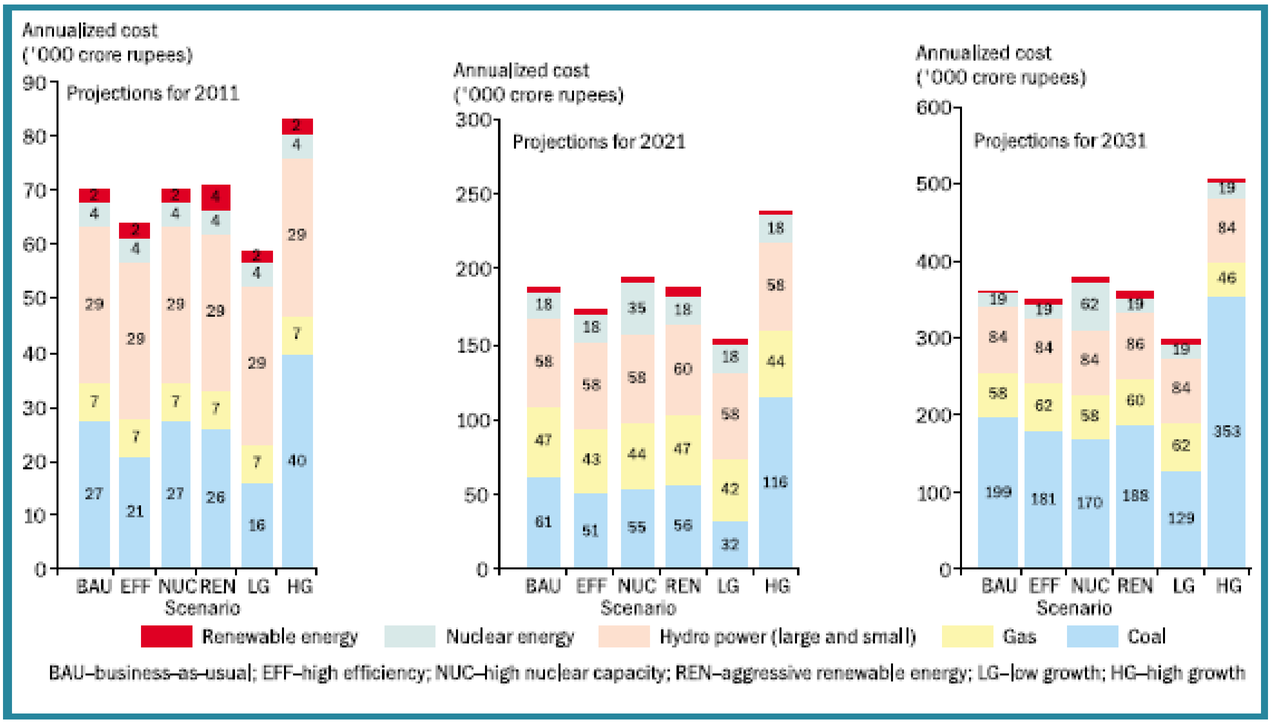


Figure 0.12 presents a comparison of the average annualized investment costs across various scenarios for 2011, 2021, and 2031. During the past five-year period of modeling time frame (2026–31), a reduction of 18 000 crore rupees per annum is effected by way of reduction in annualized capital costs of coal-based power plants (centralized). However, there is an increase in

the annualized cost of gas-based power plants (centralized) by 5000 crores vis-à-vis the BAU scenario. The increase in the cost of gas based power plants is due to increased capacity of gas-based generation as well as penetration of H-frame combined cycle gas turbine that has higher capital cost.

Figure 0.12 Average annualized investment cost in the centralized power generation across various scenarios

In the NUC scenario, although the annualized costs for coal-based capacity decrease by 29000 crore rupees as compared to the BAU scenario, the increase in the annualised cost of nuclear power capacity (43 crore rupees) is more than the cost reduction.



1.3.2 Technology deployment in the power sector across the business-as-usual and high efficiency scenarios

Table 0.2 presents the technology deployment in the power sector in 2021 and 2031 for the BAU and EFF scenarios. Pictorial representation of the same is given in Figure 0.13.

The total installed capacity for power generation from both centralized and decentralized technologies decreases from 441 GW in the BAU scenario to 392 GW in the EFF scenario in 2021, which is about 11% reduction to meet the required demand. Similarly, in 2031, the power generating capacity reduces from 795 to 681 GW, which amounts to 14% reduction. This is primarily due to the improvement in efficiency in the various end-use sectors.

The model results indicate that IGCC (integrated gasification combined cycle) is preferred to super-critical- and ultra supercritical- based power generating technologies. In the BAU scenario, IGCC technologies were not introduced in the model. These were introduced in the EFF scenario; due to better economics, the model preferred IGCC to other coal-based technologies.

In the BAU scenario, gas-based power generation hits the upper limits based on the availability of natural gas in 2021 and 2031, replacing sub-critical coal-based power generation. This is primarily due to the higher efficiency of the CCGT (combined cycle gas turbine) compared to rankine cycle power generation in coal-based power generation. IGCC and H-frame CCGT are almost equally preferred options for power generation in the EFF scenario. IGCC based on imported coal has better economics (lower cost of generation) and, hence, is a preferred option as against the IGCC based on indigenous coal. In the EFF scenario, the installed capacity based on H-frame CCGT technology hits the upper bound based on the limits of gas availability.

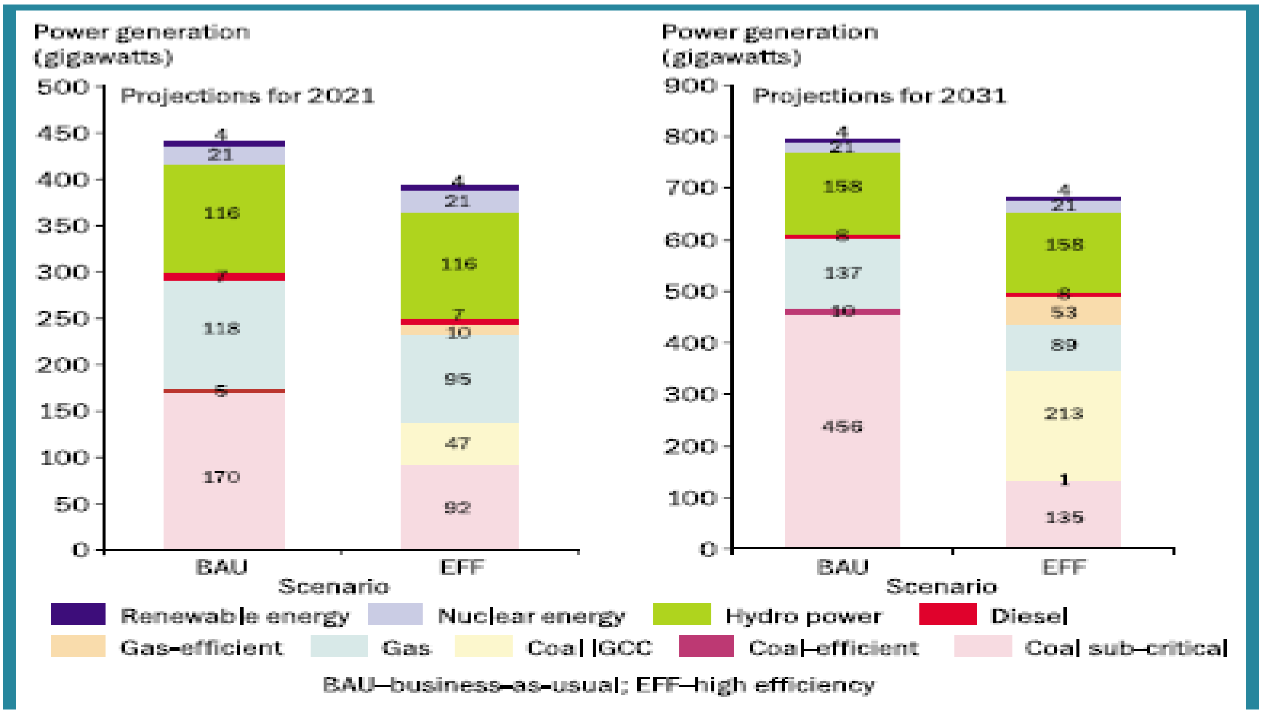
In the BAU scenario, for 2021, the sub critical coal-based generation capacity is 175 GW, whereas the power generation capacity of natural-gas-based CCGT is 118 GW. However, in the EFF scenario, the sub critical coal-based generation capacity is reduced to 92 GW, and IGCC is preferred to the extent of 47 GW and efficient CCGT (H-frame) to the extent of 10 GW. In 2031, IGCC is the preferred option in the EFF scenario among the coal-based technologies, with the generation capacity of 213 GW that is much more than the sub-critical coal based generation capacity of 135 GW. In 2031, efficient CCGT generation capacity increases to 53 GW compared to negligible generation capacity in the BAU scenario. The nuclear-energy-based generation capacity remains constant at 21 GW throughout the decade (2021–31). The hydro capacity remains at 116 GW (in 2021) and 158 GW (in 2031) in both the scenarios.

Table 0. 2 Comparison of technology deployment for centralized and decentralized power generation in the BAU and EFF scenarios for 2021 and 2031 (in GW)

	Year 2021		Year 2031		2050	
Technology	**BAU**	**EFF**	**BAU**	**EFF**	**BAU**	**EFF**
Coal sub – critical	170	92	456	135		
Coal – efficient	5	0	10	1		
Coal IGCC	0	47	0	213		
Gas – based	118	95	137	89		
CCGT (H-frame GT)	0	10	0	53		
Diesel	7	7	8	8		
Hydro power (large and small)	116	116	158	158		
Nuclear Energy	21	21	21	21		
Renewable Energy	4	4	4	4		
Total	**441**	**392**	**795**	**681**		

BAU – business-as-usual; EFF – high efficiency; IGCC – integrated gasification combined cycle; CCGT – combined cycle gas turbine; GW – gigawatts

Figure 0.13 Comparison of fuel-wise technology deployment in the business-as-usual and high-efficiency scenarios in the power sector



Reference: Summary , National Energy Map for India: Technology Vision 2030, The Energy and Resources Institute Office of the Principal Scientific Adviser, Government of India2006, TERI Press, The Energy and Resources Institute Office of the Principal Scientific Adviser, Government of India.

(Sankey diagrams from National Energy Map for India: Technology Vision 2030, The Energy and Resources Institute, Office of the Principal Scientific Adviser, Government of India 2006, Publishers TERI Press, The Energy and Resources Institute and Office of the Principal Scientific Adviser, Government of India).

SUMMARY 2050

CHAPTER 1

INTRODUCTION

1.1 Introduction

India is a party to the United Nations Framework Convention on Climate Change (UNFCCC) and the Government of India attaches great importance to climate change issues. The Convention aims to stabilize greenhouse gas concentrations in the atmosphere at levels that would prevent dangerous anthropogenic interference with the climate system. Eradication of poverty, avoiding risks to food production, and sustainable development are three principles embedded in the Convention.

India is a vast country covering 3.28 million km2 with diverse surface features. India occupies only 2.4 per cent of the world's geographical area, but supports 16.2 per cent of the global human population. India is endowed with varied soils, climate, biodiversity and ecological regimes. Under such diverse natural conditions, over a billion people speaking different languages, following different religions and living in rural and urban areas, live in harmony under a democratic system.

Climatic Conditions:

India's land surface may be classified as (a) the Great Mountain Wall of the North; (b) the Northern Plains; (c) the Great Southern Peninsular Plateau; (d) the Coastal Plains; and (e) the Islands. India's unique geography produces a spectrum of climates yielding a wealth of biological and cultural diversity. Land areas in the north have a continental climate with high summer temperatures with cold winters when temperatures may go below freezing. In contrast are the coastal regions of the country where the temperature is more even throughout the year and rains are more frequent. There is large variation in the amounts of rainfall received in different parts of the country. Average annual rainfall is less than 13 cm in the Thar desert, while at Cherrapunji in the North- East it is as high as 1080 cm. The different climate regimes of the country vary from humid in the North- East (about 180 day's rainfall in a year) to arid in Rajasthan (20 days rainfall in a year). A semi-arid belt in the peninsular region extends in the area between the humid west coast and the central and eastern part of the country. The most important feature of India's climate is the season of concentrated rain called the "monsoon". The Southwest (SW) monsoon (May - September) is the most important feature of the Indian climate.

Surface Water: India is a land with many rivers. The twelve major rivers spread over a catchments area of 252.8 million hectares (Mha) cover more than 75 per cent of the total area of the country. Rivers in India are classified as Himalayan, Peninsular, Coastal, and Inland drainage basin rivers.

Land Use Pattern: The land use pattern is influenced by diverse factors such as population density, urbanization, industry, agriculture, animal husbandry, irrigation demands, and natural calamities like floods and droughts. Despite stresses, the area under forests has increased in recent years due to proactive reforestation and afforestation programmes of the Government of India. Presently 23 per cent of the total land area is under forest and tree cover, while 44 per cent is net sown area. The remaining one-third is roughly equally distributed between fallow land, non-agricultural land, and barren land.

Forest: The panorama of Indian forests ranges from evergreen tropical rain forests in the Andaman and Nicobar Islands, the Western Ghats, and the North-east, to dry alpine scrub high in the Himalayas in the north .between these extremes, the country has semii evergreen rain forests, deciduous monsoon forests, thorn forests, subtropical pine forests in the lower montane zone, and temperate montane forests. According to the Forest Survey of India, the total forest cover in the year 2000 was 6, 75,538 km2.

Agriculture: India is a largely agrarian society with nearly 64 per cent of the population dependent on agriculture, although the share of agriculture in the gross domestic product has been continuously declining over the last 50 years. Crop production in India takes place in almost all land class types, namely, dry, semi dry, moist, sub humid, humid, fluvisols and gleysols. Agriculture will continue to be important in India's economy in the years to come as it feeds a large and growing population, employs a large labour force, and provides raw material to agro-based industries.

Population and Households: India is the second most populous country in the world. The population crossed the one billion mark in 2000. The decadal population growth rate has steadily declined from 24.8 per cent during 1961-1971 to 21.3 per cent during 1991-2001 and is expected to further decline to 16.2 per cent during 2001-2011, due to various policies of the Government of India relating to family welfare, education, health and empowerment of women.

India had more than 160 million households in 1994. Nearly three fourths of these households live in rural areas, accounting for one-third of total national primary energy consumption. With rising incomes, household's at all socioeconomic levels are increasingly using energy using devices such as electric bulbs, fans, televisions, refrigerators, washing machines, air-coolers, air-conditioners, water heaters, scooters and cars. The related greenhouse gas (GHG) emissions will continue to rise even though the energy efficiencies of the appliances are continually improving.

GDP (at factor cost and constant prices) grew by 7.2per cent in the fiscal year 1994. In the decade following 1990s, the annual average GDP growth rate was 6.6 per cent making India one of the 10 fastest growing economies of the world.

The high incidence of poverty underlines the need for rapid economic development to create more remunerative employment and for investment in social infrastructure such as health and education. Notwithstanding the climate friendly orientation of national policies, the development to meet the basic needs and aspirations of a vast and growing population will lead to increased GHG emissions in the future.

Its true that the population of India is very high but another fact is that per capita emission of India is negligible in comparison to western countries. Very high number of population lives under poverty line and do not have access to electricity. There are number of power plants but still capacity to meeting the energy demand is not achieved yet.

Energy: Energy use during the past five decades has expanded with a shift from non-commercial to commercial energy. Among commercial energy sources, the dominant source is coal with a share of 47 per cent.

The shares of petroleum and natural gas in the total commercial energy used in the country are 20% and 11 percent respectively. The total renewable energy consumption including biomass amounts is about 30% of the total primary energy consumption in India. A number of steps are being initiated to develop renewable sources of energy in a systematic manner. However, coal being abundant, cheap and locally available would remain mainstay of the Indian energy system for energy security reasons.

Future Climate –Engineering Solutions Project and Government of India:

Future climate engineering solutions is international project for engineers association. The purpose of project is to demonstrate sustainable energy technologies and solutions in order to support national and international efforts to reduce emissions of greenhouse gases. The project objective is to develop climate plan and present sustainable energy technologies as well as the as the measures which will need to be taken in order to development these technologies. The core of the project is technology- based national climate plan developed by the participating associations for the period up to 2050.

The Institution of Engineers - India (IEI) was allocated this project for preparing the Climate Plan for India thru the initiative taken by The Danish Society of Engineers (IDA), Copenhagen, Denmark. In addition to providing input to decision makers at national levels, the climate plans will provide an opportunity for the participating associations to demonstrate the proficiency of their engineers and members before national and international audiences.

The Government of India plans to achieve a GDP (gross domestic product) growth rate of 10% in the Eleventh Five Year Plan and maintain an average growth of about 8% for the next 15 years (Planning Commission Report 2002).

Given the plans for rapid economic growth, it is evident that the country's requirements for energy and supporting infrastructure would increase rapidly as well. In view of the rising energy prices and other geo-political considerations regarding energy imports, it is important to identify and adopt policies and measures that enhance energy security and help reduce the final energy requirements of the economy. An integrated assessment of all the technological options available to the economy is therefore crucial to examine possible energy pathways and their impacts in terms of costs, patterns over time.

Government of India follows the model of envisaging the GHG emissions upto year 2031. Further studies are not yet made by the Government or any other organization. This project will be for the first time envisaging the GHG emissions upto year 2050. Implementation of clean and green technologies will be contributing for sustainable development.

1.2 Overview of the energy sector

India faces formidable challenges in meeting its energy needs and in providing adequate energy of desired quality in various forms in a sustainable manner and at competitive prices.

India needs to sustain an economic growth of at least 9 percent over the next 25 years if it is to eradicate poverty and meet its larger human development goals. Meeting the energy requirements of this growth in a sustainable manner presents a difficult challenge and one that has become more formidable following the steep rise in international energy prices since 2006. It is necessary in this backdrop to evolve an integrated energy policy provides a coherent frame work of policy covering different energy sources in a consistent manner. To deliver a sustained growth rate of 8% through 2031-32 and to meet the lifeline energy needs of all citizens, India needs, at the very least, to increase its primary energy supply by 3 to 4 times and, its electricity generation capacity/supply by 5 to 6 times of their 2003-04 levels. With 2003- 04 as the base, India's commercial energy supply would need to grow from 5.2% to 6.1% per annum while its total primary energy supply would need to grow at 4.3% to 5.1% annually. By 2031-32 power generation capacity must increase to nearly 8, 00,000 MW from the current capacity of around 1,60,000 MW inclusive of all captive plants. Similarly requirement of coal, the dominant fuel in India's energy mix will need to expand to over2 billion tonnes/annum based on domestic quality of coal. Meeting the energy challenge is of fundamental importance to India's economic growth imperatives and its efforts to raise its level of human development.

In order to achieve sustainability in the energy chain, it is important to identify, measure, value, and integrate the environmental impacts of activities in the energy sector. Environmental concerns are associated with all forms of energy including fossil fuels, nuclear energy, and renewables, throughout the energy chain from exploration/mining, transportation, and generation to end-use. However, the precise nature, intensity, and spatial extent of environmental impacts vary across different energy forms. These effects can occur at the household, local, regional, national or global levels. India, with its size, diversity and current pace of growth, needs to use and to develop all forms of energy sources optimally, in particular to be able to meet its poverty alleviation goals.

1.2.1 Energy supply side: environment concerns

Energy production and use often involves environmental externalities. These externalities, as well as any social externalities such as for example, the social value of employment created in a bio-diesel programme, need to be economically valued and appropriately reflected in the prices of various fuels and energy sources. _ Studies should be carried out to determine the economic value of externalities in the production and use of different sources of energy.

Environmental Impacts Associated with Energy Transformation Based on Fossil Fuels details given in the below table 1.1

Environmental Impacts Associated with Energy Transformation Based on Fossil Fuels

Stage of fuel cycle	Natural gas	Oil	Coal
All stages/all fuels	CO_2, CH_4, N_2O, NO_x, CO, Reactive organic gases, Hydrocarbons, partial trace metals, and thermal pollution		
Exploration/Mining	Drilling accidents, sludge	Drilling accidents, sludge, SO_2	Mining injuries, land degradation, SO_2, NO_x
Processing/Refining	Refinery accidents, waste disposal	Refinery accidents, waste disposal SO_2	SO_2, SPM
Transport/distribution	Pipeline accidents, Liquefied natural gas explosion	Pipeline accidents, oil spills, SO_2	SPM, SO_2, NO_x, CO, CO_2
Conversion/electricity generation		Ash disposal, SO_2	Fly ash SO_2, CO_2, NO_x, Sludge

1.2.2 Environmental impacts of nuclear power

While SPM, CO2, SOx, and NOx, emissions and waste disposal are dominant in the context of generating energy from fossil fuels, nuclear power is associated primarily with risks of radioactive release. Environmental impacts identifiable at various stages of the nuclear fuel cycle are: mining (accidents, release of radon gas and radioactive dust from Uranium mines and mills), radioactive seepage from waste and land degradation, processing (accidents),transport (accidents, risk of proliferation), and electricity generation (risk of catastrophic accidents, low and high level radioactive wastes). Additionally, decommissioning of nuclear plants entails the disposal of radioactive wastes. While significant technological development has been made in the area of radioactive waste disposal and decommissioning, they are yet to be proven at large enough scale to satisfactorily resolve economic issues. However, despite these risks, global data suggests that of all the conventional energy options, nuclear energy has posed the least risks in terms of mortality per billion megawatt hours of generation.

1.2.3 Environmental impacts of large scale hydropower

The major impacts of large hydro projects are rather site specific, and in particular, centre around submergence of land and displacement of traditional communities from their ancestral domains. Such displacement inflicts a high social cost including change in the resource base of traditional culture and aloss of livelihood. In such cases, rehabilitation efforts can address only a part of the social costs experienced. In addition, loss of pristine natural forests and its associated unique biodiversity may occur due to submergence. Methane emissions, a major greenhouse gas, may also be emitted in large quantities if insufficient care is taken to remove vegetative matter susceptible to anaerobic microbial processes from the submerged area. Submergence of large areas may also increase the risk of seismic events, for which dams need to be designed, for if they lead to failure of the dam structure, it may be catastrophic for downstream populations. Other adverse impacts include the spread of water-borne disease, such as schistosomiasis.

1.2.4 Environmental impacts of renewable energy

Energy from renewable sources is generally viewed as involving lower environmental impacts than that based on fossil fuels, nuclear and large hydropower. The main environmental benefits of renewable energy sources are that they avoid the air pollution emissions from fossil fuels and the catastrophic risks associated with nuclear plants. Small hydro projects may also help conserve water supply. Biomass based systems promote the cultivation of energy crops in wastelands and help arrest land degradation. Nevertheless, renewable energy sources may also cause environmental degradation of a different kind. Unsustainable use of biomass leads to depletion of forests; wind energy may cause noise, result in bird mortalities, and despoil the aesthetics of landscapes. Large arrays of solar photovoltaic panels put considerable demand on land and impair aesthetics. Use of chemicals in the manufacture of solar panels and use of lead acid batteries cause several adverse environmental impacts. While bio-energy is generally considered carbon neutral over the vegetation life cycle, the potential environmental impacts of such projects can include impacts on soil and water resources in addition to an increased competition for land use.

Since net carbon emissions correspond only to net deforestation, sustainable harvested biomass fuels do not add to green house gases.

1.2.5 Environmental dimensions of demand side impacts

The end-use of energy may also impose severe environmental costs. Industrial and vehicular emissions have assumed serious proportions in urban areas. Petrol-driven vehicles are the major source of CO emissions, contributing over 85% of total emissions, while diesel-driven vehicles are the major source of NOx, contributing over 90% of total emissions. Improper use of energy in the agricultural sector has resulted in the depletion of groundwater in several parts of the country.

Indoor air pollution due to the domestic consumption of both traditional and commercial fuels is most likely the second largest source of disease, particularly among women and children, in the country.

To understand the demand side of energy-environment interactions, one can begin with an impact matrix that classifies each fuel by key end-use, environmental effects, indicators, and level of impact. For example, diesel fuel is (a) commonly consumed in trucks and buses; (b) has negative impacts on respiratory health, acid deposition, lead contamination and related health ailments, (c) has effluents of CO and particulates that can be measured; and (d) generates environmental impacts at the community, local and regional levels. To go beyond this simple level of matrix analysis requires an assessment of the causes of energy related environmental concerns, information on the physical amounts of pollution from each source that users are exposed to, and a quantification of impacts according to indicators for human health, the economy, and/or ecosystems.

Energy has been across the world recognized as one of the most essential inputs for economic growth and human development. There is a strong two-way relationship between economic development and energy consumption. On one hand, the growth of an economy, with its global competitiveness, hinges on the availability of cost-effective and environmentally benign energy sources, and on the other hand, the level of economic development has been observed to be contingent on energy demand.

The energy–GDP elasticity, defined as the ratio of the growth rate of energy to the growth rate of GDP, captures both the structure as well as efficiency of the economy. The energy–GDP elasticity during 1953–2001 has been above unity. However, the elasticity for primary commercial energy consumption for 1991–2000 was less than unity (Planning Commission 2002). This could be recognized to several factors, some of them being demographic shifts from rural to urban areas, structural economic changes towards lesser energy industry, impressive growth of services, improvement in efficiency of energy use, and inter-fuel substitution.

The energy sector in India has been receiving high priority in the planning process. The total outlay on energy in the Tenth Five Year Plan was about 4.03 trillion rupees at 2001/02 prices, which comprised 26.7%of the total outlay. An increase of 84.2% is projected over the Ninth Five Year Plan in terms of the total plan outlay for the energy sector. The Government of India in the mid-term review of the Tenth Five Year Plan recognized the fact that under-performance of the energy sector can be a major constraint in delivering a growth rate of 8%GDP during the plan period It has, therefore, called for acceleration of the reforms process and adoption of an integrated energy policy. In the recent years, the government has rightly recognized the energy security concerns of the nation and more importance is being placed on energy independence. On the eve of the 59th Independence Day (on 14 August 2005), the resident of India emphasized that energy independence has to be the nation’s first and highest priority, and India must be determined to achieve this within the next 25 years.

1.3 Energy demand and supply scenario

India’s per capita consumption of energy in its various forms in 2003-04 is well below that of developed countries and the world average in 2003. Even in 2032, the per capita consumption in India from various sources of energy will be well below the 2003 level of per capita consumption in respect of developed countries. India’s projected level of per capita energy consumption in 2032 will be less than 74% of the world average in 2003. Table 1.2 is given below.

Per Capita Energy Requirements in Selected Countries (2003)

	TPES (kgoe)	Electricity Consumption (kWh)	Oil (kgoe)	Gas (Cu.m.)	Coal (Kg)	Nuclear (kWh)	Hydro (kWh)
India 2003-04	439	553	111	30	257* (375)	16	69
India 2031-32 (projected @ 8% GDP growth)**	1250	2471	331	149	925* (1388)	256	273
World Average (2003)	1688	2429	635	538	740	403	423
OECD (2003)	4668	8044	2099	1144	1651	1924	1076
U.S.A. (2003)	7840	13066	3426	2176	3410	2624	948
China (2003)	1090	1379	213	32	1073	32	215
South Korea (2003)	4272	7007	2264	627	1541	2570	101
Japan (2003)	4056	7816	2146	845	1247	1859	816

*Per capita coal consumption of India has been estimated based on the calorific value of hard coal used internationally (6000 kcal/kg) to maintain uniformity. The figures in brackets are the actual per capita consumption based on Indian coal with a calorific value of 4000 kcal/kg.

** Based on numbers estimated in *Tables 2.7, 2.12* and *2.15.*

Source: IEA (2005), *Key World Energy Statistics 2005*

In the recent years, India's energy consumption has been increasing at one of the fastest rates in the world due to population growth and economic development. Primary commercial energy demand grew at the rate of 6% between 1981 and 2001 (Planning Commission 2002). India ranks fifth in the world in terms of primary energy consumption, accounting for about 3.5% of the world commercial energy demand, as per 2003 data. Despite the overall increase in energy demand, per capita energy consumption in the country – 323 kilograms of oil equivalent in 2003 – is still very low compared to other developing countries (MoPNG 2004a). Coal, oil, and natural gas are the three primary commercial energy sources. Coal was by far the largest source of energy.

Table 1.3 Production of primary energy sources of conventional energy in India

Source	Unit	1970/71	1980/81	1990/91	2001/02	2002/03	2003/04
Coal and Lignite	MT	76.34	119.02	228.13	352.60	367.29	389.11
Crude Oil	MT	6.82	10.51	33.02	32.03	33.04	33.38
Natural Gas	BCM	1.45	2.36	18.00	29.71	31.40	31.95
Nuclear Power	bkWH	2.42	3.00	6.14	19.48	19.39	17.78
Hydro Power	BkWH	25.25	46.54	71.66	73.70	64.10	75.33
Wind power	bkWH	-	-	0.03	1.97	2.10	3.40

MT – million tonnes; BCM – billion cubic metres; bkWh – billion kilowatt-hours **Source** MoC (2004); CEA (2005)
Source Figures of fuel economy compiled from Overdrive and Autocar (October 2005); TER I (2004)

Despite the increasing dependency on commercial fuels, a sizeable quantum of energy requirements (40% of total energy requirement), especially in the rural household sector, is met by non-commercial energy sources like fuel wood, crop residue, and animal waste, including human and India continues to face serious energy shortages. This has led to increased reliance on imports.

Per capita consumption of energy in India is one of the lowest in the world. India consumed 439 kg of oil equivalent (kgoe) per person of primary energy in 2003 compared to 1090 in China, 7835 in the U.S. and the world average of 1688. India's energy use efficiency for generating Gross Domestic Product (GDP) in Purchasing Power Parity (PPP) terms is better than the world average, China, US and Germany However; it is 7% to 23% higher than Denmark, UK, Japan and Brazil. Clearly, significant reduction in the energy intensity of growth can be achieved based on existing technologies.

Table 1.4 Selected Energy Indicators for 2003

Region/Country	GDP Per Capita-PPP (US $ 2000)	TPES Per Capita (kgoe)	TPES/GDP (kgoe/ $-2000 PPP)	Electricity Consumption Per Capita (kWh)	kWh/ $-2000 PPP
China	4838	1090	0.23	1379	0.29
Australia	28295	5630	0.20	10640	0.38
Brazil	7359	1094	0.15	1934	0.26
Denmark	29082	3852	0.13	6599	0.23
Germany	25271	4210	0.17	6898	0.27
India*	2732	439	0.16	553	0.20
Indonesia	3175	753	0.24	440	0.14
Netherlands	27124	4983	0.18	6748	0.25
Saudi Arabia	12494	5805	0.46	6481	0.52
Sweden	27869	5751	0.21	15397	0.55
United Kingdom	26944	3906	0.14	6231	0.23
United States	35487	7835	0.22	13066	0.37
Japan	26636	4052	0.15	7816	0.29
World	7868	1688	0.21	2429	0.31

TPES: Total Primary Energy Supply
*Data for India are corrected for actual consumption and the difference in actual and IEA assumed calorie content of Indian coal

Source: IEA (2005), Key World Energy Statistics 2005, International Energy Agency, Paris,

1.4. Power

India is third amongst the coal producing countries in the world. It accounts for 55% of the country's total energy supplies. Power sector alone consumes 75% of the coal produced in the country (MoC 2005).

India has made significant progress towards the expansion of its power infrastructure. In absolute terms, the installed power capacity has increased from only 1713 MW (megawatts) as on 31 December 1950 to 118 419 MW as on March 2005 (CEA 2005). The all-India gross electricity generation, excluding that from the captive generating plants, was 5107 GWh (gigawatt-hours) in 1950 and increased to 565 102 GWh in 2003/04 (CEA 2005).

Energy requirement increased from 390 bkWh (billion kilowatt-hours) during 1995/96 to 591 bkWh by 2004/05, and peak demand increased from 61 GW (gigawatts) to 88 GW over the same time period. The country experienced an energy shortage of 7.3% and peak shortage of 11.7% during 2003/04. The growth in electricity consumption over the past decade has, however, been slower than the GDP growth. This could be due to the high growth of the service sector and efficient use of electricity.

Per capita electricity consumption rose from merely 15.6 kWh (kilowatt-hours) in 1950 to 592 kWh in 2003/04 (CEA 2005).

1.5 Oil sector

India is becoming a major player in the international oil and gas industry and is willing to take on the political and financial risks inherent in overseas investments. The country currently imports 70% of its oil and this share is expected to exceed by 90% by 2030. It began importing gas in 2004 and is projected to reach an import dependency of almost 40% in 2030.. India aims to produce 20 MT of equity oil by 2010 and 60 MT by 2025 so that domestic consumption could reach 250 MT. The latest estimates indicate that India has about 0.4% of the world's proven reserves of crude oil. The production of crude oil in the country has increased from 6.82 MT in 1970/71 to 33.38 MT in 2003/04 (MoPNG 2004b).

The quantity of crude oil imported increased from 11.66 MT during 1970/71 to 81 MT by 2003/04. Besides, imports of other petroleum products increased from 1 MT to 7.3 MT during the same period. The exports of petroleum products went up from about 0.5 MT during. 1970/71 to 14 MT by 2003/04. The refining capacity, as on 1 April 2004, was 125.97 MTPA (million tonnes per annum). The production of petroleum products increased from 5.7 MT during 1970/71 to 110 MT in 2003/04.

1.6. Natural gas sector

India has recently entered a new era in its gas industry with large discoveries of indigenous gas and the arrival of the first LNG (liquefied natural gas) tanker in 2004. The importance of gas in India's energy mix is expected to increase sharply from 7% of TPES (total primary energy supply) in 2000 to 13% by 2030. In the same year, import dependency on gas will reach almost 40%. In order to meet the projected consumption, investment needs of about 44 billion dollars between 2001 and 2030 are projected.

India will continue to depend on importing LNG in the short- to medium-term to bridge the demand gap. The capacity of India's only operating LNG terminal is expected to double by 2005 and two more LNG terminals are expected to become operational in the next two years.

The major challenges that India faces towards becoming a sophisticated gas economy include lack of sufficient transmission infrastructure and lack of a coherent legal and regulatory framework.

India's consumption of natural gas has risen faster than any other fuel in the recent years. Natural gas demand has been growing at a growth rate of about 6.5% for the last 10 years. Industries such as power, fertilizer, and petrochemical are shifting towards natural gas. Although India's natural gas demand has traditionally been met entirely through domestic production for the past few years, the core sectors of the economy have started facing a gas shortage. To bridge this gap, apart from encouraging domestic production, the import of LNG is being considered as one of the possible solutions. Several LNG terminals have been planned in the country and two have already been commissioned: (1) a petronet LNG terminal of 5 MTPA at Dahej, and (2) an LNG import terminal at Hazira. In addition, an in-principle agreement has been reached with Iran for import of 5 MTPA of LNG.

1.7 Renewable energy sources

Renewable energy sources are clean and indigenously available, and can play a key role in addressing the energy security concerns of a country. Today, India has one of the highest potentials for effectively using renewable energy sources. The country is the world's fifth largest producer of wind power after Germany, USA, Spain, and Denmark. There is a significant potential in India for the generation of power from renewable energy sources—wind, small hydro, biomass, and solar energy. The country has an estimated SHP (small hydro power) potential of about 15 000 MW. The installed combined electricity generation capacity of hydro and wind has increased from 19 194 MW in 1991/92 to 31 995 MW in 2003/04, with a compound growth rate of 4.35% during this period (MoF 2005). The penetration of other renewable energy technologies, including solar photovoltaic, solar thermal, small hydro, and biomass power is also increasing. Greater reliance on renewable energy sources offers enormous economic, social, and environmental benefits.

The potential for power production from captive power plants and field-based biomass resources, using technologies for distributed power generation, is currently assessed at 19 500 MW, including 3500 MW of exportable surplus power from bagasse based cogeneration in sugar mills (MNES 2005).

1.8 Future scenario

The energy needs of the country are expected to increase at a rapid rate in the coming decades. Therefore, it is imperative to take steps to increase the indigenously available energy resources so as to avoid excessive reliance on external sources.

Increasing pressure of population and increasing use of energy in different sectors of the economy are concern areas for India. With a targeted GDP growth rate of 8% during the Tenth Five Year Plan, energy demand is expected to grow at the rate of 5.2%. Driven by the rising population, expanding economy, and a quest for improved quality of life, the total primary energy consumption is expected to be about 412 Mtoe (million tonnes of oil equivalent) and 554 Mtoe in the terminal years of the Tenth and Eleventh Five Year Plans, respectively (Planning Commission 1999) (Table 1.2). The *International energy outlook 2005*

EIA 2005 show India's gas consumption to grow at an average annual rate of 5.1%, thereby reaching 2.8 trillion cubic feet by 2025 with electric power accounting for a share of 71%. Coal consumption is expected to increase to 315 MT over the forecast period. Coal-fired generation capacity is expected to increase by 59 000 MW between 2002 and 2025 such that use of coal for electricity generation would be 2.2% per annum. Oil demand in India is expected to increase by 3.5% per annum during the same period. It is quite apparent that coal will continue to be the predominant form of energy in future. However, imports of petroleum and gas would continue to increase substantially in absolute terms, involving a large energy import bill. There is, therefore, an urgent need to reduce energy requirements by demand-side management and by adopting more efficient technologies in all sectors.

Plan (Planning Commission 2005) also emphasizes on regulatory reform to improve the energy efficiency of the country. However, availability of capital and environmental considerations is appearing as serious constraints to the efforts of generating more capacity to meet the growing demand. Prudent management of the indigenous energy resources; judicious approach to energy imports; and progressive shift in favour of environmentally benign sources of energy, including non-renewable sources and demand-side management, are some of the solutions to the problems and can, therefore, be the guiding principles for long-term energy policy of the country.

1.8.1 Investments in energy infrastructure

India faces the challenging task of mobilizing financial resources to invest in energy infrastructure. The problem is further aggravated by the different financial risks that have been introduced by the transition to Competitive markets. Far-reaching reforms are urgently needed to facilitate higher capital flows in the energy sector.

1.8.2 Role of new and energy efficient technologies

New and energy-efficient technologies have a key role to play in the optimal utilization of resources. At this juncture, there is an urgent need to address barriers to the adoption of clean coal technologies and other new energy processing technologies. R&D (research and development) and estimated energy demands.

Table 1.5 Estimated energy demands

	Demand (in original units)			Demand (Mtoe)	
Primary fuel	**Unit**	**2006/07**	**2011/12**	**2006/07**	**2011/12**
Coal	MT	460.50	620.00	190.00	254.93
Lignite	MT	57.79	81.54	15.51	22.02
Oil	MT	134.50	172.47	144.58	185.40
Natural gas	BCM	47.45	64.00	42.70	57.60
Hydro power	bkWh	148.08	215.66	12.73	18.54
Nuclear power	BkWh	23.15	54.74	6.04	14.16
Wind power	bkWh	4.00	11.62	0.35	1.00
Total commercial energy				411.91	553.68
Non-commercial energy				151.30	170.25
Total energy demand				563.21	723.93

MT – million tonnes; BCM – billion cubic metres; bkWh – billion kilowatt-hours; Mtoe – million tonnes of oil equivalent. **Source** Planning Commission (2002)

1.9 Energy security

The focus currently is on energy security. The energy security concerns now encompass access to coal, natural gas, electricity, and oil, and insulation from abnormal price fluctuations. India's oil import dependency is expected to increase from 70% at present to 90% by 2030. Apart from this, imports of coal as well as gas are expected to increase significantly in the next couple of decades. Furthermore, access to energy supply needs to be compatible with policy objectives like mitigation of environmental consequences. The Government of India has a policy to mitigate risks by diversifying geological resources of fuel supply and maximizing indigenous use of renewable energy sources and non-renewable energy sources.

1.10 Objectives of the study

In order to have an integrated energy approach and to meet the policy goals of economic efficiency, energy security, energy access, and environment protection, some studies are done by Government Institutions. The time frame of the study is from 2001 to 2031 as per suggested model by Government of India. The objectives of the study are to develop a framework for optimal exploitation of energy resources through appropriate technology deployment, to determine the energy technology policies and strategies that would lead to optimal use of energy resources, to suggest a technology deployment strategy at the national level; and, to identify energy demand and supply and energy-technology related data gaps that will strengthen such analyses in the future. The above-mentioned objectives are to be addressed by building a national-level, bottom- up, technology-driven, optimization modeling framework.

Green House Gas Emissions in India:

Indian CO_2 emissions are very high but its per capita emissions are very low. The growth rate of CO_2 emissions will remain the same as it was up to 1994, the projected CO_2 emissions 2000 and 2002 would be 842 million tones and 2233 million tones.

Nitrous oxide has 310 times the global warming potential of CO_2. The major sources of N_2O emissions in the country is traditional biomass burning contributing approximately3.4 million tones of carbon dioxide equivalent emissions in 1990.

Methane emissions have twenty-one times the global warming potential of CO_2. Methane emissions from the Indian energy sector are confined to fugitive emissions from fossil fuel mining and handling.

The Central Mining Research Institute (CMRI) has calculated the methane emission coefficients and according to their estimates, 1.09 cubic meters of methane are emitted per tonne of coal mined by open cast methods and degree-I underground mining are 11.07 and 23.53m^3 per tonne of coal mined, respectively.

The IPCC commission coefficients for under ground mining are more than double the CMRI coefficients and as per IPCC estimates, coal mining and handling will contribute 20.5 million tonnes of carbon dioxide equivalent. This is still not significant when compared to the net carbon dioxide emissions from the energy sector.

Fugitive emissions of methane from oil exploration, production, transport, refining and storage are 9.5 kilometers per year or nearly 0.2 million tones of carbon dioxide equivalent.

(**Reference**: Introduction, India's Initial National Communication to the united Nations Framework Convention on Climate Change, government of India, pg no i –iii)

(Introduction, National Energy Map for India: Technology Vision, The Energy and Resources Institute Office of the Principal Scientific Adviser, Government of India2006, TERI Press)

(CO_2 Reduction Potentials Through Renewable Energy Sources and Rational Energy Use in India; Shri Narendra Bansal; Strategies and Technologies for Greenhouse Gas Mitigation, pg. 171-185)

(Integrated Energy Policy, Planning Commission 2006, Government of India)

CHAPTER 2

METHODOLOGY OF STUDY FOR THE PROJECT

2.1 Approach

The model provided by the Government of India for the studies is upto year 2031 is followed. This report is formulated on the model provide and inline with the standards by Government of India. Three brainstorming sessions and various meeting of experts were organized to formulate the expert team. Authentic data for upto year 2031 was available with Indian Government Organizations and is used while formulating this report. Further the data for year 2050 is calculated and consequences are envisaged. Latest technologies, their implementation possibilities and barriers are explained.

Data Collected from International Energy Outlook **(**IEA), World Energy Council, Planning Commission, Government of India, Carbon Dioxide Analysis Information Centre, International Comparision of CO_2 Emissions (IEA), The United Nations Frame Work Convention on Climate Change(UNFCCC), The Energy and Resources Institute (TERI).

The key focus of this study was to examine the role that various technological options could play under alternative scenarios of economic growth and development; resource availability; and technological progress.

TERI used an integrated modeling framework that would facilitate the creation and analysis of various scenarios of energy demand and supply at the national level, as well as provide a detailed representation and analysis at the technological level for each category of resource as well as sectoral end-use demand.

Energy demand is driven by the GDP (gross domestic product) and population growth. Different GDP growth rates were used to develop various scenarios of economic growth while the population projections of the PFI (Population Foundation of (India) were considered to reflect trends in population growth. These population and GDP figures were used to estimate end-use demand in the five sectors of the economy (agriculture, commercial, residential, industrial-power, and transport) over the modeling period. The MARKAL (MARket ALLocation) Program model was selected to examine the pathways for optimal energy supply to meet the end-use services in the five economic sectors under each scenario. The model indicates the minimized total system cost of the energy sector under various scenarios. Also, the main outputs provided by the model include information regarding the level of uptake of total energy resources, their distribution across the consuming sectors, choice of the technological options at the resource supply end, conversion and end-use levels, investment levels during each five year time period, an indication of capacity addition, retirement of equipment and appliances, emission levels associated with resources, end-use technological options adopted, and so on.

The modeling time frame is from 2001 to 2031, and the data input to the model is from 2001 to 2036. The overall methodology is schematically depicted in Figure 2.1.

Enter data for 2050---

The choice of the possible technological options (existing and futuristic) to be included in the model, the development of the RES (reference energy system), and the technology characterization for each option on the demand side as well as the supply side evolved on the basis of an extensive literature review. This climate plan presents the detailed study about 4 sectors.

i) Power Sector

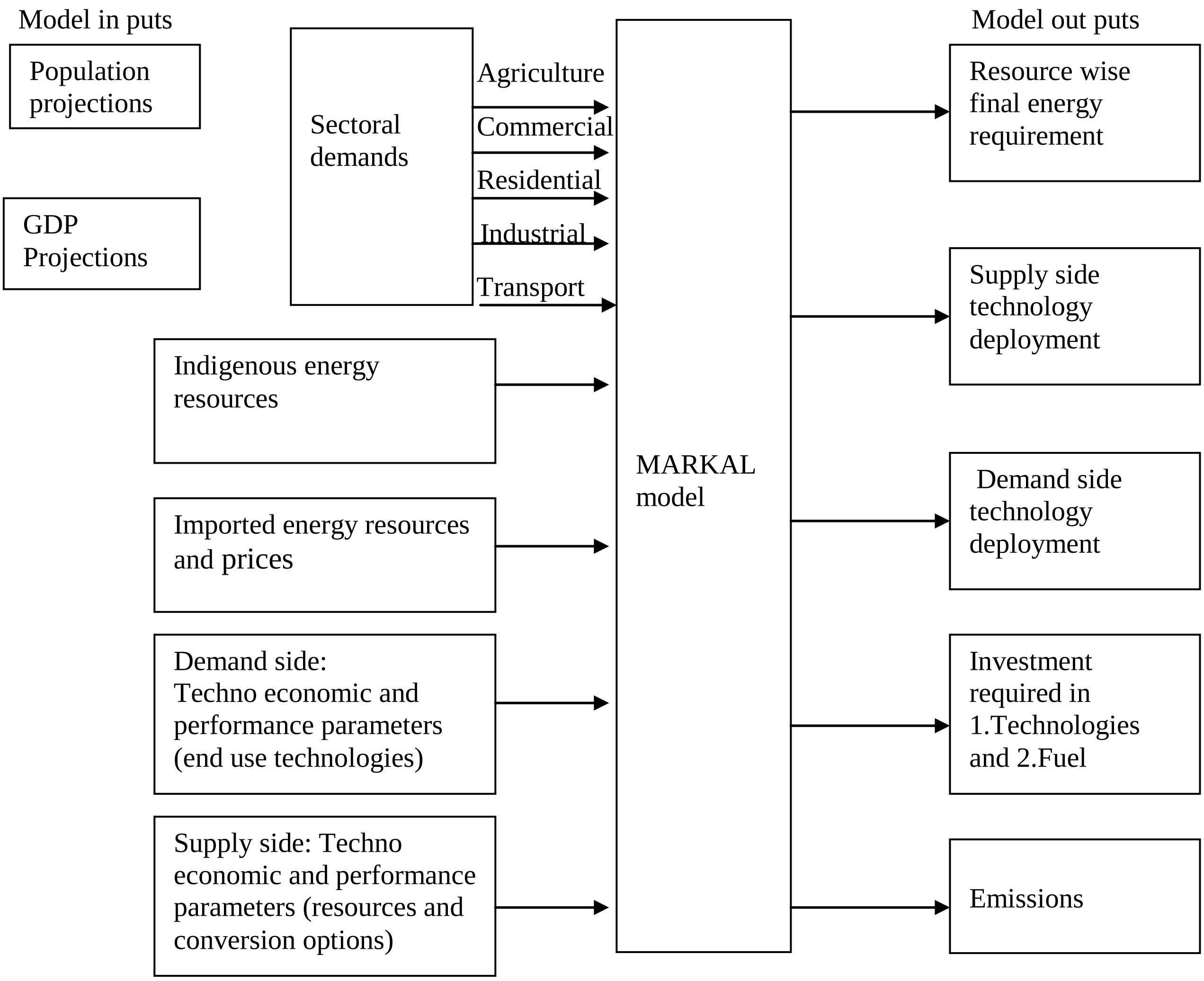
ii) Transport Sector

iii) Agriculture Sector

iv) Construction Sector

MARKAL Model is used for the studies as used by TERI, India.

Figure 2.1 Schematic representation of methodological framework



2.2 MARKAL Model

The model is dynamic in the sense that it optimizes over the entire time period and considers retirement of equipment and appliances over their lifetime and investment in new capacities while considering the entire modeling time period. MARKAL is accordingly an appropriate framework for conducting a medium- to long-term analysis. The model has the ability to include/ use redefined constraints to reflect physical restrictions on the availability or processing of resources, maximum penetration ratios for a set of technologies, and so on.

MARKAL model provides a generalized structure that can be adapted well for the Indian energy sector analysis. It allows for formulating and analysing policy and technology scenarios easily, so that the implications pertaining to economy, energy, and environment of a particular set of policies can be evaluated.

The MARKAL model was developed by the IEA (International Energy Agency) to evaluate optimal mix of energy supply and demand technologies under different scenarios and objectives. The MARKAL framework is, therefore, geared towards expressing energy technology interactions.

As a mathematical tool, it is used for optimizing technology mixes to meet specified objectives such as least energy system costs.

2.3 Description of the model frame work used in Analysis

The MARKAL database has been created over a 36-year period, from 2001 to 2036, at five-year intervals, coinciding with the Government of India's Five Year Plans. The year 2001-02 is chosen as the base year as it coincides with the first year of the Government of India's Tenth Five Year Plan (2001/02– 2006/07). In the model, the Indian energy sector is disaggregated into five major energy- consuming sectors, namely, agriculture, commercial, industry, residential, and transport. Each of these sectors is further disaggregated to reflect the sectoral end-use demands. The model would be driven by the demands on the end-use side.

The effects of inconsistent behaviour of the MARKAL, an optimization model, are thus avoided with perfect foresight.

2.4. Population and demographic trends in India

All the sectors selected for studies are basically affected by the population growth. Therefore the population growth assessment plays an important role in the study. Simple fact is that population increases then population demand will increase more, constructed area will be required to accommodate the population, it will stress the agriculture as the demand will increase and transportation needs will also increase.

India's population stood at nearly 350 million at the time of independence. It increased at an unprecedented annual growth rate of 2.11% during 1951–2001 to reach the one billion mark at the dawn of new millennium. Although the family planning programme was initiated in the country in 1951, the 1971 census indicated that due to high growth rate, the population had increased by 24.8% during 1961–71 as compared to 21.5% during 1951–61. In spite of the vast network of personnel involved in the programme and sizable expenditure from the centre, this continuing increase in population growth rate disturbed the policy-makers and programme administrators, which led to the adoption of draconian measures during the emergency period of 1975/76.

A revised population policy was adopted in 1977 and the 'family planning programme' was renamed as 'family welfare programme'. This programme chose to achieve demographic change through education and motivation.

2.5. Population projection for India

Within the country, prominent research organizations like the PFI and renowned demographers like P N Mari Bhat have also made population projections for India. Their projections are based on the Component method, although different assumptions for various influencing factors, such as fertility rate, mortality rate, and migration, are used. Table 2.2 provides a comparative assessment of the assumptions used by the above-mentioned agencies.

A close look at the estimates reveals that the UNPD (medium variant) estimates are not very different from the PFI estimates. For the period 2001–36, the UNPD projects population to increase at an annual growth rate of 1% while the PFI estimates the growth rate to be 1.14%. Both the agencies estimate that the annual population growth rate would decline over the decades during the forecast period. As per the UNPD figures in the medium-variant scenario, annual growth rate of population declines from 1.41% to 1.08% to 0.73% during 2001–11, 2011–21, and 2021–31, respectively. As per the PFI's projections, the growth rate is 1.37%, 1.34%, and 0.92% during the same time periods.

For this study, the PFI estimates are preferred to the UNPD estimates, since the PFI relies more on the country-specific details. The UNPD estimates are based on the assumptions that are derived on the basis of experience of all the countries in the world, which might not reflect the specific characteristics inherent in Indian demography. The PFI estimates, on the other hand, have been derived on the assumptions specific to various Indian states. The PFI population projections are used by the Office of Registrar General of India that conducts the population census in the country every 10 years. Moreover, the Planning Commission also adopts the set of population projections provided by the PFI for formulation of various national plans and policies.

2.6. Rural–urban population

As energy-use patterns, choice of fuels, and so on vary considerably among rural and urban areas, examining the trend of urbanization in the future assumes high significance for a country like India. India's population has grown 2.84 times from 1951 to 2001, that is, from 361 million in 1951 to 1027 million in 2001. Its rural urban distribution has also undergone structural changes over the same period. Its population in rural areas has more than doubled (~2.5 times) from 298 million during 1951 to 740 million in 2001, whereas population in urban areas has increased more than four times (~4.6 times) from 62 million to 287 million during the same time period. The UNPD estimates the urban population to increase by about 33% by 2016 and 42% by 2031, while corresponding figures given by the Census of India are 34% and 40% for the same time period.

Table 2.1. Assumptions for population projections

Factors	UNPD	PFI	Mari Bhat
Total fertility rate Mortality	Assumed to decline based on the past trend of fertility rate during 1950–2000 (a lower limit of 1.85 children per woman)	Extrapolation by fitting linear trend (1971–96) for each of the larger states in India. The figure 1.6 is taken as the floor value	Assumed to fall to 2.8 in 2010 and reach very close to the replacement level only by 2025
Mortality rate	Medium path of mortality decline is used to project future mortality levels	Three values of life expectancy for the periods 1991–95, 2011–16, and 2021–26 were extrapolated, using linear fit, at five-year intervals from 2001 to 2051, for each of the 15 larger states. The figures for India are obtained as weighted average of the figures of the major states	The life expectancy at birth has been assumed to reach 67 for males and 71 for females by 2025

Migration	The future path of international migration is set on the basis of past international migration estimates and on assessment of the policy stance of countries with regard to future international migration flows	No large-scale inter-state migration in the country	Net migration to India assumed to be zero

As indicated in Tables 2.3 and 2.4, the percentage shares of the population residing in urban areas projected by both the UNPD and the PFI are more or less similar. The data given by the PFI is considered in this analysis to ensure consistency with the set of population projection provided by the PFI and adopted by the Office of Registrar General of India, Government of India.

Table 2.2 Population projections (in million)

Source	Scenario	2001	2006	2011	2016	2021	2026	2031	2036
UNPD	Low variant	1031	1099	1156	1203	1242	1269	1282	1283
	Medium variant	1033	1112	1188	1259	1323	1378	1424	1461
	High variant	1034	1125	1220	1315	1405	1490	1573	1653
MariBhat	Optimistic	1026	1109	1191	1271	1345			
	Realistic	1025	1103	1173	1244	1320			
PFI		1027	1092	1177	1264	1344	1413	1473	1526

PFI – Population Foundation of India; UNPD – United Nations Population Division
Note UNPD projections were available from 2000 to 2050 on a five-year interval. Figures presented in this table are Interpolated for the years mentioned.

Table 2.3 Rural–urban distribution (%) as per the UNPD

Region	2001	2006	2011	2016	2021	2026	2031	2036
Urban	28	29	31	33	35	37	42	45
Rural	72	71	69	67	65	62	58	56

UNDP – United Nations Population Division; PFI – Population Foundation of India
Source UNPD (2003)
Note Projection distribution was available from 2000 to 2016 on a five-year interval. Figures presented in this table are interpolated for 2001, 2006, 2011, etc. and, based on the past trend of 2001–16, these have been extrapolated for the period 2016–36.

Table 2.4 Rural–urban distribution (%) as per the Census of India

Region	2001	2006	2011	2016	2021	2026	2031	2036
Urban	28	30	32	34	36	38	40	42
Rural	72	70	68	66	64	62	60	58

Source Census of India (1991)
Note Figures were available till 2016 and, based on the past trend of 2001–16, these have been extrapolated for the period 2016–36.

2.7. Number of households

The household size for rural and urban areas has been estimated based on the rate of decrease in average number of households in rural and urban areas during the period 1981–2001. Following the rate of decrease during this period, household size has been projected to decline by 4.75% and 4.46% for rural and urban, respectively, by 2036. Table 2.5 presents the projected population and number of households in rural and urban areas.

Table 2.5 Projected population and number of households in rural and urban areas (million)

	Population		Number of households	
Year	Rural	Urban	Rural	Urban
2001	739.44	287.56	137.34	56.26
2006	764.40	327.60	144.53	65.36

2011	800.36	376.64	154.06	76.62
2015-16	834.24	429.76	163.48	89.14
2021	860.16	483.84	171.60	102.34
2026	876.06	536.94	177.92	115.80
2030-31	883.80	589.20	182.73	129.57
2036	885.08	640.92	186.30	143.71
2050				

Source Census of India (1991)
Note The figures were available till 2016 and, based on the past trends, have been extrapolated for the period 2016–36.

2.8 Gross domestic product (GDP) as a measure of economic growth

The significance of economic growth for a polity cannot be undermined in the context of overall development. Economic growth results from an increased production of goods and services leading to high income generation. This ultimately translates into improvement in the quality of life of the people in terms of various economic and social indicators such as enhanced purchasing power and improved access to quality education and health care services. GDP is considered as the most commonly used measure of economic growth. It tracks the domestic economic activity in terms of the value added and income generated (in monetary terms) during a specified time period.

2.9. Gross domestic product growth projections

GDP would be no more than 6.7% over the 30-year modeling period. (TERI national energy map for India: Technology vision 2030) The methodology for the same is provided in detail in Appendix `1. This particular study, however, was conducted with a projected GDP growth rate of 8% considered in the BAU scenario that reflected government plans. The rationale for choosing a GDP growth rate of 8% throughout the period 2004–36 is also explained in detail in Appendix 1 The Government of India is expected to target a growth rate of 10% for the Eleventh Five Year Plan period. Hence, additionally, a 10% GDP scenario has been considered to reflect an even higher growth rate of the economy, as suggested by the Office of the PSA (Principal Scientific Advisor), to examine the impact of a two digit (a higher rate of GDP growth relative to the BAU) GDP growth on the future trajectories of energy consumption. Accordingly, two GDP growth rates have been considered in this study: 8% (reflecting the BAU scenario) and 10% (representing a high-growth scenario).

Table 2.6 Projections of GDP at factor cost at 1993/94 prices (in crore rupees) under various GDP growth rate scenarios

GDP growth (%)	2001	2006	2011	2016	2021	2026	2031	2050
6.7	1 267 945	1 676 029	2 240 639	3 061 793	4 258 687	6 004 800	8 551 719	
8	1 267 945	1 802 078	2 647 845	3 890 552	5 716 498	8 399 411	12 341 490	
10	1 267 945	1 904 059	3 066 507	4 938 640	7 953 729	12 809 559	20 629 924	

GDP – gross domestic product

Table 2.7 Sectoral composition of GDP (%)

	Sectoral composition of GDP (%)		
	Reference	Estimates	Estimates
Sector	2020	2020	2050
Agriculture	6	17	

Industry	34	28	
Services	60	55	

GDP – gross domestic product
Source Reference 2020 data is from the World Bank(2001)

The services sector continues to grow at the current rate (0.51% during 2003/04) till 2036/37, achieving a share of 60% in the GDP by 2036/37. The share of industrial sector in the aggregate GDP has increased at an average annual growth rate of 0.31%. It is estimated that it will achieve a share of 30% in the GDP by 2036/37. The rest of the share (10%) is accounted for by the agriculture sector in our analysis.

3.0 Approach for sectoral endues demand estimation

Econometric techniques, such as regression techniques, process models, and end-use methods, are deployed to estimate and project the end-use sectoral demand. The population and GDP projections were used as the main driving force for estimating the end-use demands in each of the energy consuming sectors.

Table 2.8 Sectoral GDP at factor cost (in crore rupees) under 8% GDP growth rate scenario

Sector	2001	2006	2011	2016	2021	2026	2036
Agriculture	333 274 (26%)	395 320 (22%)	533 024 (20%)	711 190 (18%)	936 593 (16%)	1 213 019 (14%)	1 536 733 (13%)
Industry	309 557 (24%)	491 106 (27%)	732 865 (28%)	1 093 635 (28%)	1 632 004 (28%)	2 435 397 (29%)	3 634 279 (29%)
Services	625 114 (49%)	915 652 (51%)	1 381 955 (51%)	2 085 727 (54%)	3 147 901 (55%)	4 750 995 (57%)	7 170 477 (58%)
Total	1 267 945	1 802 078	2 647 845	3 890 552	5 716 498	8 399 411	12 341 490

GDP – gross domestic product

Table 2.9Sectoral GDP at factor cost (in crore rupees) under 10% GDP growth rate scenario

Sector	2001	2006	2011	2016	2021	2026	2036
Agriculture	333 274 (26%)	358 212 (19%)	383 575 (13%)	410 734 (8%)	477 224 (6%)	768 574 (6%)	1 237 795 (6%)
Industry	309 557 (24%)	539 630 (26%)	987 235 (29%)	1 670 286 (31%)	2 704 268 (34%)	4 355 250 (34%)	7 014 174 (34%)
Services	625 114 (49%)	1 006 218 (53%)	1 695 697 (58%)	2 857 620 2 857 620	4 772 237 (60%)	7 685 736 (60%)	12 377 954 (60%)
Total	1 267 945	1 802 078	2 647 845	3 890 552	5 716 498	8 399 411	12 341 490

GDP – gross domestic product

The industrial sector is disaggregated into eight energy-consuming industries, like chlor-alkali, aluminum, iron and steel, cement, textile, fertilizer, and pulp and paper, along with other manufacturing units grouped as other industries. The physical outputs from the aforesaid industries are considered as the demands of industrial outputs. The future demand of industrial output for each of the abovementioned industrial sub-sectors is based on income generated by various sectors of the economy. This is measured by the GDP and the value added by the industrial sector (GDP of industry), per capita income, and so on. Similarly, the transportation demand (disaggregated further into mode-wise passenger demand and freight transport demand) is projected using various socioeconomic indicators such as per-capita income (indicator of purchasing power), percentage share of population residing in urban areas, population, and so on. In the agriculture sector, demand is estimated for land preparation and irrigation pumping. In the residential sector, the demand is projected for lighting, space conditioning, cooking, and refrigeration separately for urban and rural households to account for the differences in lifestyles and choice of fuel and technology options. In the commercial sector, the demand is projected for cooking, lighting, and space conditioning, using the value added by the services sector as an explanatory variable. The detailed methodology and estimates of energy demands for each of the end-uses are presented in Chapter 3.

(Reference: Methodology, National Energy Map for India: Technology Vision, The Energy and Resources Institute Office of the Principal Scientific Adviser, Government of India2006, TERI Press)

CHAPTER 3

SECTORS SELECTED FOR THE STUDY

Future Climate – Engineering Solutions project is a step for envisaging a scenario for 2015, 2030 and 2050. According to IPCC 15 sectors should be studies for formulation the perfect climate plan for any country. India being a vast country studying all the sectors was not possible. In this study four sectors that are major emitters of CO2 and equivalent gases are selected, namely:

i) Agriculture

ii) Transport

iii) Construction

iv) Power

CO2 and equivalent gases data of each sector is presented in this chapter.

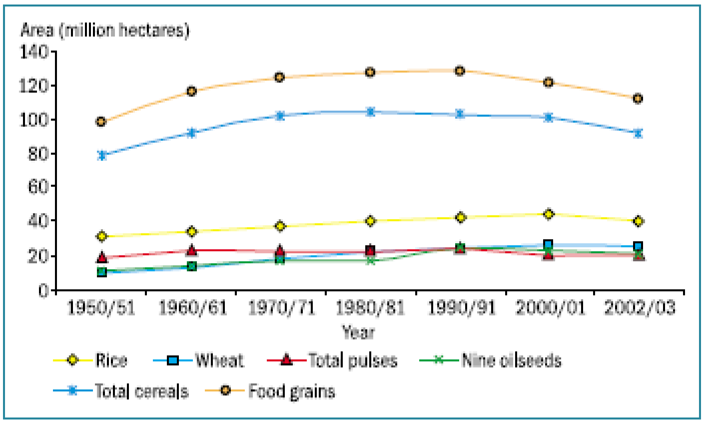
3.1 Agriculture sector

Traditionally, India has been an agricultural economy. Since Independence, the share of agriculture in the country's GDP has been declining in comparison to the growth of the industrial and services sectors. The percentage share of GDP from agriculture at factor cost at current prices has come down from 28.4 in 1993/94 to 20.3 in 2002/03 (MoA 2004 *Ministry of Agriculture* ***Agricultural Statistics at a Glance 2004*** *New Delhi: Department of Agriculture and Cooperation, MoA, Government of India)*. However, agriculture is still a major source of income for about 53.2% of the population (MoA 2004). It provides raw material to several major industries, such as sugar, textiles, jute, paper, food processing, and milk and milk processing. Agriculture is crucial for maintaining the food security of the country. This sector has forward and backward linkages with other economic sectors.

Therefore, changes in the agricultural sector have a multiplier effect on the entire economy. High growth rate of agriculture ensures good performance of agro-based industries, supports creation and improvement of the rural infrastructure, and facilitates reduction in poverty.

Agriculture accounts for 43% of the total geographical area. In terms of cultivated area, the leading crop is rice – the staple food of a large section of the Indian population (Figure 3.1) – followed by wheat.

Figure 3.1 Area under cultivation in India (million hectares)

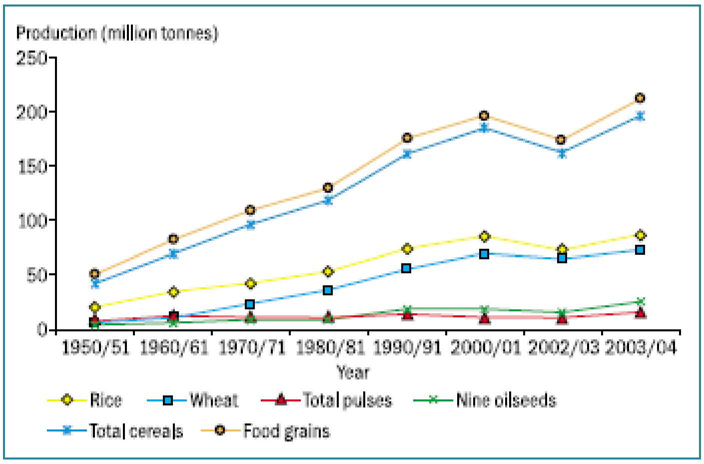


Source FAI (2004)

There has been a continuous fragmentation of land holdings, partly because of the growing population pressure and partly because of the peculiar slow shift of the labour force from agriculture to non-agricultural economic activities. Per capita availability of cultivable land (excluding forests) has decreased from 0.48 ha (hectares) in 1951 to0.15 ha in 2000.

Development of improved production technologies, efficient input use and improved delivery system, rural infrastructure development, pricing policies, and marketing arrangements have led to a remarkable increase in food grain production from just 51 MT (million tonnes) in 1950/51 to 174.19 MT in 2002/03 and further to 212.02 MT in 2003/04 (Figure 3.2).

Figure 3.2 Food grain production in India (million tonnes)



Source FAI (2004)

Yield of rice and wheat increased from 668kg/ha and 663 kg/ha to 2051 kg/ha and 2707 kg/ha, respectively, during the same period. Yield of coarse cereals went up from 408 kg/ha in 1950/51 to 1228 kg/ha in 2003/04.Yield of nine oilseeds and pulses increased from 481 kg/ha and 441 kg/ha to 1072 kg/ha and 623 kg/ha, respectively, during the same period.

Horticultural production was 156.1 MT in 2003/04. This sector contributed 30% of the share of agriculture to the GDP. India was the largest producer of vegetables and the second largest producer of fruits in the world with 90 MT and 47.5 MT of production, respectively, and accounted for about 10% of the global production of fruits. India is ranked first in the production of mango, banana, sapota, acid lime and cauliflower; second in onion; and third in cabbage (MoF 2005 *Ministry of Finance.2005* ***Economic Survey 2004/05*** *New Delhi: Economic Division, MoF, and Government of India)*

India is the largest producer and consumer of tea in the world, accounting for 27% of the world production, with 850.5 thousand tonnes of production in 2003/04. India is also among the leading producers of sugar cane, cotton, and jute in the world, with production of 236.2 MT, 13.8 MT, and 11.2 MT, respectively, in 2003/04. Cashews, coffee, and spices are also important cash crops (MoF 2005).

3.1.1 End-use demand estimation for the agriculture sector

During the past five-and-a-half decades, Indian agriculture has witnessed numerous changes. The 'Green Revolution' is one of the most striking success stories of the post-Independence era. The impact of the Green Revolution was, however, so dramatic that India became a role model for many developing countries. This innovation – coupled with investments in irrigation infrastructure and expansion of credit, marketing, and processing facilities – led to a significant increase in the use of modern inputs. As a consequence, the requirement of commercial energy of the farm sector increased by several times.

The availability of farm power per unit area (kW/ha [kilowatt per hectare]) has been considered as one of the parameters for expressing the level of mechanization. Power availability for carrying out various agricultural operations has increased from 0.3 kW/ha in 1971/72 to 1.4 kW/ha in 2003/04 (MoF 2005).

The contribution of different power sources to the total power has also changed over time. The share of mechanical and electrical power in agriculture increased from 40% in 1971/72 to 84% in 2003/04 (MoF 2005). However, the extent of use of mechanical power in agriculture is much below the ideal value.

Various agricultural operations like threshing, harvesting, land preparation, and irrigation, account for energy demand in the agricultural sector. But, energy demand in the agricultural sector in India is mainly attributed to two major agricultural operations. 1. Land preparation 2. Irrigation

3.1.1.1 Demand for land preparation

3.1.1.1.1 Gross cropped area

Energy demand for land preparation depends on the extent of area under cultivation. The total land area being constant, NCA (net cropped area) has also remained constant at about 141 Mha since 1970s. This implies that increase in GCA (gross cropped area) has been made possible by increase in CI (cropping intensity) over the years. NCA has been assumed to remain constant in the next 30 years also.

Facilitated by improvement in the irrigation sector, CI is initially expected to increase. However, with further development of the sector, CI will move towards its saturation level because production time of crops cannot be reduced beyond a certain level. logistic curve equation is used to calculate GCA.

During 1971–99, GCA increased at an annual growth rate of 0.496% and is expected to increase at the rate of 0.430% during 2001–36 (Table 3.1).

3.1.1.1.2 Number of tractors

At the time of Independence, and even in the 1950s, the use of tractors for agricultural purpose was very limited. Tractor manufacturing in India started in 1961 with a capacity to manufacture 11 000 tractors per year. The level of mechanization has been increasing steadily over the years as a result of joint efforts made by the government and the private sector. The number of tractors manufactured from all units during 1997 was over 255 000 (Venugopal and Pingali 2004 State of India Farmer: a millennium study–input management, New Delhi: Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India)

Annual average rate of growth for tractors manufactured was 9.73% during 1971–2001.

The negative intercept indicates that the number of tractors starts increasing only after a certain level of GDP is attained. In other words, it implies that mechanization of agriculture picked up only after a certain level of growth was achieved by the agriculture sector.

Table 3.1 Projected cropping intensity and gross cropped area

Year	Cropping intensity intensity	Gross cropped area (million hectares)
2001	1.360	192.054
2006	1.391	196.472
2011	1.423	200.904
2015-16	1.454	205.345
2021	1.485	209.792
2026	1.517	214.240
2030-2031	1.548	218.687
2036	1.580	223.127
2050		

3.1.1.1.3 Area under tractors

At 8% and 10% GDP growth rate scenarios, the GCA under tractors increases at the rate of 5.2%, and by 2036, the entire GCA would be under tractors.

Table 3.2 Projected cropping intensity and gross cropped area

Year	8% GDP	10% GDP
2001	38.28	38.28
2006	47.06	44.87
2011	64.57	50.98
2015-2016	56.75	57.41
2021	114.40	68.48
2026	147.93	05.50
2030-2031	186.93	163.08
2036	223.13	223.12
2050		

3.1.1.1.4 Demand for irrigation

Irrigation plays a vital role in Indian agriculture for two important reasons. First, India has a monsoon-dependent farming system, with large areas receiving inadequate rainfall. Moreover, much of this rainfall is restricted temporally to a few months while the rest of the year is predominantly dry. In such a circumstance, it is only with irrigation that cultivation on an annual basis is possible. Second, irrigation has acquired an additional importance since the Green Revolution in India. The Green Revolution has been characterized by the use of high-yielding crop varieties, fertilizers, and other inputs. These inputs into agriculture are combined with a regular water supply provided by irrigation. In such a situation, irrigation has assumed considerable significance at the state, regional, and national levels.

3.1.1.1.5 Gross irrigated area

Increase in cropping intensity is difficult in the absence of proper irrigation facilities. Therefore, it has been assumed that the increase in GCA is due to an increase in the area irrigated, and thus, GIA is calculated as.

ΔGIAt, t-1 = GCAt – GCAt-1 (3.1) The GIA has increased from 38.4 Mha in 1971/72 to 76.3 Mha in 1998/99. (TERI report)

GIA increases at the rate of 0.97% during the forecast period (2001–36) (determined by the equation above) and increases from about 78 Mha in 2001 to 110 Mha by 2036 in the low- and medium-growth scenarios.

In the high-growth scenario, it has been assumed that the government allocates funds to make more canals and builds more infrastructures for irrigation. Therefore, the percentage area under irrigation follows the rate of increase during 1971–2001, thereby increasing from 41% in the base year to 65% by 2036 (Table 3.3). One of the biggest developments that have taken place in Indian irrigation after Independence is in the field of groundwater irrigation, and one of the major engineering inputs adopted has been irrigation pumps. Farmers use electric-motor- and diesel-engine-operated irrigation pumps with a preference for the former. Groundwater now is an important source of irrigation and fulfils about 43.6% of the total irrigation demand in the country (CMIE *Centre for Monitoring Indian Economy 2004a,* ***National Income Statistics,*** *Mumbai.)*

Table 3.3 GIA and GCA under irrigation under various growth scenarios

Year	6% and 8% GDP		10% GDP	
	GIA million	GCA under	GIA million	GCA under
2001	78.90	41.22	78.90	41.22
2006	83.34	42.55	88.93	45.26
2011	87.85	43.85	97.54	48.55
2015-16	92.45	45.11	106.46	51.84
2021	97.07	46.33	115.66	55.13
2026	101.97	47.51	125.16	58.42
2030-2031	106.58	48.66	134.95	61.71
2036	110.46	49.34	145.03	65.00

2050				

GIA – gross irrigated area; GCA – gross cropped area; GDP – gross domestic product

In the coming years, groundwater utilization is likely to increase for the expansion of irrigated agriculture. Given that tube wells (especially, individual-owned tube wells) are a perennial source of irrigation, as they encourage crop activity in rain deficient seasons with minimum risk, the percentage area under groundwater irrigation is expected to increase with time.

Pump sets costing about 10 000–15 000 rupees are encouraged in the wake of subsidized power tariffs, soft loans, and subsidies.

The government can make efforts to bring about more area under irrigation by increasing the production of pump sets.

The projections of GIA for groundwater irrigation are shown in Table 3.4.

In the medium- and high-growth scenarios, it is assumed that the government has resources to allocate for boosting the number of pump sets. Therefore, the percentage area under groundwater irrigation increases at an average annual growth rate of 1.11%—the rate of increase during 1971–2001 (CMIE 2004). Accordingly, the percentage area under groundwater irrigation increases from 43.6% in the base year to 64% by 2036.

Table 3.4 GIA under groundwater irrigation at various GDP growth rate scenarios

Year	**6% GDP**		**8% GDP**		**10%GDP**	
	GIA under ground water irrigation (million hectares)	**GIA under ground water irrigation %**	**GIA under ground water irrigation (million hectares**	**GIA under ground water irrigation %**	**GIA under ground water irrigation (million hectares**	**GIA under ground water irrigation %**
2001	34.40	43.60	34.40	43.60	34.40	43.60
2006	36.33	43.60	38.40	46.08	40.84	46.08
2011	38.30	43.60	42.79	48.71	47.33	48.71
2015-16	40.29	43.60	47.59	51.49	54.57	51.49
2021	42.3	43.60	52.83	54.43	62.64	54.43
2026	44.38	43.60	58.56	57.73	71.61	57.73
2030-2031	46.46	43.60	64.82	60.81	81.58	60.81
2036	48.16	43.60	71.01	64.28	92.62	64.28
2050						

GIA – gross irrigated area; GDP – gross domestic product

3.1.1.1.6 Groundwater requirement

Table 3.5 gives the crop-wise GCA and water consumption. The weighted average of water consumption for GIA under various crops was calculated to get the water consumption per hectare of GIA. The weighted water requirement per hectare for agriculture has been assumed to remain constant over the years. Total groundwater demand = water demand per hectare × GIA under groundwater irrigation. (TERI report)

A complexity of factors – hydrological and climatologically – controls the groundwater occurrence and movement. Energy requirement for pumping out water depends on the water table.

Table 3.5 Crop-wise GCA and water consumption

Crop	**Irrigation water**	**Water**	**GCA (Mha)**	**Percentage of**	**Water**

	requirement (mm)	consumption (m3)		GCA irrigated	consumption (MCM)
Rice	300-950	6250	45.16	53.9	152 133
Jowar	350-650	5000	10.25	7.7	3946
Maize	400-750	5750	6.42	22.9	8453
Wheat	300-450	3750	27.49	87.2	89892
Pulses		5000	21.12	16.1	17002
Soyabean	500-860	6800	6.22	1.6	677
Sugar cane	1000-1500	12500	4.22	92.0	48530
Cotton	550-950	7500	8.71	35.2	22994
Tobacco	600	6000	0.43	46.0	1187
Groundnut	506	5060	24.28	25.2	30960
Bajra		5000	8.9	803	3693
Gram		5000	6.15	29.1	8948
Sunflower	350-500	4350	1.29	23.3	1307
Total			170.64		389723

GCA – gross cropped area; Mha – million hectares; mm – millimetres; m3 – cubic metres; MCM – million cubic metres

Sources <http://www.iasri.res.in/agridata/db2002tb3_27.htm>; <http://www.ikisan.com/links/ap_irrigation.shtml>; <www.Indiastat.com>; MoA 2004,teri

Note Average figure is considered for water consumption.For pulses, bajra, and gram, water consumption corresponding to Jowar is considered

An attempt has been made wherein maximum number of villages in India at a particular water head is taken as a representative figure of water head for India based on the *Third Census of Minor Irrigation Schemes 2000/01* (Ministry of Water Resources (MoWR)) New Delhi, Government of India.

The Census reveals that shallow tube wells constitute 94.03% of the total tube wells in the country. Andhra Pradesh, Bihar, Haryana, Madhya Pradesh, Punjab, Uttar Pradesh, and West Bengal constitute 85.7% of the total shallow tube wells in India. In these states, pumps of 6–8 hp are dominant, constituting 26.4% of the total pumps, whereas, pumps of 4–6 hp constitute 24% of the total pumps.

States like Haryana, Punjab, and Uttar Pradesh having more than 89%, 90%, and 62% of the NCA irrigated have maximum number of villages at 10–15 m water head. Consequently, these states have the maximum number of pump sets of 6–8 hp. This supports the fact that as the area under irrigation increases, groundwater extraction increases and so does the water head.

3.1.2 Technologies in the agriculture sector

In the past two decades, there has been a proliferation of groundwater irrigation in India and, therefore, large penetration of pump sets. Estimates put the figure of diesel pump sets in India at 6.5 million. To this, another 11 million pumps with electric motor can be added (Bom and Steenbergen 1997, **Fuel efficiency and inefficiency in private tube well development,** Energy for Sustainable Development **3**(5): 46–50).

The *Minor Irrigation Census 2001* reveals that 94% of the total tube wells in India are shallow tube wells. About 85% of the shallow tube wells are accounted for by states such as Andhra Pradesh, Haryana, Punjab, Madhya Pradesh, Uttar Pradesh, West Bengal, and Bihar.

The configuration of pump sets in areas with shallow water tables ranges between 2.5- and 10-hp engines. The typical irrigation tube well configuration differs within this broad range in different areas depending on the depth of water table, prevailing land ownership, soil conditions, and local tradition. However, the tube well configuration is not optimal in terms of fuel consumption or water saving.

Electricity consumption for electric pump sets can be reduced by 30%–50% employing simple measures, such as pipes with larger diameter (Sant and Dixit 1996 *Agricultural pumping efficiency in India: role of standards, Energy for Sustainable Development 3(1): 29–36)*

Therefore, diesel and electric pump sets are mainly divided into two categories: standard and efficient (Table 3.6). An attempt has been made to study the energy-saving potential. Fuel consumption of the efficient diesel pump is 45% lower than that of a standard pump set. For efficient electric pump sets, it has been assumed that 30% efficiency improvements would be realized by 2036. Other than improvement in the efficiency of pump sets, the efficiency scenario also considers augmentation of irrigation efficiency In India, the existent irrigation practice results in considerable amount of water wastage. For example, the evapotranspiration requirement for growing paddy is about 800–1000 mm (millimetres), whereas in canal/ tank command areas, farmers use as much as 2000–2500 mm, which is wasteful and also affects the yield due to drainage problems. Scientists have found that there is no need to flood the paddy field to a depth of 15–20 cm (centimeters), as practiced by farmers, and it is enough to irrigate the field to a depth of 3–5 cm as soon as the standing water disappears. This can reduce the water use by 30% while increasing the productivity substantially

For row crops, such as cotton, sugar cane, and vegetables, the furrow method is suitable. In addition, the skip furrow, pair row, or alternate furrow method can reduce the need for water by 25%–30%, without affecting the yield (Sivanappan 1995 Many cost effective options for water Management, The Hindu Survey of Indian Agriculture, New Delhi: The Hindu)

Therefore, the efficiency scenario also considers the improvement in irrigation efficiency, whereby, the concern of water wastage is addressed and 30% reduction in the water requirement of 2036 is realized.

Technical specifications are considered for standard and efficient tractors. A 35-hp standard tractor is priced at 260 000 rupees and it ploughs 0.31 ha in one hour by consuming 4.5 liters of fuel. It is assumed that an efficient tractor ploughs 0.40 ha of land in 1 hour by consuming 3 liters of fuel per hour and is priced at 310 000 rupees.

Table 3.6 Technology characterization of pump sets

	Diesel pump sets		**Electric pump sets**	
	Standard	Efficient	standard	efficient
Price (rupees)	10000	14600	8000	10600
Water discharge (litres per second	4	4.5	5.5	5.5
Diesel/electricity consumption	1.1 liters per hour	0.6 liters per hour	4.8 kWh	4.8-3.4 kWh

Kwh kilowatt hour

(**Reference:** Agriculture sector, National Energy Map for India: Technology Vision 2030, The Energy and Resources Institute and Office of the Principal Scientific Adviser, Government of India 2006, TERI Press)

Recommendations

In the agriculture sector, the pump sets and the water delivery system engineered for high efficiency would be promoted. In the industrial sector, energy efficient technologies should be used and energy audits carried out to indicate scope for energy conservation measures. Motors and drive system are the major source of high consumption in Agricultural and Industrial Sector. These need to be addressed. Energy efficient lighting technologies should also be adopted in industries, commercial and domestic establishments.

(**Reference**: Recommendations, India's Initial National Communication to the united Nations Framework Convention on Climate Change, government of India, pg no i –iii)

Barriers

3.2 Transport sector

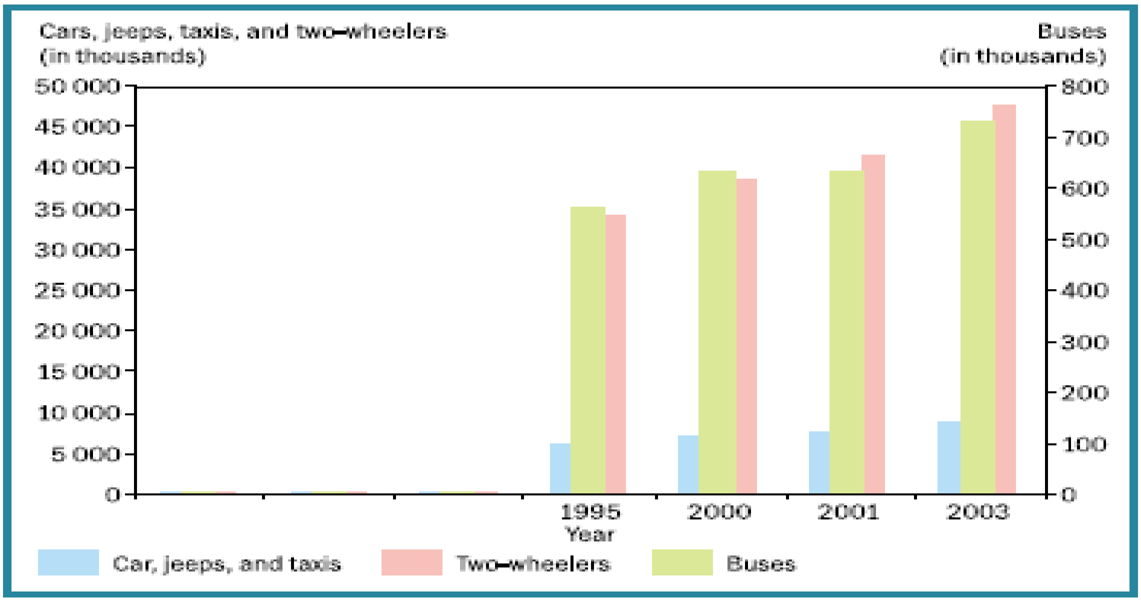
Transport sector studied while formulating this report includes all modes of transportation. Study is based on population growth and GDP. Keeping in view that oil and coal crises, different fuel-efficient technologies and the alternative fuels are envisaged and suggested.

The GDP accruing from the services incidental to transport is also included in the GDP generated by the transport sector. The GDP (measured at 1993/94 prices) accruing In the analysis, the focus is mainly on road- and rail-based freight and passenger traffic, although air- and coastal-based movements are also included in the framework. Figure 3.3 depicts the composition of fleet of registered passenger vehicles consisting of cars, jeeps, taxis, and buses for the period 1980–2003. The fleet of cars, jeeps, taxis, and two-wheelers (depicted on primary y-axis in Figure 3.3) taken together exhibits an average annual growth rate of 13% for the 1980–2003 period. In contrast, the fleet of buses has registered a low growth of 7.4% for the same period. Two-wheelers account for more than four-fifth that is, 84%, of the total passenger vehicle fleet. The remaining 16% is accounted for by cars, jeeps, from the transport sector activities (comprising railways, road, air, and coastal transportation) has increased at an average annual rate of 6.42% for the time period 1990–2003, doubling from 35 356 crore rupees in 1990/91 to 79 374 crore rupees in 2003/04 (MoSPI 2005).

The road and rail transport modes carried about 95% of the total passenger and freight traffic in the country in 2001 (GoI 2001).

Air and inland water transport assume importance for long-distance travel. In the analysis, the focus is mainly on road- and rail-based freight and passenger traffic, although air- and coastal-based movements are also included in the framework Figure 3.3 depicts the composition of fleet of registered passenger vehicles consisting of cars, jeeps, taxis, and buses for the period 1995–2003.

Figure 3.3 Trends in the composition of fleet of registered passenger vehicles



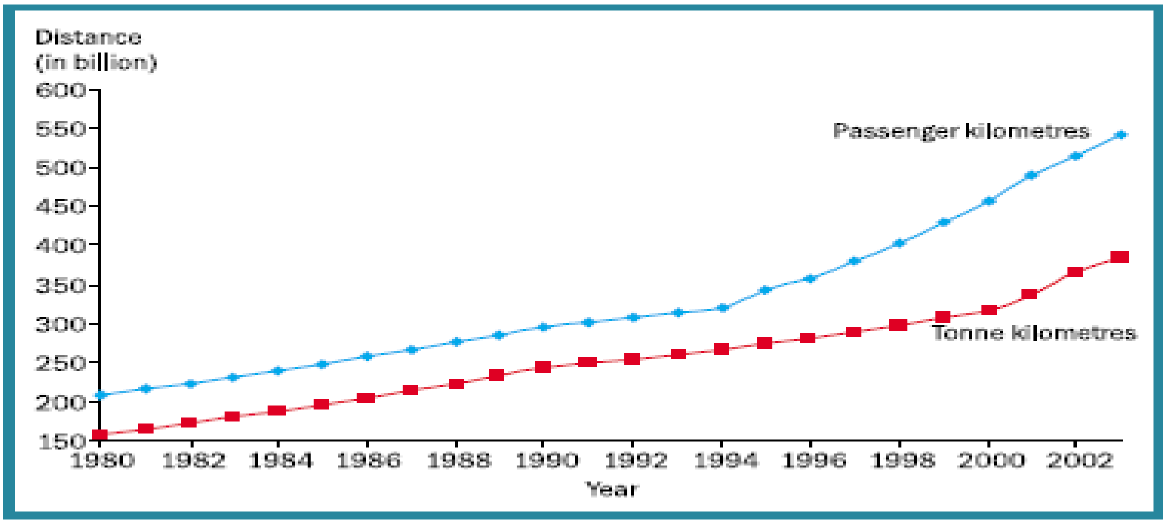
Source MoRTH (2005)

Two-wheelers account for more than four-fifth that is, 84%, of the total passenger vehicle fleet. The remaining 16% is accounted for by cars, jeeps, taxis, and buses. Of all the road passenger vehicles, the number of cars, jeeps, and taxis has increased at an average annual growth rate of 10%, whereas the two-wheelers have exhibited the highest average annual growth rate of 14% during the period 1980–2003.

However, the bus fleet has grown at an average annual growth rate of 7%.

The freight traffic (both the revenue earning and non-revenue-earning traffic) handled by railways has more than doubled from 158.5 billion tonne kilometers in 1980 to 384.1 billion tonne kilometers in 2003.

Figure 3.4 Trends in passengers and freight carried by railways



Source MoR (2005)

3.2.1 Transport sector end-use demands

3.2.1.1 Data problems in road-based movement

There exist wide variations in the estimates of various agencies for the year 1999 and 2000 as shown in Tables 3.7 and 3.8.

3.2.1.2 Methodology for projecting mode-wise road transport demand

A bottom-up approach has been deployed to estimate and project the road passenger, and freight transport demand. For estimating and projecting the mode-wise transportation demands, the motorized transport vehicles have been classified separately into transport vehicles for passenger and freight movement. Detail follows.

_ Vehicles for passenger movement

_ Cars and jeeps

_ Taxis***3***

_ Two-wheelers

_ Buses

_ Three-wheelers

_ Vehicles for freight movement

_ LCVs (Light goods/commercial vehicles)

_ HCVs (Heavy goods/commercial vehicles)

The objective is to estimate the travel demand separately for each of the vehicle types (on-road/in use***4***) mentioned above. The following equation is used to estimate the total passenger or freight travel demands in the year t' by the vehicle type 'j'.

PKmtj or TKmtj = Vtj × Otj × (Utj × 365) (3.2)

Where, PKmtj is the passenger travel demand by the vehicle type j in the year t (measured in passenger kilometres). TKmtj is the freight travel demand by the vehicle type j in the year t (measured in tonne kilometres). Vtj is the number of vehicles (on-road/in use) of the type j in the year t. Otj is the occupancy rate (measured in number of persons per vehicle per trip) for the year t of the vehicle type j. Utj is the utilization factor (kilometers travelled by a vehicle per day) for the vehicle of type j for the year t. Multiplying Utj by 365 gives the annual utilization rate for the vehicle type j for the year t.

Table 3.7 Comparison of the transport sector demand estimates by various agencies for the year 1999

Study	Estimated road traffic movement in 2000	
	Passenger traffic (billion passenger kilometres)	Freight traffic (billion tonne kilometres
RITES study (1998)	1880	1136
MOST: Study on estimation of total Road transport in 2000	3000-4000	600-1000
Steering Committee on Respective Planning for Transport	2400-4000	540-900
Planning for Transport	3000	800

Source Kapoor (2002)

3.2.1.2.1 Cars

Car sales are projected till 2036. The number of registered passenger cars for each year within the forecast period 2004–36 is obtained by adding the forecasted annual sales figures to the number of registered vehicles. The number of cars in use/on-road is less than the total number of registered cars. Therefore, the number of passenger cars, in use is obtained by deducting the number of cars considering a lifetime of eight years there exist variations in the average annual utilization rate as reported in different sources (Table 3.8). The occupancy rate for cars is assumed to decline from three persons per car in 1980 to 1.5 persons in 2036 (that is, decline by half). The rationale behind this assumption is that with increasing passenger car sales, vehicle ownership (number of vehicles owned per capita) would rise. As a result, the number of persons travelling per car is assumed to decline during the entire period, from 1980 to 2036. Similarly, with reference to the sources mentioned in the table, it has been assumed that the utilization rate of passenger cars (effective average distance travelled by a passenger car) would increase by 100 km every year (that is, 0.27 km daily), starting from 21.4 km/day in 1980.

3.2.1.2.2 Taxis

The historical annual time-series data on the number of registered commercial passenger taxis for the period 1980 until 2003 is used for estimating and projecting the travel demand by taxis until 2036.

Econometric technique (regression model) is used for estimating the number of commercial passenger taxis for the period 1980–2003. The percentage of population in urban areas (urbanization index/urban size) and the growth of the economy in general measured by GDP are considered as variables significant in explaining growth in the number of taxis plying on Indian roads. In order to measure the extent of responsiveness of demand for taxi services in India to changes in economic growth, and to account for the impact of increasing urbanization, log–linear (double log) specification of regression model was considered appropriate. The estimated regression equation is

$$\text{Log (Taxis)} = 0.11 \times (\text{UI}) + 0.70 \times \text{Log (GDP)}$$

(4.7) (14.8) (3.3)

(adjusted R2 = 0.91)

Where, UI = urbanization index

GDP = gross domestic product

Both the independent variables (GDP and UI) are found to be statistically significant in explaining the equation as indicated by values of the t-statistic (given in brackets) associated with the coefficients of the model estimated above. The adjusted R2 is as high as 0.91, implying that 91% of the variation in passenger sales can be explained by variations in the economic growth and the urbanization index.

The number of registered passenger taxis for each year within the forecast period 2004–36 is obtained by inserting the projected values of GDP and UI. The number of taxis in use/on-road is less than the total number of registered taxis. Therefore, the number of passenger cars in use is obtained by deducting the number of taxis, considering a lifetime of eight years (same as that of passenger cars).

The travel demand by taxis (measured in passenger kilometers) is estimated using Equation 3.2. The occupancy rate for taxis is assumed to remain constant at three persons per taxi throughout the projected period. The effective distance travelled daily by a taxi is assumed to increase from 60 km/day in 2001 to 80 km/day in 2036. The rationale behind assuming varying utilization rate lies in the fact that with huge investments pumped into the construction of roads and highways, commercial passenger taxi services are being used for long-distance intercity travel as well.

3.2.1.2.3Two-wheelers

The number of registered two-wheelers for each year within the forecast period 2004–36 is obtained by adding the forecast annual sales figures to the number of registered two-wheelers. The number of two wheelers in use/on-road is less than the total number of registered two-wheelers. Therefore, the number of two-wheelers in use is obtained by deducting the number of two wheelers, considering lifetime of eight years.

The travel demand by two-wheelers (measured in passenger kilometers) is estimated using Equation 3.2. The assumptions on occupancy rate and utilization rate for two-wheelers as reported in different sources are as follows.

For the purpose of our analysis, the occupancy rate for a two-wheeler is assumed to be constant at 1.2 persons per two-wheeler throughout the projection period (2004–36). The average annual utilization rate is assumed to be constant at 27.4 km per two wheeler per annum (Table3.10).

3.2.1.2.4 Buses

The historical annual time-series data on the number of registered buses for the period 1980 until 2003 is used for estimating and projecting the travel demand by buses until 2036.

Table 3.8 Assumptions on occupancy rate and utilization rate for cars

Source	**Assumptions on occupancy rate per car**	**Assumptions on utilization rate per car**
IEA (2004)	1.89 persons per car in 2000 declining to 1.64 persons in 2035	8000 km/year equivalent to 21.4 km/day (assumed constant throughout the projection period
Kapoor (2002)	1.5 persons	7000 km/year (equivalent to 19.76 km/day) in 1995 increasing by 100 km/year (0.27 km/day)
by 100 km/year (0.27 km/day)	1.9–2.9 persons per car/jeep	26 km/day in 2000/01

The travel demand by buses (measured in passenger kilometres) is estimated using Equation 3.2 as the product of number of buses on road, the occupancy rate, and the average annual utilization rate. The Occupancy rate for buses is assumed to be constant at 50 persons per bus throughout the projection period (2004–36). The average annual utilization is assumed to increase by 400 km/year over the modelling time frame starting from 40 000 km/year in 1995 (Table 3.11).

Table 3.9 Assumptions on occupancy rate and utilization rate for two wheelers

Source	**Assumptions on occupancy rate per two-wheeler**	**Assumptions on effective distance travelled per day by a two-wheeler**
IEA (2004)	1.7 (assumed constant)	10 000 km/year equivalent to 27.4 km/day (assumed constant throughout the projection period)
Kapoor (2002)	1.2 (assumed constant)	3500 km/year (equivalent to 9.6 km/day) assumed constant
Bose and Chary (1993)	1.2–1.7 (assumed constant)	25 km/day in 2000/01 (assumed constant throughout the projection period)

Table 3.10 Assumptions on occupancy rate and utilization rate for buses

Source	**Assumptions on occupancy rate per bus**	**Assumptions on utilization rate per bus**
IEA (2004)	28 persons per bus	40 000 km/year in 2000 (assumed to be constant throughout the projection period)
Kapoor (2002)	40 persons per bus (assumed constant throughout the projection period)	40 00 by 400 km/year 0 km/year in 1995, increasing
Bose and Chary (1993)	30–47 persons per bus	46 355 km/year

3.2.1.2.5 Three-wheelers

The historical annual time-series data on the number of registered passenger three-wheelers for the period 1980 until 2001 is used for estimating and projecting the travel demand by three-wheelers until 2036.

The number of registered three-wheelers for each year within the forecast period 2002–36 is obtained using the regression equation estimated above by inserting the values of forecast population into the regression equation.

The occupancy rate for two-wheelers is assumed to be constant at two persons per three-wheeler throughout the projection period (2002–36).

The average annual utilization rate is assumed to increase by 80 km/year from 29 200 km/year in 1980 until 2036.

The figures for mode-wise road passenger demand expressed in billion passenger kilometres are presented in Tables 3.12 , 3.13 for 8%, and 10% projected GDP growth rates.

Table 3.11Mode-wise road passenger travel demand (in billion passenger kilometres) under 8% GDP (gross domestic product) growth scenario

Mode	2001	2006	2011	2015-2016	2021	2026	2030-2031	2050
Cars and taxis	102	142	216	412	733	1550	3117	
Two-wheelers	255	344	354	466	616	823	1107	
Buses	1177	1594	2141	2790	3493	4234	4969	
Three-wheelers	116	116	200	306	447	618	808	
Total	1650	2280	3018	4117	5461	7416	10196	

Table 3.12 Mode-wise road passenger travel demand (in billion passenger kilometres) under 10% GDP (gross domestic product) growth scenario

Mode	2001	2006	2011	2015-2016	2021	2026	2030-2031	2050
Cars and taxis	102	144	236	487	956	2167	4760	
Two-wheelers	255	351	394	558	799	1230	1908	
Buses	1177	1594	2141	2790	3493	4234	4969	
Three-wheelers	116	200	306	447	618	808	1003	
Total	1650	2289	3077	4281	5866	8440	12641	

3.2.2 Freight transport t

The historical annual time-series data on the number of registered HCVs and LCVs for the period 1980 till 2002 is used for estimating and projecting the travel demand by two wheelers till 2036.

LCVs for each year within the forecast period 2003–36 are obtained from the estimated regression equations by inserting the projected values of GDPA and GDPI.

The payload for HCV is assumed to increase by 0.1 tonne until 2036, from 5.5 in 1995. Similarly, it is assumed that the average annual utilization for HCV will increase by 400 km every year until 2036, from 40 000 km in 1995 (Planning Commission 2001).

Similarly, the travel demand (measured in tonne kilometres) for LCV is estimated using Equation 3.2. The payload for LCV is assumed to be constant at 1.7 tonnes throughout the projection period. Similarly, it is assumed that the average annual utilization for LCV will increase by 200 km every year, from 23 000 km in 1995 until 2036.

The above demand estimation and projection exercise has been undertaken for 8%, and 10% growth rates of GDP. The projected figures for mode-wise freight transport movement by road under alternative growth scenarios, expressed in billion tonne kilometres, are presented in Tables 3.13, 3.14.

Table 3.13 Mode-wise freight travel demand (in billion tonne kilometres); 8% GDP (gross domestic product) growth scenario

Mode	2001	2006	2011	2015-2016	2021	2026	2030-2031	2050
HCV	531	914	1523	2487	3996	6341	9955	
LCV	37	57	99	162	256	393	593	
Total	568	970	1622	2649	4252	6734	10548	

HCV – heavy commercial vehicle; LCV – light commercial vehicle

Table 3.14 Mode-wise freight travel demand (in billion tonne kilometres); 10% GDP (gross domestic product) growth scenario

Mode	2001	2006	2011	2015-2016	2021	2026	2030-2031	2050
HCV	531	1044	1858	3219	5615	10085	17948	
LCV	37	66	124	214	365	632	1078	
Total	568	1111	1982	3433	5980	10717	19026	

HCV – heavy commercial vehicle; LCV – light commercial vehicle

3.2.3 Rail transport

3.2.3.1 Passenger movement

The historical annual time-series data on the passenger traffic (in billion passenger kilometres) for the period 1983until 2003 is used for estimating and projecting the travel demand by rail till 2036.

The figures for projected rail passenger travel demand expressed in billion passenger kilometres are presented for the three alternative growth scenarios in Table 3.17.

3.2.3.2 Freight movement

The historical annual time-series data on the freight traffic (in billion tonne kilometres) for the period 1983 till 2003 is used for estimating and projecting the travel demand by rail till 2036.

Table 3.15 Rail passenger transport demand (in billion passenger kilometres) under alternative GDP (gross domestic product) growth scenarios

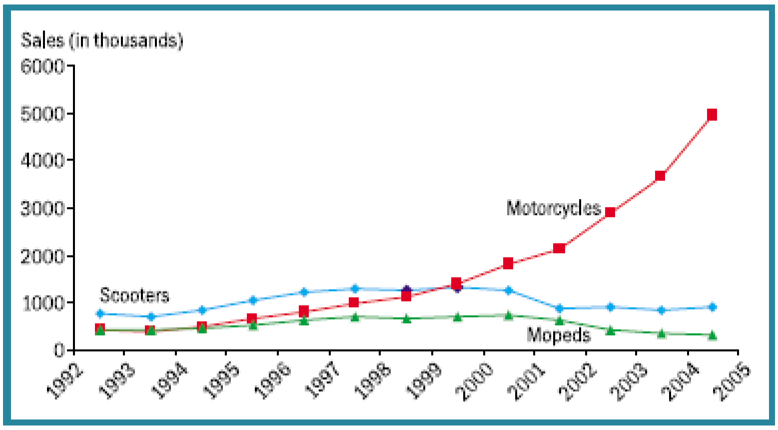
GDP growth rate (%)	2001	2006	2011	2015-2016	2021	2026	2030-2031	2050
8	491	637	864	1184	1634	2264	3125	
10	491	673	986	1458	2174	3254	4853	

The figures for projected rail freight transport demand expressed in billion tonne kilometres are presented for the three alternative GDP growth rates in Table 3.16

Table 3.16 Rail freight transport demand (in billion tonne kilometres) under alternative GDP (gross domestic product) growth rates

GDP growth rate (%)	2001	2006	2011	2015-2016	2021	2026	2030-2031	2050
8	336	423	534	691	912	1223	1662	
10	336	456	668	987	1481	2354	3758	

Figure 3.5 Category-wise sale of two-wheelers



Source SIAM (2005)

3.2.4 Description of technology options in the transport sector

3.2.4.1 Two-wheelers

There are three different types of two-wheelers that have been considered in the model: scooters, motorcycles, and mopeds. Figure 3.5 is the graphical representation of the category- wise sales of two-wheelers.

The figure indicates that the motorcycle segment exhibits the highest growth rate (37%) amongst the three categories of two wheelers.

At present, two-wheelers use petrol as fuel and employ the spark-ignition system. They can be classified further into those employing the two- and four-stroke technology. The population of two-stroke engines is very large. Two-stroke engines are widely used for motorcycles, scooters, and mopeds, primarily because of their high specific power output, simple and compact design, lower engine fraction, less pumping losses at part load, better cold startability, and low production and maintenance cost (MoPNG 2005). The disadvantages are high fuel consumption and high un burnt hydrocarbon emission. Hence, penetration of the four stroke technology into different segments of two-wheelers has been increasing rapidly over the last few years. This can be attributed partly to the enforcement stringent emission regulations and partly to the fast-changing consumer preferences. However, penetration of the four-stroke technology is limited in the scooter and moped category as compared to motorcycles. As such, many buyers still prefer two-stroke to four-stroke. The techno-economic parameters of two-wheelers are presented in Tables 3.17and 3.18.

3.2.4.2 Three-wheelers

A wide variation exists in the Indian three wheeler market in terms of the current technological status as well as its progression over the modelling time frame. Three-wheelers powered by petrol two-stroke engines occupy a major share in the Indian three-wheeler market. The penetration of three-wheelers powered by petrol four stroke engine is lower as compared to its two-stroke counterpart due to the resistance offered by owners/operators of auto rickshaws.

Table 3.17 Technological characterization of two-stroke two-wheelers

Two-wheeler category	Technology	Start year	Efficiency (km/litre)/ (MJ/km)	Investment (km/litre)/ cost* (rupees)	Fixed operating (km/litre)/

					cost (rupees/km)
Motorcycle	Improved engine with improved oxicat using petrol as fuel	2001	53.83	36000	0.18
	Hydrogen IC engine	2031	0.56	42000	
Scooters	Improved engine with improved oxicat using petrol as fuel	2001	66.11	32000	0.14
	Hydrogen IC engine	2031	0.16	37000	
Mopeds	Improved engine with improved oxcat using petrol as fuel	2001	78.51	22000	0.18
	Hydrogen IC engine	2031	0.38	25000	
		2050			

MJ – megajoules; IC – internal combustion
* Investment cost here is the vehicle price.
Source TERI (2004)

Table 3.18 Technological characterization of four-stroke two-wheelers

Two-wheeler category	Technology	Start year	Efficiency (km/litre)/ (MJ/km)	Investment (km/litre)/ cost* (rupees)	Fixed operating (km/litre)/ cost (rupees/km)
Motorcycle	Improved engine with improved oxicat using petrol as fuel	2001	85.64	43500	0.11
	Hydrogen IC engine	2031	0.36	50000	
Scooters	Improved engine with improved oxicat using petrol as fuel	2001	71.00	39000	0.13
	Hydrogen IC engine	2031	0.42	45000	
Mopeds	Improved engine with improved oxcat using petrol as fuel	2001	94.21	34000	0.12
	Hydrogen IC engine	2031	0.32	40000	
		2050			

MJ – megajoules; IC – internal combustion
* Investment cost here is the vehicle price.
Source TERI (2004)

The CNG (compressed natural gas) three-wheelers are prevalent mainly in the four-stroke version.

The penetration of CNG-based auto rickshaws is limited mainly to major metropolitan cities like Delhi and Mumbai. The limited penetration of CNG three-wheelers can be attributed primarily to the inadequate CNG supply infrastructure and the high investment cost entailed in developing this infrastructure. Diesel three-wheelers powered by four-stroke technology are also available in the country. The introduction of hybrid electric vehicles*7* (powered by CNG and petrol) as well a s the electric/battery-operated vehicles is likely only by 2020 and 2025, respectively. The introduction of hybrids before the battery-operated vehicles is due to concerns regarding the range of battery-operated vehicles. Three-wheelers and electric vehicles are also commercially available in the country.

The three-wheelers are used for commercial purposes and thus, have a high daily utilization. The techno-economic parameters for three-wheelers are given in Table 3.19.

Table 3.19 Technological characterization of three-wheelers

Technology	Efficiency (km/litre	Investment cost (rupees)	Fixed operating and maintenance cost (rupees/km)
Petrol two-stroke	36.00	75000	0.27
Petrol four-stroke	41.00	100000	0.22
CNG four-stroke	1.00	95000	0.22
Diesel four-stroke	27.00	125000	0.21
Battery operated	0.36	115000	0.22
Petrol hybrid	120.00	125000	0.30
CNG hybrid	120.00	125000	0.30
Hydrogen four-stroke	51.00	114000	8.45

CNG – compressed natural gas; MJ – megajoules
* Efficiency expressed in MJ/km.
Source TERI (2004)

3.2.4.3 Cars

As per the classification norms adopted by SIAM (Society of Indian Automobile Manufacturers) in 2002, passenger cars are classified, according to lengths, under the following five categories.

_ Mini (up to 3400 mm)

_ Compact (3401–4000 mm)

_ Mid-size (4001–4500 mm)

_ Executive (4701–5000 mm)

_ Luxury (5001 mm and above)

The classification is further extended to take into account the fuel- and technology wise break-up. Petrol-based cars (based on internal combustion engine) constitute the majority of the passenger car segment. In India, indirect injection diesel engine is used in passenger cars.

The benefit offered by diesel cars in terms of higher fuel efficiency relative to the gasoline cars is offset by the higher maintenance/servicing cost. However, due to the pricing policies of fuels, the running cost of diesel cars is lower as compared to petrol cars. This makes diesel engines more popular for taxis.

New technologies, such as battery-operated cars, are also available commercially in the country Furthermore; cars running on alternative fuels such as CNG have also penetrated the Indian market. The technology characterization of cars is given in Table 3.20.

Table 3.20 Technological characterization of cars

Technology	Start year	Efficiency (km/litre	Investment cost (rupees)	Fixed operating and maintenance cost (rupees/km)
Small car diesel	2001	13.39	388000	0.80
Small car gasoline	2031	12.25	387000	1.43
Small car gasoline hybrid	2021	14.70	670140	1.43
Small car diesel hybrid	2021	16.06	671140	0.80
Battery-operated car	2001	14.70	249500	0.64
CNG car	2001	13.37	354000	1.64
Large car based on diesel	2001	10.85	646000	0.80
Large car based on gasoline	2001	9.55	625667	1.43

MJ – megajoules; CNG – compressed natural gas
*Efficiency expressed in MJ/km.
** Efficiency expressed in km/kg.
Source Figures of fuel economy compiled from Overdrive and Auto car (October 2005); TER I (2004)

3.2.4.4 Buses

The fuels used by buses plying on Indian roads are mostly diesel and CNG. Until 1991, buses powered by compression ignition engines consuming diesel were plying on Indian roads. Delhi Transport Corporation (DTC) became the first transport corporation in the country to have inducted CNG buses in its city fleet in 2001. The entire fleet of DTC buses has been replaced by CNG buses. Table 3.21

Table 3.21 Technological characterization of buses

Types of buses	**Start year of technology**	**Life (years)**	**Efficiency** (km/litre)	**Investment cost** million rupees/bus)
Diesel bus	2001	15	4.63	2.48
CNG bus	2001	15	3.84	3.66
Hybrid electric bus powered by diesel	2021	15	6.71	8.38

* Efficiency expressed in km/kg

3.2.4.5 Goods vehicles

Both the heavy and light goods vehicles use diesel and ULSD (ultra low-sulphur diesel) as fuels. The parameters related to cost, efficiency, and so on associated with each of the technologies are shown in Table 3.22

Table 3.22 Technological characterization of goods vehicles

Types of good vehicles	**Start year of technology**	Life **(years)**	Efficiency (km/litre)
HCV: diesel	2001	15	5.0
HCV: ULSD	2031	15	5.0
LCV: diesel	2001	15	8.5
LCV: ULSD	2031	15	8.5

HCV – heavy commercial vehicle; LCV – light commercial vehicle; ULSD – ultra-low sulphur diesel

3.2.4.6 Locomotives

Diesel and electric locomotives are used for both passenger- and freight-based rail movements. The technological details of these options are provided in Tables 3.23 and 3.24.

Table 3.23 Technological characterization of locomotives (freight)

Type	**Fuel efficiency** (Mtoe/btkm)	**Investment cost** (million rupees/btkm)
Diesel locomotive	0.0041	344
Electric locomotive	0.0021	450

Mtoe/btkm – million tonnes of oil equivalent per billiontonne kilometres

Table 3.24 Technological characterization of locomotives (passenger)

Type	**Fuel efficiency** (Mtoe/btkm)	**Investment cost** (million rupees/btkm)
Diesel locomotive	0.0041	156
Electric locomotive	0.0021	132

Mtoe/bpkm – million tonnes of oil equivalent per billion passenger kilometres

3.2.5 Alternative fuels for transport

3.2.5.1 Biofuels

Biofuels are receiving a great deal of attention as a substitute to petroleum since they can be produced from several agricultural sources and also because of their low-emission characteristics. The two biofuels considered as the potential fuels for surface transportation are bio-diesel and ethanol. The term ‘bio-diesel’ refers to the neat ethyl esters of vegetable oils. Presently, pure 100% or neat methyl esters of rapeseed, soyabean, sunflower, talon, and other fats and oils are used as diesel fuel without any substantial modification to the existing design of the engine. According to a survey of 26 countries by the IEA (International Energy Agency), biofuels are being produced for the past six years in 21 countries, mainly in the European Union, East Europe, Malaysia, and the US, with an overall capacity of about 1.3 MT. In most of the developed countries, bio-diesel is produced from saffola, sunflower, peanut, and so on that are essentially edible in the Indian context. On the other hand, there are a host of forest and non-edible plant resources from which oil can be generated. Biofuels have the following advantageous properties: high oil-bearing capacity, low cost, easy to develop and use, environmentally safer and compatible, biodegradable, non-toxic, and free of sulphur and aromatic compounds. In this analysis, the maximum production of bio-diesel is assessed based on the potential area for jatropha plantation, which is estimated at about 40.03 Mha. Based on the seed yield of 2 tonnes/hectare, oil yield of 27% and percentage area brought under the plantation of jatropha over the modeling time frame, Table 3.29 provides the estimates of bio-diesel production as used in this study. Based on the discussion with experts it has been assumed that 5% of the potential area is likely to be brought under jatropha plantation by 2011, 25% by 2021, and 100% by 2036. Various scenarios have been developed for the transport sector, which represent different types of policy interventions, technical measures, and so on. transport sector scenarios is Assumptions for each of the scenarios are detailed in Table 3.25.

Table 3.25 Estimates of bio-diesel production

Year	**Area under plantation (%)**	**Bio-diesel**

2006	0	0
2011	5	2.9
2015-16	10	3.9
2021	25	9.8
2026	70	27.5
2030-31	90	31.9
2036	100	35.4
2050		

Table 3.26 Assumptions in various transport scenarios

Scenario	**Parameter**	Year 2001	Year 2030-36	Year 2050
Business-as-usual	_ Share of rail vis-à-vis road in passenger movement	23%	23%	
	Share of rail vis-à-vis road in freight movement	37%	17%	
	Share of public transport modes vis-à-vis personalized transport modes in road transport	80%	51%	
	Bio-diesel penetration in transport	No bio-diesel penetration in transport		
	Autonomous efficiency improvements in transport	Fuel economy of existing motorized transport modes constant throughout the period 2001–36		
High efficiency	Share of rail vis-à-vis road in passenger movement	23%	35%	
	Share of rail vis-à-vis road in freight movement	37%	50%	
	Share of public transport modes vis-à-vis personalized transport modes in road transport	80%	60%	
	Autonomous efficiency improvements in transport	Fuel economy of existing motorized transport modes increasing by 50% throughout the period 2001–36		
Bio-diesel	Bio-diesel penetration in transport	Maximum level of bio-diesel penetration is 35.4 million tonnes by 2036		
Hybrid	Combination of high efficiency and bio-diesel scenario			

Bio-diesel scenario

In addition to the power generation technologies, bio-diesel is also assumed to be available to the transport sector in this scenario. Based on the maximum potential area that is available for plantation for bio-diesel production, the lower bound is imposed on the availability of bio-diesel in the REN scenario. Table 3.27 below presents the availability of bio-diesel for transportation in India

Table 3.27 Availability of bio-diesel for transportation

Table 3.27 Lower bound on the availability of bio – diesel in MT

	Lower bound on the availability of bio – diesel in MT									
Scenario	2001/02	2006/07	2011/12	2015/16	2016/17	2021/22	2026/27	2030	2031/32	2050
REN	0	0	2		3.9	9.8	27.5		31.9	

MT – million tonnes; REN – aggressive renewable energy

3.2.6 Intra-sector scenarios: transport sector illustration

The transport sector is a major consumer of petroleum products. From the point of view of energy security concerns for the Indian economy at large, five alternative scenarios in addition to the BAU have been developed using the MARKet ALLocation model. These scenarios enable the analysis of the impact of different policy and technology alternatives and their quantitative significance on energy consumption in transport. Each of the five scenarios encompasses different policy and technology options related to the transport sector. Table 3.28 lists these scenarios and provides a description.

Table 3.28 Description of energy-efficient scenarios for the transport sector

Scenario	**Description**
Enhanced share of public transport	Share of public transport modes to increase to 60% in 2036.
Increased share of rail in passenger and freight movement vis-à-vis road	Railway freight share to increase from 37% in 2001 to 50% in 2036 Railway passenger share to increase from 23% in 2001 to 35% in 2036. Share of electric traction to increase for rail Passenger and Freight to 80%.
Fuel efficiency improvements	Fuel efficiency of all existing motorized transport modes to increase by 50% from 2001 to 2036.
Use of bio-diesel in transport	Enhanced penetration of bio-diesel by 65 Mtoe by 2036.
Transport sector hybrid	Incorporates all the above-mentioned scenarios, in addition to those in the BAU.

Mtoe – million tonnes of oil equivalent

(**Reference**: Transport sector, The Gazette of India No 23/40/2004-R & R (Vol. III) Part I Section I, Ministry of power, New Delhi

Transport ,Energy Map for India: Technology Vision 2030, The Energy and Resources Institute, Office of the Principal Scientific Adviser, Government of India 2006, Publishers: TERI Press)

Recommendations

Barriers

3.3 Construction

Construction sector is studied for formulation of technology based climate plan. It is studied in 2 parts i.e. residential sector and commercial sector. Existing residential construction is detailed under residential sector and construction under the commercial use is under commercial sector.

3.3.1 Residential sector

The population of India was about 1.027 billion in 2001 as per *Census 2001* of the Government of India (GoI 2001).

The average number of members per household is 5.15 in rural areas and 4.47 in urban areas. Out of 10 households, seven in India are in the rural areas, and 0.09% of the households do not have a dwelling unit. Of the every 100 households in the rural areas, 36 are *pucca* houses, 43 are semi-*pucca* houses, and the rest are *kuchcha* houses. On the other hand, out of every 100 households in urban areas, 77 are *pucca* structures, 20 semi-*pucca*, and only 3 are *kuchcha* structures.

On an average, a rural household occupies 38 m2 (square meter) of floor area and an urban household occupies 37 m2. The poorest segment, that is, households in the lowest PCE (monthly per capita consumption expenditure) class of less than 225 rupees in rural areas, occupy 31 m2 of floor area and those in urban slums, 29 m2. About 30% of the dwelling units in rural and 4% in urban areas do not have basic facilities like drinking water, electricity for lighting, and a toilet. About 97% of the rural and 99% of the urban households get drinking water within half a kilometre of their premises (MoSPI 2004).

Non-commercial energy requirement

The so-called "Non-commercial" sources of energy, including fuel wood, agricultural waste and dung, are primarily used by households for cooking energy. These are called non-commercial because a major proportion of these are simply gathered by actual users directly as opposed to being traded commercially.

The projections are summarised in the below Table no.3.29

Table 3.29 The Demand Scenario of Various Energy Items for Household Consumption in India

(Mtoe)

Year	Fire Wood & Chips		Electricity		Dung Cake		Kerosene		L.P.G.	
	8%	9%	8%	9%	8%	9%	8%	9%	8%	9%
2009	79.62	79.62	8.43	8.43	29.61	29.61	10.07	10.07	6.42	6.42
2006	88.64	88.78	18.17	19.26	36.97	37.33	12.68	12.77	15.85	16.87
2011	94.11	94.05	27.17	29.68	40.42	40.48	14.01	14.02	23.94	26.07
2015/16	98.44	98.50	38.38	42.28	41.93	41.35	14.84	14.70	33.11	35.93
2021	102.06	102.46	50.39	54.78	41.79	40.87	15.16	14.93	41.93	44.16
2026	104.64	105.07	61.37	64.95	40.95	40.28	15.17	14.93	48.11	49.63
2030/31	106.39	106.59	69.72	71.80	40.47	40.21	15.12	14.96	52.27	52.89
2050										

Household demands are projected from 2009-10 onwards using the energy use pattern of only those households in the NSS 55th round sample, which had electricity. These are given in Table no 3.30

Table 3.30 The Impact of Electrification on the Demand Scenario of Various Energy Items for Household Consumption

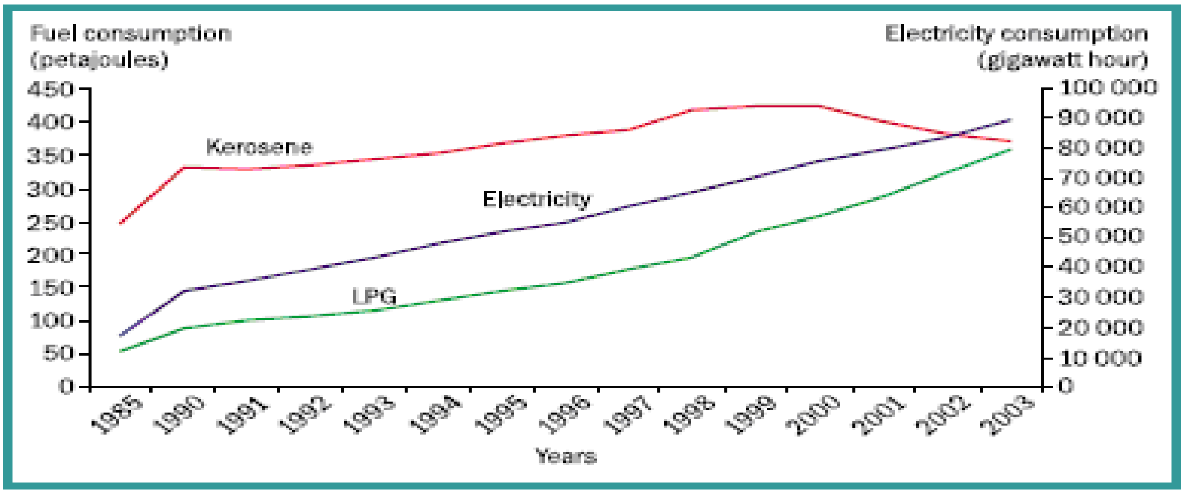
(Mtoe)

Year	Fire Wood & Chips		Electricity		Dung Cake		Kerosene		L.P.G.	
	8%	9%	8%	9%	8%	9%	8%	9%	8%	9%
2011	87.90	88.00	31.13	33.63	31.03	31.16	13.18	13.16	25.27	27.36
2015/16	92.59	93.02	42.58	46.51	32.21	31.53	13.82	13.64	34.30	36.95
2021	96.85	97.67	54.89	59.35	31.45	30.28	13.98	13.71	42.45	44.72
2026	100.01	100.72	66.19	69.86	30.00	29.12	13.88	13.61	48.55	49.88
2030/31	102.08	102.41	74.82	76.95	29.14	28.78	13.76	13.59	52.49	53.05
2050										

3.3.1.1 End-use demands in the residential sector

Energy services make up a sizeable part of the total household expenditure. The residential sector in India is responsible for 13.3% of the total commercial energy use (TERI 2004). The energy sources utilized by the residential sector in India mainly include electricity, kerosene, LPG (liquefied petroleum gas) (propane), firewood, crop residue, dung, and other renewable sources such as solar energy.

Figure 3.6 Time trend of fuel and electricity consumption in the residential sector



Source CEA (2004); MoPNG (2004)

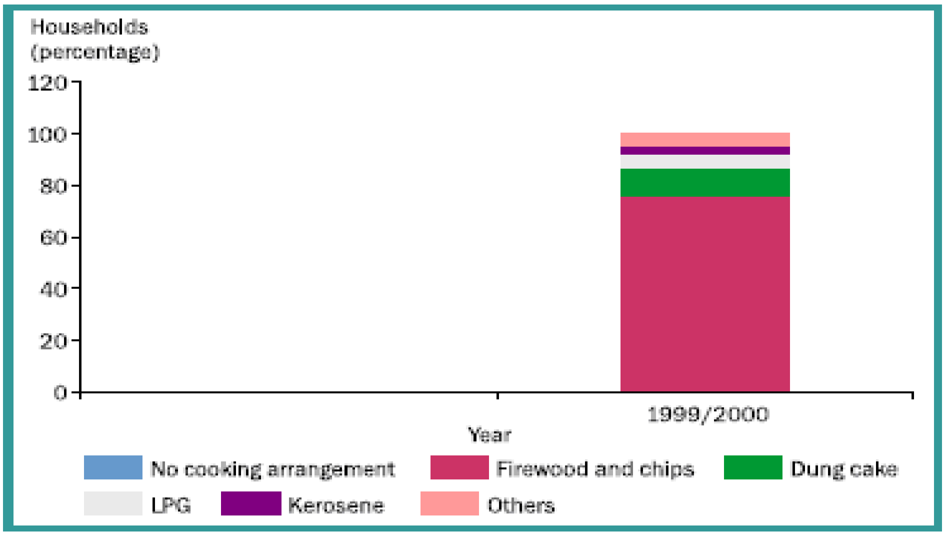
Figure 3.6 indicates that commercial energy use has been growing quite rapidly in the residential sector.

Since year 2000, kerosene consumption in the residential sector has declined in absolute terms. Kerosene use in the residential sector came down by 13.9% during 2000–03. This high rate of consumption of LPG and electricity vis-à-vis kerosene explains the substitution of kerosene, a primary source of energy, amongst the lower- and middle-income groups.

Despite its impressive growth in the residential sector, the fuel consumption is still very low in India as compared to that in other countries. Commercial energy consumption in the residential sector in the US for 2002 was 2466.91 Mtoe (US DoE 2003) whereas for India, the figure is only about 22 Mtoe (TERI 2004). The per capita energy use in the residential sector of the US is about 8.56 ToE/year while this is as low as 0.22ToE/yearforIndia. Households use energy for many purposes: cooking; cooling and heating their homes; heating water; and for operating many appliances such as refrigerators, stoves, and televisions.

The energy mix for cooking in the domestic sector in India shows that traditional fuels are predominantly used in the household sector. In the rural areas of the country, the households use mainly three primary sources of energy for cooking: firewood and chips, dung cake, and LPG. Fuel wood is a major source of cooking for 61.1% of the total households in India. Among the different sources, firewood and chips are used by almost three fourths of the rural households. Only % of the households have switched away from it since 1993/94 (Figure 3.7).

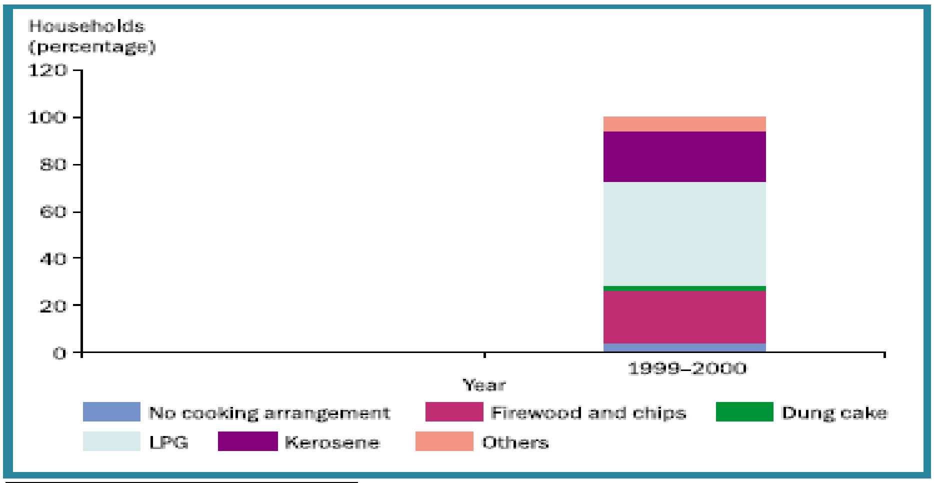
Figure 3.7 Percentage distributions of households by source of cooking in rural India



Source MoSPI (1997, 2001)

As can be seen in Figure 3.8, in urban areas of the country, the households use mainly three primary sources of energy for cooking: firewood and chips, kerosene, and LPG. Of these, LPG is predominant, with 45% of the households using it. About 22% of the urban households use firewood and chips.

Figure 3.8 Percentage distributions of households by source of cooking in urban India



Source MoSPI (1997, 2001)

An estimated 84 million households still do not have access to electricity. The majority of these households are using fuel-based lighting systems, mainly in the form of kerosene. These systems are less energy-efficient than electrical lighting systems, and have a wide range of adverse social and environmental impacts.

The Rajiv Gandhi Grameen Vidyutikaran Yojana (plan) of the Government of India (MoP 2005) plans to provide electricity to all households in the next five years. It should be noted here that providing access to electricity to all households does not necessarily imply that every household will have a metered connection. Here fore, we expect that all households may have access to electricity by 2010/11 but actually every household will have a metered connection only by 2020/21.

The amount of energy that the households consume and the types of fuel they use also depend on a variety of other factors. The micro-perspective of each consumer is the driving force behind the sector's use of energy, and opportunities for change in the demand and supply patterns. This is because, a household's total energy consumption and use of mix of fuels are the result of the family's attempt to provide for its various needs by employing its labour or cash and specific technologies that use a certain type of energy. Other factors include issues of supply such as availability of fuels, energy prices, and technologies, which have a very large range of end-use efficiencies and hence, a large potential for energy saving. The rising rate of growth of GDP, growth in disposable income, improved lifestyles, and the rising purchasing power of people with higher propensity to consume with preference for sophisticated appliances and modern fuels would provide constant impetus to the growth of energy demand in the residential sector.

For the present study, on the basis of end use, a household's energy consumption has been divided into six categories.

_ Lighting

_ Cooking

_ Space conditioning

_ Refrigeration

_ Water heating

_ Others

The energy demand for fans, air conditioners, and air coolers has been categorized as energy demand for space conditioning. The category 'others' comprises energy demand for appliances such as televisions, washing machines, VCRs/VCPs, and music systems.

3.3.1.1 .1 Demand for lighting

Electricity and kerosene being the primary fuels used for lighting, the energy demand for lighting has been estimated for households that have electrified source of lighting and for those that depend on kerosene for lighting.

Table 3.31 Income categories based on MPCE in rural and urban areas

Class	Rural (rupees)	Urban (rupees)
Low	<615	<665
Medium	615-950	665-1925
High	>950	>1925

3.3.1.1 .2 Electricity demand for lighting

Three categories in rural and urban areas based on MPCE (Table 3.31). The number of light points per household has been assumed as shown in Table 3.32. It has further been assumed that for rural households, a light point is used for 4 hours per day whereas for urban households, the usage is 5 hour per light point per day. The lighting requirement has been taken as 100 lux per light point.

DLi = HHi × Lpi × H × 100 × 365 (3.4)

where,

DLi = annual demand for lighting by electrified households in ith income group

HHi = number of electrified households in the ith income group

Lpi = light points per household in the ith income group

H = hours of usage

Table 3.32 Number of lighting points per household in various income classes in rural and urban areas

Rural	Lamp type	Lamp wattage	Light points	Urban	Lamp type	Lamp wattage	Light points
RL	GLS	60	1	UL	GLS GLS	60 60	2
RM	GLS GLS GLS	60 60 60	3	UM	TL TL GLS GLS	55 55 60 60	4
RH	TL TL GLS GLS	55 55 60 60	4	UH	TL TL TL GLS GLS CFL	55 55 55 60 60 11	6

RL – rural low; RM – rural middle; RH – rural high; UL – urban low; UM – urban middle; UH – urban high;
GLS – generalized lighting system; TL – tube light; CFL – compact fluorescent lamp * These are total light points actually used at a time by a household

3.3.1.1.3 Kerosene demand for lighting

It has been assumed that the un electrified households used one lamp for lighting.

A hurricane lamp gives an illuminance of 70lux per hour while a wick lamp provides 7lux per hour (Stanford University 2003).

DLi = HHi × H × 365 (3.30)

where,

DLi = annual demand for lighting by

unelectrified households in the ith income group

HHi = number of unelectrified households in the ith income group

H = hours of usage

The demand for kerosene-based lighting is expected to decrease and become zero by 2021 because of the assumption that as per the Rajiv Gandhi Grameen Vidyutikaran Yojana of the Ministry of Power (MoP 2005), all households may have access to electricity by 2010/11. However, every household is assumed to have a metered connection only by 2020/21.

Demand for lighting for various GDP growth scenarios is presented in Table 3.33.

Table 3.33 Demand for lighting (trillion lux hours)

	8% GDP				**10% GDP**			
	Electricity-based		**Kerosene-based**		**Electricity-based**		**Kerosene-based**	
Year	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**
20001	36.0	33.8	2.8	0.7	36.0	33.8	2.8	0.7
2006	54.9	44.3	2.1	0.5	56.6	45.1	2.1	0.5
2011	77.1	57.6	1.4	0.3	80.4	59.6	1.4	0.3
2015-16	100.3	72.6	0.7	0.2	104.7	75.4	0.7	0.2
2021	120.9	89.0	0.0	0.0	124.3	91.9	0.0	0.0
2026	129.1	104.3	0.0	0.0	129.9	105.5	0.0	0.0
2030- 31	133.4	118.0	0.0	0.0	133.4	118.2	0.0	0.0
2036	136.0	131.0	0.0	0.0	136.0	131.1	0.0	0.0
2050								

GDP – gross domestic product

3.3.1.1.4 Demand for cooking

Cooking requires energy in the form of heat. Cooking energy consumption has been estimated separately for rural and urban regions.

The per capita per day useful energy requirement for cooking is taken to be 620 kcal in rural areas and 520 kcal in urban areas (ABE 1985)

Since the per capita cooking energy requirement remains constant, the total energy demand for cooking increases at the rate of population growth, that is, at the rate of 2.32% in urban areas and at 0.51% in rural areas during the time period 2001–36 (Table 3.34).

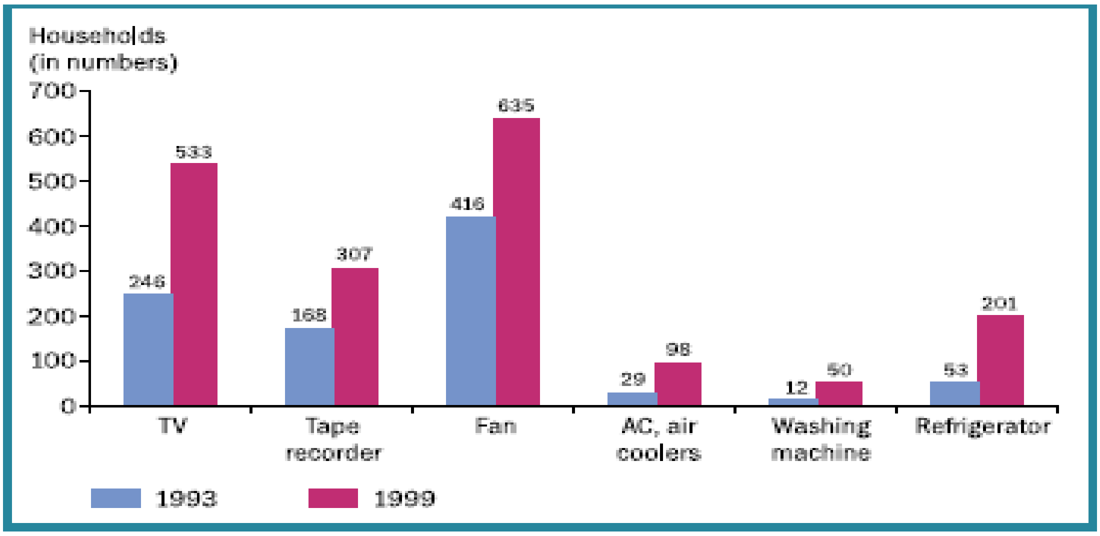
Table 3.34 Useful energy demand for cooking (petajoules)

	2001	2006	2015-16	2021	2026	2030-31	2036	2050
Rural	700.60	724.25	790.42	814.98	830.04	837.38	838.59	
Urban	228.51	260.33	299.30	341.51	348.49	426.68	509.31	

3.3.1.1.5 Demand for electrical appliances

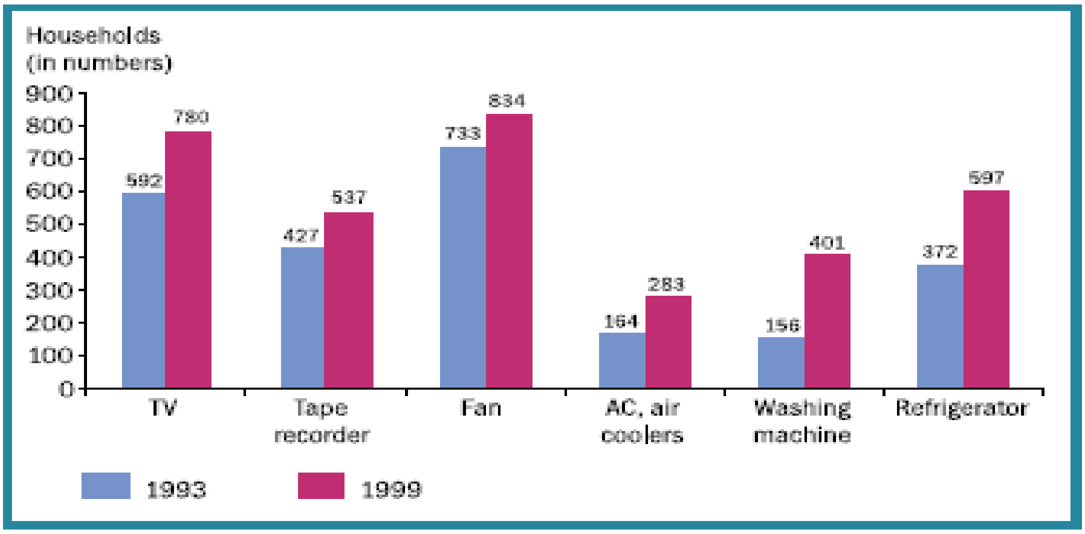
The energy demand for appliances in the country depends on the number of appliances being used/expected to be used, hours of usage, and wattage of the appliance Data on penetration of appliances per 1000 households is available from the NSS (National Sample Survey) for 1999/ 2000 (Figures 3.9 and 3.10).

Figure 3.9 Number of households (per 1000) in highest income class possessing specified durable goods (rural)



Source MoSPI (2001)

Figure 3.10 Number of households (per 1000) in highest income class possessing specified durable goods (urban)



Source MoSPI (2001)

As the households shift from one income class to another over time, and as their purchasing power increases, the 'demonstration effect' sets in. In other words, person always aspires to reach the consumption level of relatively higher income groups. Therefore, as a household moves up the income ladder, it tries to adopt the consumption pattern of the higher income group. It also aspires to acquire the basket of goods/appliances possessed by the relatively higher income group.

For the highest income groups in rural and urban, the increase in penetration of appliances over the forecast period has been calculated based on the growth rate of appliances for the same income group during 1993/94 to 1999/2000. The penetration rate per 1000 households has been capped in the case of growth rate being unreasonably high.

Based on the appliance penetration rate (Figures 3.9 and 3.10), the income shifts over time, and the usage norms (Table 3.34), the energy demand has been calculated.

Table 3.35 Usage norms for electrical appliances

	Working hours/ day	Watt	Working hours/ year
Device	10	60	225
Fan	1	1500	150
Geyser	24	2400	365
AC	4	2100	100
Cooler	8	250	90
Washing machine	0.5	1000	200
TV	3.1	120	365
VCR/VCP	3	20	25
Music system	1	60	200

The demand for fans, coolers, and air conditioners has been categorized under 'space conditioning'.

In the BAU scenario, useful energy demand for space conditioning is expected to increase at the rate of 14.16% in rural areas and at 12.87% in urban areas during 2001–36 due to the air conditioners becoming more popular and affordable in the future.

Useful energy demand for refrigeration is expected to increase at the rate of 13.03% and 7.05%, respectively, during the same time period. TVs, VCRs/VCPs, washing machines, and music systems comprise the category 'others'. The useful energy demand for this category is expected to increase at the rate of 11.1% in rural areas and 7.7% in urban areas during 2001–36.

The energy demand is likely to increase at a relatively faster rate in rural areas as a result of greater reach of these appliances in the rural market. Useful energy demand for space conditioning, refrigeration and 'others' under various GDP growth rate scenarios is presented in Tables, 3.36, and 3.37.

Table 3.36 Useful energy demand for various end uses (petajoules) at 8% GDP growth rate

		2001	**2006**	**2011**	**2015-16**	**2021**	**2026**	**2030-31**	**2036**	**2050**
Space conditioning	Rural	10.38	23.57	56.76	133.45	279.92	461.34	710.66	1069.70	
	Urban	23.51	37.50	69.22	145.42	310.48	576.15	984.40	1628.31	
Refrigeration	Rural	8.08	27.13	78.48	178.90	320.33	424.34	510.02	587.51	
	Urban	41.77	67.73	109.33	166.96	240.18	314.05	383.76	453.21	
Others	Rural	2.76	6.85	16.50	34.62	60.17	79.16	95.21	109.96	
	Urban	7.66	11.62	18.48	29.76	46.48	83.82	83.82	102.86	

GDP – gross domestic product

Table 3.37 Useful energy demand for various end uses (petajoules) at 10% GDP growth rate

		2001	**2006**	**2011**	**2015-16**	**2021**	**2026**	**2030-31**	**2036**	**2050**
Space conditioning	Rural	10.38	25.07	65.81	155.01	302.30	470.23	711.32	1.69.70	
	Urban	23.51	38.88	78.19	172.60	349.81	599.98	989.36	1628.31	
Refrigeration	Rural	8.08	30.06	95.55	212.40	347.54	432.62	510.49	587.51	
	Urban	41.77	71.11	120.4 2	186.29	258.65	322.24	385.08	453.21	
Others	Rural	2.76	7.35	19.30	40.17	64.745	80.58	95.29	109.96	
	Urban	7.66	12.08	20.49	34.23	51.58	67.80	84.25	102.86	

GDP – gross domestic product

3.3.1.1.6 Demand for water heating

Data on penetration of geysers is not available with the NSSO (National Sample Survey Organization) for 1999/2000. Therefore, it has been assumed that the penetration rate of geysers is equal to that of air conditioners and coolers. Moreover, apart from electricity, LPG, kerosene, and firewood are also used for meeting the energy needs for heating water in the country. It has been assumed that 80% of the total households in the country do not require hot water because of hot/moderate climatic conditions or because of their preferences. Specifically, it can be observed in rural areas that people do not heat water for bathing. Instead, they rely on fresh water at early morning hours. Therefore, households requiring hot water but not having geysers have been assumed to depend on fuels other than electricity. For estimating energy demand for lighting, households have been divided into three categories in rural and urban areas (Table 3.38).

It has been assumed that a household depending on firewood, on an average, requires 1 kg of wood for heating water per day. On the other hand, for households using LPG, it has been assumed that an LPG cylinder of 14.2 kg lasts roughly 30 days, that is, 0.5 kg per day, and that 30% of the LPG is consumed for heating water, that is, 0.15 kg/day/ household. An electric rod has been assumed to be consuming 2 kW/h electricity.

$Dw = HH \times N$ (3.5)

where,

Dw = energy demand for water heating

HH = number of households using different fuels for lighting

N = the usage and fuel consumption norms

The useful energy demand for heating water is likely to increase at the rate of 13.65% and 8.27% in rural and urban areas, respectively, during the time period 2001–36 for 8% GDP. The useful energy demand for heating water under various GDP growth rate scenarios is presented in Table 3.38

Table 3.38 Percentage distribution of households in various income groups using sources other than geyser for heating water

Income class	Fire wood	Electric rod	LPG
RL	100	0	0
RM	70	10	20
RH	60	20	20
UL	60	30	10
UM	20	20	60
UH	0	30	70

RL – rural low; RM – rural middle; RH – rural high;
UL – urban low; UM – urban middle; UH – urban high;
LPG – liquefied petroleum gas

3.3.1.2 Description of technology options in the residential sector

3.3.1.2.1 Lighting

New ways of generating light have been invented, and new technologies have been developed with the objective of achieving economy, efficient use of lighting, comfort, and aesthetic applications.

Broadly there are GLS (generalized lighting system); incandescent lamps; tungsten halogen lamps; CFLs (compact fluorescent tubes); gaseous discharge lamps such as mercury vapour, sodium vapour, metal halide; light-emitting diodes; and so on.

Table 3.39Useful energy demand for heating water (petajoules) under the three GDP growth rates

	8% GDP		10% GDP	
Year	Rural	Urban	Rural	Urban
2001	1.4	5.8	1.4	5.8
2006	4.7	8.8	5.1	9.2
2011	14.0	14.5	17.0	16.3
2015-16	33.6	24.6	40.0	28.9
2021	62.4	40.3	67.7	45.4
2026	84.6	58.4	86.3	60.9
2030-31	103.5	75.8	103.6	76.2
2036	120.7	93.1	120.7	93.1
2050				

GDP (gross domestic product)

3.3.1.2.1.1 Incandescent generalized lighting system bulbs

It is the earliest and simplest of lamps, and consists of a gas-filled glass tube with tungsten wire filament, which glows when electric current is passed through it. The GLS bulb is often described as poor man's light bulb but with the escalating energy costs. Only the rich are able to afford these grossly inefficient lamps.

3.3.1.2.1.2 Compact fluorescent lamps

Fluorescent lamps used to be available only in cool daylight colour temperatures, and were restricted to the linear 20-W and 40-W execution. The energy-saving 18-W and 36-W linear fluorescent lamps are now available in the market. The demand growth of fluorescent lamps declined from 7% to 5.5%, and in 1998/99, 145 million pieces were sold, 10% of which were manufactured by the organized sector. The demand for CFLs is growing at a steep rate of 35% per annum, with sales in 1998/99 crossing 6.5 million pieces.

The GLS(Generalized Lighting System) lamps account for nearly 80% of the lighting source market, and the rest is claimed mainly by the tubes market. CFLs have managed to gain a share of 1%–2%. This low share is due to high per unit price.

Table 3.40 gives the characteristics of electricity- based lighting devices.

Table 3.40 Techno-economic parameters for various lighting devices

	Wick	Hurricane
Consumption of kerosene (litre per hour)	0.008	0.05
Lumen output	10..000	100.00
Lux available	7.000	70.00
Total assembly cost (rupees	45.000	135.00
Life (years)	3.000	3.00

Source Rubab and Khandpal (1997)

Despite the developments, the domestic market for lighting equipment remains sluggish and localized. Major share of the market is limited to urban areas and even there, power shortages, voltage fluctuations, and so on, limit the usage of electricity-based lighting equipment. Moreover, India is yet to achieve 100% electrification. Therefore, the use of kerosene-based lighting devices becomes imperative in the country, particularly in the rural areas. Moreover, the cost per lumen is more important to a user than efficiency in lumen per watt. Kerosene lamps are a cheaper source of lighting, and this makes up for their inefficiency but not for their poor quality of light (Table 3.41).

Table 3.41 Techno-economic parameters for kerosene-based lighting devices

	Device		
Characteristics	GLS 100 W	FTL 40 W TL + 15 W Choke	CFL (13 W CFL + 3 W Choke) × 2
Lumen output	1300	2500	2200
Lux available	100	100	100
Total assembly Total assembly cost (rupees)	20	240	1360
Life (hours)	1000	5000	10000

Source Rubab and Khandpal (1997)

3.3.1.2.2 Cooking

1. Biogas is produced by the anaerobic digestion of animal dung and other biomass. The gas can be burnt in a specially designed stove that produces little CO (carbon monoxide) and no smoke. Furthermore, the digester slurry provides more fixed nitrogen to the soil than dung.

2. Charcoal emits relatively less smoke but generates considerable CO. Converting wood to charcoal has long been a way to improve fuel quality.

3. Crop residues and other biomass wastes are alternative cooking fuels. When they have no fertilizer value, their use reduces the problem of waste disposal and the demand for fuel wood. Plant stalks and straw can generally be burnt in traditional fuel wood stoves

4. A variety of stoves made up of mud are used in the country, which use firewood, crop residue, or dung. Many attempts have been made to improve the energy efficiency of these stoves.

5. Kerosene is an important cooking fuel among the urban poor. However, it is a smelly fuel that blackens pots and ranks low I n convenience of use as compared to the more modern fuels like LPG and electricity.

6. Electricity can be termed as the cleanest fuel. However, because of its expensive nature and unreliable supply, its use in cooking is still minimal.

7. LPG is recommended both for its higher efficiency and lower environmental impact than the alternatives. Techno-economic parameters of various cooking devices are shown in Table 3.42.

Table 3.42 Techno-economic parameters of various cooking devices

Device	Capital cost (rupees	Efficiency (%)	Life (years)
Liquefied petroleum gas stove	1200	60	20
Kerosene stove: wick	150	40	5
Kerosene stove: pressure	250	45	4
Dung chulha	10	8	11
Firewood based chulha	10	10	1
Biogas burner	800	55	4
Electric oven	5000	100	
Electric hot plate	400	71	15
Solar cooker	1460	100	5
Crop residue chulha	10	8	1
Microwave oven	10000	100	15

3.3.1.2.3 Electrical appliances

3.3.1.2.3.1 Refrigerators

Among the consumer durables, refrigerators rank next to televisions in the Indian middleclass homes. The refrigerator market in India has two segments: the conventional direct-cool system having a share of about 83% and the frost-free type, which accounts for the remaining 17%. The frost-free type enjoys a price supremacy between Rs 6000 and 8500. Households account for 85% of the refrigerator market, and the remaining 15% is institutional. Rural areas have a share of just 22% in the total refrigerator sales as compared to the urban areas (78%). The 165-litre refrigerators, which were the most preferred over, have now given way to 185– 225 litre ones, and recently 200–300 litre refrigerators are witnessing an emerging trend. Table 3.44 gives the technological characterization of refrigerators.

Table 3.43 Characterization of refrigerators

	Standard	Efficient
Cost (rupees)	8000	15000
Capacity (watt	1570	1115
Working hours/day	24	24
Working days/year	365	365
Life (years)	25	25

3.3.1.2.3.2 Fans

Electric fan is a necessity for more than six months in most parts in a tropical country like India.

In India, 65% of the fans are ceiling fans and 33% are wall/table ones, whereas, pedestal fans make up for a small share of 2% About 45% of the market for fans is organized and 55% is informal. Urban areas account for a bigger market share (58%) compared to rural areas (42%). Table 3.44 gives the technological characterization of fans.

Table 3.44Technological characterization of fans

	Standard	Efficient
Cost (rupees)	8000	15000
Capacity (watt	1570	1115
Working hours/day	24	24
Working days/year	365	365
Life (years)	25	25

3.3.1.2.3.3 Air conditioners

Among the consumer durables, the market for ACs (air conditioners) is growing at a fast pace.

Reduction in excise and import duties on components has brought down the price of the products manufactured by the organized the market. However, still the unorganized market of ACs has a 25% market share. The domestic sector accounts for 20% of the total ACs. Window ACs is the most popular type with a share of 48% of the total market. Packaged/ducked and mini split make up for 40% and 12% of the AC market, respectively. Table 3.45gives the characterization of ACs.

Table 3.45 Technological characterization

	Standard	Efficient
Cost (rupees)	20000	45000
Capacity (watt)	2000	1300
Working hours/day	8	8
Working days/year	120	120
Life (years)	15	15
Investment cost (million rupees/PJ)	6510	2893

3.3.1.2.3.4 Washing machines

Increasing incomes and changing lifestyles have resulted in a spectacular increase in the penetration of washing machines, especially in urban households. About 82% of the washing machines are sold in urban areas while the rural market accounts for only 18%. A price differential of about 10 000–15 000 rupees between a semi-automatic and a fully automatic washing machine makes the semi-automatic one more popular with a share of 85% in the market, and fully automatic accounts for 15% of the market.

3.3.1.2.3.5 Television

About 75 million households in India possess a television. The market for CTVs (colour televisions) is expanding very fast. Between 1996 and 1999, the market registered a growth rate of 28%. About 60% of the market is organized whereas 40% is unorganized. About 98% of the products are conventional, and flat-screen televisions have negligible share of 2%. Urban areas have a share of 60% in the CTVs market and rural areas account for the remaining 40%. However, in case of black and white television, the rural areas account for 75% of the total market and the share of urban area is 25%.

Table 3.46 Characterization of washing machines, televisions, VCRs/ VCPs, & music systems

	Washing machine	Television	VCR/VCP	Music system
Cost (rupees)	7500	8000	2500	1500
Capacity (watt)	1000	120	20	60
Working hours/day	0.5	3.1	3	1
Working days/year	200	365	25	200
Life (years)	15	20	25	20

3.3.1.2.3.6 Audio–video systems

The audio industry can be divided into various segments: radios, cassette recorders/ players, CD players, and their combination. CD-based systems are a recent development but are replacing the cassette players very rapidly. The market is divided into organized and unorganized segments. Rural and urban areas have a 50:50 share in the market.

3.3.2 Commercial sector

The commercial sector comprises various institutional and industrial establishments such as banks, hotels, restaurants, shopping complexes, offices, and public departments supplying basic utilities. In other words, the commercial sector is a subset of the services sector as defined by the Central

Statistical Organization, Government of India. Given the structural changes in the economy, especially during the post-liberalization period, the services sector now accounts for a high share (about 50% share of the GDP of services sector in aggregate GDP) in the total national income.

Energy consumption in the commercial sector has, thus, increased as a consequence of the accelerated growth of the commercial sector. Most commercial energy is used in buildings or structures for the purpose of space heating, water heating, lighting, cooking, and cooling. Energy consumed for services not associated with buildings such as for traffic lights, city water, and sewer services is also categorized under commercial sector energy use.

3.3.2.1 End-use demands in the commercial sector

In India, the commercial energy demand estimation and projection are beset with numerous data gaps, particularly with respect to the reporting of the number of commercial establishments/consumers, their energy consumption patterns, degree of usage of energy for different end-use energy consuming activities, and penetration of appliances and other end-use devices in the sector.

Therefore, the entire demand estimation exercise is driven by assumptions on the distribution of fuels consumed for cooking, lighting, space conditioning, refrigeration, and miscellaneous services.

For the purpose of energy demand estimation and projections in the commercial sector, a top-down approach is used in which the total fuel consumption is first estimated and projected using an appropriate econometric model (TERI report). The projected fuel consumptions then divided amongst various end-use activities involving that particular fuel.

Fuels such as LPG and kerosene, and traditional fuels such as firewood/charcoal are used for cooking in the commercial sector LPG is used as fuel for cooking in hotels and restaurants, that is, under the purview of the services sector. Thus, the high rate of growth of the service sector, measured by the GDP generated by the sector, result in high LPG consumption and vice-versa.

Due to other exogenous factors such as constraints on the accessibility to the small vendors, eateries in the rural and remote areas use kerosene as a fuel for cooking. Historical data on kerosene consumed in all sectors is available but the quantities consumed in the commercial sector are not known. Hence, it has been assumed that 1.42 MT of kerosene is consumed in the commercial sector in 2001 (14% of total kerosene consumed). The underlying rationale is that kerosene consumption would decline in absolute terms in the future as bottlenecks to the accessibility of LPG are expected to ease in the future. However, the extent of decline in kerosene consumed in the commercial sector is not reported. Hence, it has been assumed that the consumption of kerosene in the commercial sector would remain constant at the 2001 consumption level of 1.42 MT over the modelling time frame of 2001 till 2036. Moreover, in the commercial sector in India,

Firewood-based stove is used commonly for grilled food items. It has been assumed that 10% of the total useful energy demand in the commercial sector is met by firewood. Therefore, the end-use devices in the commercial sector comprise the LPG burner, wick-type kerosene stove, and firewood- based stove. The efficiency of these devices is listed in Table 3.47.

Table 3.47Technological options for cooking in the commercial sector

Technology	**Efficiency** (%)
LPG burner	60
Wick-type kerosene	48

stove	
Firewood-based stove	10

LPG – liquefied petroleum gas

The energy demand for cooking in the commercial sector under different GDP growth scenarios (expressed in Mtoe) is presented in Table 3.48.

Table 3.48 Energy demand for cooking in commercial sector (in Mtoe)

GDP growth rate (%)	2001	2006	2011	2015-16	2021	2030-31	2036	2050
8	65	83	107	139	180	234	302	
10	65	84	114	155	212	290	397	

Mtoe – million tonnes of oil equivalent

3.3.2.2 Electricity demand in the commercial sector

Electricity consumption in the commercial sector is estimated using the historical data on electricity sale to the commercial sector. Electricity consumption in the commercial sector has been growing at an average annual rate (Figure 3.11) of 8.1% per annum. The growing electricity demand can be explained by the increasing demand for services measured by value of output from the services sector, that is, GDP of the services sector.

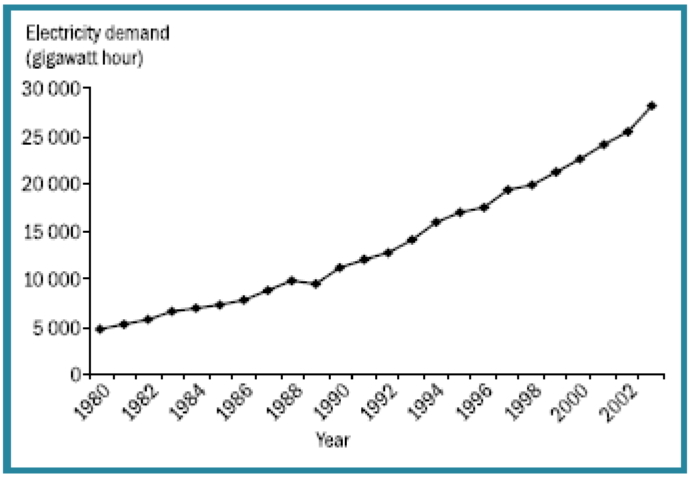
The bifurcation of electricity consumption amongst various electricity consuming activities such as lighting, space conditioning, and refrigeration is based on electricity usage norms.

The efficiency of technologies for lighting in the commercial sector is shown in Table 3.50 Upper and lower bounds represent the realistic levels of penetration of each of the above technologies. It is assumed that 50% of the total lighting demand is met by GLS, 49% by tube lights, and 1% by CFLs. These shares are fixed for the modelling time frame 2001–36. Thus, the electricity demand for lighting (in GWh) under different scenarios is presented in the Table 3.49

Table 3.49 Technologies for lighting in the commercial sector

Technologies	**Efficiency**
GLS (generalized lighting system)	Normalized to 1
Tube light	1.818
CFL (compact fluorescent lamp)	3.125

Figure 3.11 Trend of electricity consumption in the commercial sector (1980–2003)



Source CEA (2004)

Electricity demand for lighting in the commercial sector (in GWh) is given below.

Table 3.50 Electricity demand for lighting in the commercial sector (in GWh)

GDP growth rate (%)	2001	2006	2011	2015-16	2021	2026	2030-31	2036	2050
8	14 484	21260	31726	47342	70646	105420	157312	234746	
10	14484	22429	36954	59702	97404	158913	259264	422986	

GDP – gross domestic product; GWh – gigawatt hour

Together with their efficiency in the commercial sector are listed in Table 3.51. The total electricity demand or space conditioning in the commercial sector is met by fans and air conditioners. The share of fans in the total electricity is assumed fixed at 70% and the remaining 30% is met by air conditioners. Each of these electrical appliances has an efficient counterpart. Under the pessimistic scenario, it is assumed that the penetration of efficient appliances is only to the extent of 45% within both the fan and air conditioner segments. These shares are assumed based on the shares of the organized market dealing with electrical appliances.

Table 3.51Technologies for space conditioning in the commercial sector

Technologies	**Efficiency**
Fan (standard	Normalized to 1
Fan (efficient)	10% efficient compared to standard (1.1)
Air conditioner (standard)	Normalized to 1
Air conditioner (efficient)	50% more efficient compared to standard

Thus, the electricity demand for space conditioning (in GWh) under different scenarios is presented in Table 3.52

Table 3.52 Electricity demand for space conditioning in the commercial sector (in GWh)

GDP growth rate (%)	2001	2006	2011	2015-16	2021	2026	2030-31	2036	2050
8	7725	11339	16920	25249	37678	56224	83900	125198	
10	7725	11962	19517	31841	51949	84753	138274	225593	

GDP – gross domestic product; GWh – gigawatt hour

Table 3.53 Electricity demand for refrigeration in the commercial sector (in GWh)

GDP growth rate (%)	2001	2006	2011	2015-16	2021	2026	2030-31	2036	2050
8	1931	2835	4230	6312	9419	14056	20975	31299	
10	1931	2991	4879	7960	12987	21188	34569	56398	

GDP – gross domestic product; GWh – gigawatt hour

The demand for refrigeration is met by a standard refrigerator alone, with its efficiency normalized to one. Thus, the electricity demand for refrigeration (in GWh) under different scenarios is presented in Table 3.53.

3.3.2.3 Electricity demand in other sectors

The other sectors consuming electricity consist of public lighting, public water works, and sewage pumping. The electricity consumption in these sectors is assumed to be a function of the expenditure incurred by the government on providing services to these sectors.

The historical time-series data clearly depicts that electricity consumption has grown at an average annual growth rate of 6% from 1980–2003 (Figure 3.12).

The appropriate regression model for estimating and projecting electricity demand in the commercial sector is as follows.

Log(ELCo,t) = 0.74 × Log(GDPSt) + 0.91 × AR(1) (3.34)

(32.58) (12.5)

(3.6)

(Adjusted R2 = 0.98)

The coefficient associated with GDPS is 0.74. This implies that 1% rise in value added by the services sector would increase the electricity demand by 0.74% implying that electricity demand is income-inelastic.

This further implies that electricity is a necessity for the other sector in carrying out its operations.

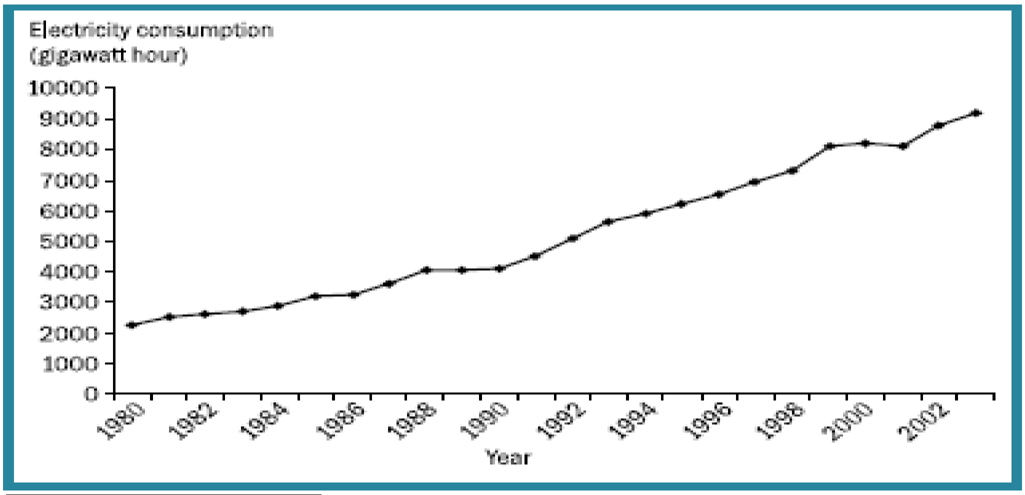
Electricity demand projections (in GWh) for other services under different growth scenarios are presented in Table 3.54 (TERI report).

Table 3.54 Final energy requirements for space heating and CO_2 emissions for building with different insulating standards

Building standard	Average final energy requirement	CO_2 emissions (current heating stock)	CO_2 savings (related to building stock)
	kWh/m^2a	kg/m^2a	kg/m^2a (%)
Houses in stock[2]	220 – 270	59 – 73	19 – 24 (32 – 34)
Heat Insulation Ordinances 1982	150 – 180	40 – 49	19 – 24 (54 – 56)
Swedish standard	100 – 120	27 – 32	32 – 41 (54 – 56)
Low – energy[3] houses	30 – 70	8 – 19	51 – 54 (74 – 86)

CO_2 factor: heating systems in stock 0.27 kg CO_2/ kWh
In Germany
Intensified heat insulation, ventilation system with heat recovery

Figure 3.12Trend of electricity consumption in other electricity consuming sectors (1980–2003)



Source CEA (2004)

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CO_2 factor: heating systems in stock 0.27 kg CO_2/ kWh
In Germany
Intensified heat insulation, ventilation system with heat recovery

(Construction, The Gazette of India No 23/40/2004-R & R (Vol. III) Part I Section I, Ministry of power, New Delhi

Construction ,Energy Map for India: Technology Vision 2030, The Energy and Resources Institute, Office of the Principal Scientific Adviser, Government of India 2006, Publishers TERI Press)

Recommendations

Periodic energy audits have been made compulsory for power intensive industries under the Energy Conservation Act. Other industries may also be encouraged to adopt energy audits and energy conservation measures. Energy conservation measures shall be adopted in all Government buildings for which saving potential has been estimated to be about 30% energy. Solar water heating systems and solar passive architecture can contribute significantly to this effort.

In the field of energy conservation initial approach would be voluntary and self-regulating with emphasis on labelling of appliances. Gradually as awareness increases, a more regulatory approach of setting standards would be followed.

Barriers

3.4. Power sector

Indian Power sector is witnessing major changes. Growth of Power Sector in India since its Independence has been noteworthy. However, the demand for power has been outstripping the growth of availability. Substantial peak and energy shortages prevail in the country. This is due to inadequacies in generation, transmission & distribution as well as inefficient use of electricity. Very high level of technical and commercial losses and lack of commercial approach in management of utilities has led to unsustainable financial operations. Cross-subsidies have risen to unsustainable levels. Inadequacies in distribution networks have been one of the major reasons for poor quality of supply.

Electricity is an essential requirement for all facets of our life. It has been recognized as a basic human need. It is a critical infrastructure on which the socio-economic development of the country depends. Supply of electricity at reasonable rate to rural India is essential for its overall development. Equally important is availability of reliable and quality power at competitive rates to Indian industry to make it globally competitive and to enable it to exploit the tremendous potential of employment generation. Services sector has made significant contribution to the growth of our economy. Availability of quality supply of electricity is very crucial to sustained growth of this segment.

Recognizing that electricity is one of the key drivers for rapid economic growth and poverty alleviation, the nation has set itself the target of providing access to all households in next five years. As per Census 2001, about 44% of the households do not have access to electricity. Hence meeting the target of providing universal access is a daunting task requiring significant addition to generation capacity and expansion of the transmission and distribution network.

3.4.1. Table 3.56 shows the generation capacities in scenario 11 (Renewables scenario) from different sources and the load factor for each type of plants for the year 2031-32. This is an extreme scenario where all options for power generation other than coal, are pushed to their limits. We have also assumed high plant load factors for biomass gasification and combustion, and somewhat lower factors for conventional plants. It gives the minimum coal requirement.

Table 3.56

Generation Capacities and Load Factors in Scenario 11

Source	Capacity (MW)	Plant Load Factor (%)
Coal	269997	67
Natural Gas	69815	27
Coal Bed Methane	27778	36
In-situ Coal Gas	22222	36
Nuclear	63060	68
Hydro	150153	30
IGCC Pet coke	3137	68
Wind – Onshore	32141	20
Wind – Off-shore	1200	25
Biomass Gasification	1200	75
Biomass combustion	50000	70
Solar	10000	17.5
Total	**700703**	**50**

The energy elasticities of GDP can be reshaped by policy interventions, the relative prices of fuels, changes in technology, changes the energy infrastructure and development priorities that affect the structure of the economy. Normally, overall elasticity falls over time as is corroborated by the time series data for India's commercial energy consumption. However, there is also a feeling that, for India, the energy elasticity of GDP growth will not fall any further as rising income levels will foster life style changes that are more energy intense. Based on these alternative views two sets of elasticities were used for projecting India's commercial energy demand. The two sets of elasticities used are shown in the below table.

Table 3.57 Elasticities Used for Projections (TPCES w.r.t. total GDP)

	TPCES 1 (Falling Elasticities)	TPCES 2 (Constant Elasticities)	Electricity (Falling Elasticities)	Electricity (Constant Elasticities)
2004 – 05 to 2011 – 12	0.75	0.8	0.95	0.95
2011 – 12 to 2021 – 22	0.70	0.8	0.85	0.95
2015 – 16				
2021 – 22 to 2031 – 32	0.67	0.8	0.78	0.95
2050				

3.4.2 Aims & Objectives

The National Electricity Policy aims at achieving the following objectives:

- Access to Electricity - Available for all households in next five years
- Availability of Power - Demand to be fully met by 2012. Energy and peaking shortages to be overcome and adequate spinning reserve to be available.
- Supply of Reliable and Quality Power of specified standards in an efficient manner and at reasonable rates.
- Per capita availability of electricity to be increased to over 1000 units by 2012.
- Minimum lifeline consumption of 1 unit/household/day as a merit good by year 2012.
- Financial Turnaround and Commercial Viability of Electricity Sector.
- Protection of consumers' interests.

3.4.3 Targets of generation:

3.4.3.1 Thermal power generation

Inadequacy of generation has characterized power sector operation in India. To provide availability of over 1000 units of per capita electricity by year 2012 it had been estimated that need based capacity addition of more than 1,00,000 MW would be required during the period 2002-12.

Even with full development of the feasible hydro potential in the country, coal would necessarily continue to remain the primary fuel for meeting future electricity demand.

Imported coal based thermal power stations, particularly at coastal locations, would be encouraged based on their economic viability. Use of low ash content coal would also help in reducing the problem of fly ash emissions.

Significant Lignite resources in the country are located in Tamil Nadu, Gujarat and Rajasthan and these should be increasingly utilized for power generation. Lignite mining technology needs to be improved to reduce costs.

Use of gas as a fuel for power generation would depend upon its availability at reasonable prices. Natural gas is being used in Gas Turbine /Combined Cycle Gas Turbine (GT/CCGT) stations, which currently accounts for about 10 % of total capacity. Power sector consumes about 40% of the total gas in the country. New power generation capacity could come up based on indigenous gas findings, which can emerge as a major source of power generation if prices are reasonable. A national gas grid covering various parts of the country could facilitate development of such capacities.

Imported LNG based power plants are also a potential source of electricity and the pace of their development would depend on their commercial viability. The existing power plants using liquid fuels should shift to use of Natural Gas/LNG at the earliest to reduce the cost of generation.

For thermal power, economics of generation and supply of electricity should be the basis for choice of fuel from among the options available. It would be economical for new generating stations to be located either near the fuel sources e.g. pithead locations or load centres.

Generating companies may enter into medium to long-term fuel supply agreements especially with respect to imported fuels for commercial viability and security of supply.

While using premium fuels like natural gas and naphtha, contemporary design of gas turbines (Table 3.58) has been adopted in the country, and the combined cycle power generation efficiency to the level of 53% has been achieved at ISO conditions, hat is, 15 °C ambient temperature, 60% relative humidity, and barometric pressure corresponding to mean sea level. The efficiency levels in Indian conditions are, thus, 50%–51%. Now, we have to look further to achieve higher efficiencies.

Table 3.58 power generation steam cycles with different unit ratings Turbine heat rate *Gross plant heat

Unit rating (MW)	**Cycle parameters**	**Turbine heat rate** (kcal/kWh)	***Gross plant heat rate** (kcal/kWh)
70	90 ata, 537 oC, non-reheat	2200	2588
120/130	130 ata, 537 oC/537 oC, reheat	1980	2330
210	150 ata, 537 oC/537 oC, reheat (with motor-driven BFP)	1970	2318
250	150 ata, 537 oC/537 oC, reheat (with motor-driven BFP)	1970	2314
500	170 ata, 537 oC/537 oC, reheat (with steam-driven BFP)	1945	2288

MW – megawatts; ata – atmospheres absolute; BFP – back focal plane; kcal – kilocalories; kWh – kilowatt-hours

3.4.3.2 Electricity generation

Requirement for electricity generation are shown in the Table 3.59 Plan-wise projected electricity generation and capacity additions are shown in Figures 3.13 and respectively.

Table 3.59 Projections for Electricity Requirement (Based on Falling Elasticities of above Table)

Year	Billion kWh				Project Peak Demand (GW)		Installed Capacity Required (GW)	
	Total Energy Requirement @ GDP Growth Rate		Energy Required at Bus Bar @ GDP Growth Rate		@ GDP Growth Rate		@ GDP Growth Rate	
	8%	9%	8%	9%	8%	9%	8%	9%
2003 – 04	633	633	592	592	89	89	131	131
2006 – 07	761	774	712	724	107	109	153	155
2011 – 12	1097	1167	1026	1091	158	168	220	233
2015								
2016 – 17	1524	1687	1425	1577	226	250	306	337
2021 – 22	2118	2438	1980	2280	323	372	425	488
2026 – 27	2866	3423	2680	3201	437	522	575	685
2030								
2031 – 32	3880	4806	3628	4493	592	733	778	960
2050								

Note : Electricity generation and peak demand in 2003 – 04 is the total of utilities and non – utilities above 1 MW size. Energy demand at bus bar is estimated assuming 6.5% auxiliary consumption. Peak deman is estimated assuming system load factor of 76% up to 2010, 74% for 2011 – 12 to 2015 – 16, 72% for 2016 – 17 to 2020 – 21 and 70% for 2021 – 22 and beyond. The installed capacity has been estimated keeping the ratio between total installed capacity and total energy required constant at the 2003 – 04 level. This assumes optional utilization of resources bringing down the ratio between installed capacity required to peak demand from 1.47 in 2003 – 04 to 1.31 in 2050.

Figure 3.13

Plan-wise Projected Installed Capacity Addition (MW)

For comparison purposes, below Table 3.60 provides projections of electricity demand. This projection is provided by the Ministry of Power, India. For the purposes of this report, however, the projections of this Table not have been used.

Table 3.60 Project for Electricity Requirement by MOP

Year	**Billion kWh**		**Installed Capacity (GW)**	
	8%	**9%**	**8%**	**9%**
2006 – 07	700	700	140	140
2011 – 12	1029	1077	206	215
2015				
2016 – 17	1511	1657	303	331
2020				
2021 – 22	2221	2550	445	510
2026 – 27	3263	3923	655	785
2030				
2031 – 32	4793	6036	962	1207
2050				

The projections in **Table 3.61** assume exploitation of full hydro potential of 1,50,000 MW in the country, a capacity addition of 63,000 MW from nuclear power sources and a14,000 MW capacity from wind farms by 2031-32. These scenario assumptions in respect of hydro and nuclear may not be fully realized and are made here in order to characterise the boundaries of alternative choices. Generation from coal-based stations also include electricity generation from lignite. The scenario also forces gas usage for power generation with gas-based electricity shares rising from about 10% to 16%between 2003-04 and 2031-32. As a result of these assumptions, the share of coal-based electricity drops from 72% to 61%. The demand for oil in power sector covers consumption of petroleum products in diesel based plants as well as secondary oil consumption in coal based plants.

Table 3.61 Sources of Electricity Generation – One Possible Scenario

Year	Electricity Generation at Bus Bar (Bk Wh)		Hydro (Bk Wh)	Nuclear (Bk Wh)	Renewables (B kWh)	Thermal Energy (Bk Wh)		Fuel Needs					
								Coal (Mt)		NG (BCM)		Oil * (Mt)	
	8%	9%				8%	9%	8%	9%	8%	9%	8%	9%
2003-04	592	592	74	17	3	498	498	318	318	11	11	6	6
2006-07	711	724	87	39	8	577	590	337	379	12	14	6	6
2011-12	1026	1091	139	64	11	812	877	463	521	19	21	8	8
2015													
2016-17	1425	1577	204	118	14	1089	1241	603	678	33	37	9	10
2020													
2021-22	1981	2280	270	172	18	1521	1820	832	936	52	59	12	12
2026-27	2680	3201	335	274	21	2050	2571	1109	1248	77	87	14	15
2030													
2031-32	3628	4493	401	375	24	2828	3693	1475	1659	119	134	17	20
2050													

Includes secondary oil consumption for coal – based generation

3.4.3.3 Captive Generation

The liberal provision in the Electricity Act, 2003 with respect to setting up of captive power plant has been made with a view to not only securing reliable, quality and cost effective power but also to facilitate creation of employment opportunities through speedy and efficient growth of industry.

The provision relating to captive power plants to be set up by group of consumers is primarily aimed at enabling small and medium industries or other consumers that may not individually be in a position to set up plant of optimal size in a cost effective manner. It needs to be noted that efficient expansion of small and medium industries across the country would lead to creation of enormous employment opportunities.

3.4.4 Description of available natural resource

3.4.4.1 Coal and lignite

Coal is increasingly catering to our growing energy needs. It meets about 60% of our commercial energy needs, and about 70% of the electricity produced in India comes from coal. With proper technologies and initiatives for better management, it is possible to reduce the hazards otherwise associated with coal. Through scientific mining practices followed by land reclamation, beneficiation to reduce ash at source, and better ways of utilization of coal like liquefaction of coal, coal gasification, in situ coal gasification, and coal-bed methane recovery, coal can be used judiciously as a major source of energy.

3.4.4.1.1 India's Coal Demand for Non-Power Use

Long-term projections of the demand for coal are quite complex owing to rapid changes in the relative availability and prices of different fuels as well as the technological advancements and new policies in the end-use sectors. Total demand, defined as the aggregate demand across various non-power coal consuming sectors such as steel, cement etc., is assessed by determining the outputs of each sector, which in turn are functions of GDP growth. In the last decade or so, a gradual decline in the elasticity of demand of coal against GDP has been observed. Possible reasons for this decline can be: (a) rising share of the non-energy consuming sector in the aggregate GDP; (b) substitution of coal by alternative fuels; and (c) technological innovations in coal consuming sectors leading to energy efficiency and a reduction in specific consumption.

Putting together the various projections discussed above for coal, oil and natural gas for non-power use, the commercial fuel requirement for non-power use are summarized below in Table 3.62

Table.3.62 Commercial fuel requirements for non-power use in physical units

Year	Non-Power- Coal Mt		Non-Power - Oil" Mt		Non-Power- Natural Gas B.Cu.M	
	8%	9%	8%	9%	8%	9%
200.1-34	91	91	113	113	20	20
2006-07	123	133	126	142	20	22
2011-12	164	170	154	178	30	32
2016-17	221	237	205	231	38	45
2021-22	299	334	266	299	96	65
2026-27	108	475	551	395	73	93
2031-32	562	6S4	469	528	100	133

Note: Estimated fuel requirements of coal, oil and neural gas are for non-power purpose*.
As explained in *Pard IS*
As explained in *Para 35 '* As
explained in *Para IS*

The commercial energy requirement estimated in Table 3.63

Table 3.63 Projected primary commercial energy requirements (one possible scenario) (Mtoe)

Year	Hydro	Nuclear	Coal		Oil		Natural gas		TPCES	
			8%	9%	8%	9%	8%	V%	8%	9%
2011-12	12	17	257	2 83	166	186	44	48	496	546
2016-17	I8	31	338	375	214	241	64	74	665	739
2021-22	23	45	464	521	278	311	97	111	907	1011
2026-27	29	71	622	706	365	410	135	162	1222	1378
2031-32	35	98	835	937	486	548	197	24O	1651	1858
CAGR-% (Com pounded Annual Growth rates)	5.9	11.2	5.9	6.3	5.1	5.6	7.2	8	6	6.4
Per capita Consumption In 2032 (Kgoe)	24	67	569	638	331	373	134	163	1124	1266
In 2004 (Kgoe)	6.5	4.6	157	157	1 11	1 11	27	27	306	306
Ratio 2032/2004	3.7	14.6	3.6	4.1	2.9	3.4	5.2	6.3	3.7	4.1

Coal and lignite availabilities I year 2001proven reserves are 84.41 billion tonnes, while 98.55 billion tonnes are indicated reserves and 38.02 billion tonnes are inferred reserves. Coal continues to remain the principal source of commercial energy, accounting for nearly 50% of the total supplies.

The current estimates of geological lignite reserves in India are 34.76 billion tonnes spread over Tamil Nadu and Pondicherry (87.5%), Rajasthan (6.9%), Gujarat (4.9%), Kerala (0.31%), and Jammu and Kashmir (0.37%). The lignite deposits in the southern and western regions have emerged as an important source of fuel supply for states like Tamil Nadu, Rajasthan, and Gujarat. Over the years, considerable emphasis has been placed on the development of lignite for power generation. The indigenous production of coking coal in the country was 30 MT during 2001/02 and is expected to increase to 50 MT by 2036/37. The production of non-coking coal was about 299 MT in 2001/02 and the maximum production is expected to be no more than 550 MT in 2036/37. The values of indigenous production of different types of coal are shown in Table 3.64.

Table 3.64 Electricity demand projections for other services (in GWh)

GDP growth rate (%)	2001	2006	2011	2015-16	2021	2026	2030-31	2036	2050
8	21551	25188	34931	48059	65793	89789	122294	166359	
10	21551	26239	38953	57371	84078	122830	179089	260791	

GDP – gross domestic product; GWh – gigawatt hour

Below table showing the Maximum values of domestic coal availability

Table 3.65 Maximum values of domestic coal availability

Fuel (MT)	2001/02	2036/37	2050
Coking coal	27	50	
Non-coking coal	299	550	
Lignite	25	50	

MT – million tonnes

3.4.4.1.2 Status of coal to oil technologies in India

In India, studies on coal hydrogenation are restricted to laboratory-scale R&D activities, principally at the CFRI (Central Fuel Research Institute), Jharkhand. A 0.5 TPD high-pressure plant was set up at the CFRI to study the hydrogenation of coal. The single-stage process followed by the plant yielded 25% oil amidst many operational problems.

3.4.4.1.3 Status of coal gasification in India

The major advantage of gasification is that coal is converted into a gaseous fuel that is a clean form of energy and easy to handle. Thus, in gaseous form, coal is able to substitute for petroleum products and natural gas.

Synthesis gas has a wide range of application. It can be used in a combined cycle system that ensures an efficient and clean generation of electric power. It is suitable for the manufacturing of hydrogen and chemicals such as ammonia, methanol, and acetic acid; as substitute natural gas; as a reducing gas for metallurgical purposes; and so on. It can be used in multipurpose plants for the simultaneous production of electric power, chemicals/fertilizers, and fuels that also improve the economics of coal gasification. India already has some experience in coal gasification and has even made advances in developing an indigenous technology.

The scenario of coal gasification, which is intimately connected to the particular characteristics of Indian coal, is not as bright as that of oil gasification. Indian coal has the advantage of relatively low sulphur content. The problem lies in the extremely high ash content, which can often be as high as 40%, and nature of the ash, which contains very high amounts of silica and alumina. (This high ash content combined with a high melting point presents great difficulties to all slagging processes. Any gasifier operating in slagging mode consumes more oxygen because of the heat required to keep the ash molten at the slag tap. In most coal types, this disadvantage is outweighed by the advantages of high-temperature operation, which ensures elimination of all volatiles in the gas, and reduced methane slip. Thus, modern process developments have taken the high-temperature route. The high-ash content of the Indian coals, however, makes modern high temperature processes extremely expensive due to their high oxygen demand. Besides, there are problems of handling large volumes of silica in an entrained flow process. Thus, when looking at gasifying Indian coal, the tendency has been to take into account non-slagging processes.

The BHEL (Bharat Heavy Electricals Ltd) Unit at Trichy is an indigenous development, also aimed at finding a way to improve coal use in India. It is, however, necessary to take cognizance of the fact that since most Indian coals have low sulphur content, relatively simple gas cleaning technologies can be introduced in conventional combustion plants to meet the environmental requirements. Indian scientists and engineers have gained experience in the gasification of coal through moving bed process on pilot/demonstration scale. This process (Lurgi dry ash process) is a commercially proven process in Germany and South Africa, and uses high ash coal for power generation and production of synthesis gas, chemicals, and liquid fuels.

Fluidized bed gasification process is superior to moving bed process for utilization of high-ash Indian coals through gasification route. The country has very limited experience in fluidized bed process. India can go in for a hybrid concept, that is, a combination of moving bed and fluidized bed gasification processes. Based on the results obtained from this concept, a fluidized bed coal gasification system can be added to the moving bed plant at the same location. As India has a vast reserve of coal, it will be advantageous for it to adopt two coal gasification processes. The hybrid concept results in the economy of coal, as coal of varying sizes supplied to a power plant can be utilized, that is, 6–50 mm size coal can be used for moving bed and coal below 6 mm for fluidized bed. Moreover, moving bed cannot tolerate more than 10% of coal fines due to operational problems.

The combined cycle technology uses gas turbine–steam turbine combination for power generation, and instead of natural gas uses coal gas along with steam for power generation in the turbines to achieve higher efficiency. Gasification is the cleanest method of utilization of coal, while combined cycle generation gives the highest efficiency. Hence, the integration of the two technologies for power generation in IGCC plants offers the benefit of very low emissions, higher efficiency, and the potential for lower cost of electricity generation. Eg: The BHEL Trichy set up a 6.2-MW IGCC power plant at a cost of 15 crore rupees in 1989, which is the first coal-based IGCC in Asiaand the second in the whole world. In 1996, a PFBG demonstration plant of 150 TPD capacities was designed and retrofitted in the 6.2-MW plant to supply coal gas to the existing unit.

3.4.4.1.4 Status of coal-bed methane in India

There are very good prospects for the development of coal-bed methane in India. The coal-bearing formations of India occur in two distinct geological horizons in the Lower Gondwana (Permian) belts of India and the Tertiary sediments (Eocene–Oliocene) of north-eastern India, Rajasthan, Gujarat, and Jammu and Kashmir. Methane gas is entrapped within these formations at a wide range of sub-surface depths. Indian coal has gas content values ranging from 1 to 23 m3 (cubic metres)/tonne. The coal-bed methane occurrence is predicted in Damodar Valley basin, a potential source presently under consideration potential source of coal-bed methane.

Giving highest priority to the efficient use of energy resources and long-term sustainability of energy supplies, the Government of India requested international assistance in coal-bed methane recovery and its commercial utilization. The country is one of the chief producers of coal from underground mines in the world.

In India, the Reliance Gas has carried out comprehensive geologic assessment of coal/lignite basins, based on which about 20 000 km2 (square kilometres) of area has been identified as a prospective site for coal bed methane, with an estimated in-place resource of about 2000 BCM (billion cubic metres). The recoverable reserve of about 800 BCM and gas production potential of about 105 million cubic metres per day over a period of 20 years have been estimated. Coal bed methane potential is thus about 1.5 times the present natural gas production in India, which is capable of generating about 19 000 MW of electricity. The potential of gas production in India is given in Table 3.66

Table 3.66 Coal-bed methane production potential in India

		Energy equivalent	
Basin/area	CBM production potential (million cubic metres/day	Power generation (MW)	LNG (MTPA)
Cambay Basin			
North Gujarat	30.0	5500	7.50
Barmer Basin			
South Rajasthan	19.0	3500	4.75
Damodar Basin			
Raniganj	12.0	2200	3.00
Jharia	3.5	650	1.00
East Bokaro	2.5	450	0.60
North Karanpura	6.0	110	1.50
Rajmahal Basin			
Rajmahal	4.5	800	1.20
Birbhum	6.0	1100	1.50
Others			
Singrauli	1.0	180	0.25
Sohagpur	4.0	720	1.00
Satpura	1.5	270	0.40
Ib River	5.0	900	1.25
Talcher	2.5	450	0.60
Wardha Valley	1.5	270	0.40
Godavari Valley	4.0	720	1.00
Cauvery Basin	2.5	450	0.60
All India	105.5	19260	26.55

CBM – coal-bed methane; MW – megawatts; LNG – liquefied natural gas; MTPA – million tonnes per annum

3.4.4.2 Crude oil & petroleum products

Following section highlights the key developments in the E&P (exploration and production) of oil and natural gas. Subsequent sections deal in detail with crude oil, petroleum products, and natural gas.

3.4.4.2.1 Crude oil/natural gas production

Company-wise details of crude oil and natural gas are given in Tables 3.67 and 3.68.

The two national oil companies – ONGC and OIL (Oil India Ltd) – accounted for 87.34% and 79.66% of the total crude oil and natural gas production in the country, respectively, with ONGC accounting for the major share, as per 2005 data. The Government of India has initiated many steps to ensure oil security for the country. One such step was to intensify domestic exploration and development efforts to explore new fields and increase the reserve base of the country. *Hydrocarbon Vision 2025* laid down a phased programme for reappraising all the sedimentary basins of the country by 2025

Table 3.67Company-wise crude oil production (MT)

	Onshore				Offshore			
Year	**OIL**	**ONGC**	**Private/JV**	**Total**	**ONGC**	**Private/JV**	**Total**	**Total**
1994/95	2883	9130	4	12017	20226	251	20477	32494
1995/96	2882	8971	26	11879	22665	624	23289	35168
1996/97	2870	8504	38	11412	20181	1307	21488	32900
1997/98	3094	8387	42	11523	19863	2472	22335	33858
1998/99	3295	8100	77	11472	18286	2965	21251	32723
1999/2000	3283	7921	94	11298	16727	3924	20651	31949
2000/01	3286	8428	293	12007	16629	3788	20417	32424
2001/02	3183	8635	71	11889	16073	4070	20143	32032
2002/03	2950	8445	75	11470	17559	4013	21572	33042
2003/04	3002	8384	74	11460	17681	4240	21921	33381
2004/05	3196	8321	74	11591	18164	4226	22930	33981

OIL – Oil India Ltd; ONGC – Oil and Natural Gas Corporation Ltd; JV – joint venture; MT – million tonnes
Source MoPNG (2005)

Table 3.68 Company-wise production of natural gas (MCM)

Year	**OIL**	**ONGC**	**Private/JV**	**Total**
1995/96	1433	20875	331	22639
1996/97	1496	21281	479	23256
1997/98	1670	23050	1681	26401
1998/99	1713	22841	2874	27428
1999/2000	1729	23252	3465	28446
2000/01	1861	24020	3596	29447
2001/02	1619	24041	4054	29714
2002/03	1744	24244	5407	31395
2003/04	1880	23584	6491	31955
2004/05	2007	22985	6782	31774

OIL – Oil India Ltd; ONGC – Oil and Natural Gas Corporation Ltd;
JV – joint venture; MCM – million cubic metres
Source MoPNG (2005)

Overseas acquisition of equity oil is another major strategy adopted to enhance oil security of the country. The Government of India aims to produce 20 MTPA (million tonnes per annum) of equity oil and gas abroad by 2010. Under the Tenth Five Year Plan, the target for oil and gas equity abroad was 5.2 MT and 4.88 BCM, respectively. The likely achievement under the plan period is expected to be about 16.45 MT for oil and 4.41 BCM for natural gas. The potential in-place reserves of oil for the block have been estimated to be more than 600 million barrels.

3.4.4.2.2 Global hydrocarbon reserves

The global hydrocarbon reserves as per the BP (2006) indicate that oil availability at the current R/P ratio is expected to be about 40.7 years. The global natural gas availability at the current R/P ratio is 65 years. Appendix 4 gives information on the region-wise hydrocarbon reserves till the end of 2005, and the daily production and R/P ratios over the past 26 years, from 1980 to 2005 (BP 2006).

3.4.4.2.3 Refineries in India

As of July 2005, there are a total of 18 refineries in the country—17 in the public sector and one in the private sector. Company-wise location and capacity of the refineries (as on 1 July 2005) are given in Table 3.69.

Table 3.69 Oil refinery capacity in India (2005)

Name of the company	Location of the refinery	Capacity (MTPA)
IOCL	Guwahati	1.00
IOCL	Barauni	6.00
IOCL	Koyali	13.70
IOCL	Haldia	6.00
IOCL	Mathura	8.00
IOCL	Digboi	0.65
IOCL	Panipat	6.00
HPCL	Mumbai	5.50
HPCL	Visakhapatnam	7.50
BPCL	Mumbai	6.90
CPCL	Manali	9.50
CPCL	Nagapattinam	1.00
KRL	Kochi	7.50
BRPL	Bongaigaon	2.35
NRL	Numaligarh	3.00
MRPL	Mangalore	9.69
Tatipaka refinery (ONGC)	Andhra Pradesh	0.08
RPL	Jamnagar	33.00
Total		127.37

IOCL – Indian Oil Corporation Ltd;
HPCL – Hindustan Petroleum Corporation Ltd;
BPCL – Bharat Petroleum Corporation Ltd;
CPCL – Chennai Petroleum Corporation Ltd;
KRL – Kochi Refineries Ltd; BRPL – Bongaigaon Refinery and Petrochemicals Ltd; NRL – Numaligarh Refinery Ltd; MRPL – Mangalore Refinery and Petrochemicals Ltd; ONGC – Oil and Natural Gas Corporation Ltd; RPL – Reliance Petroleum Ltd;
MTPA – million tonnes per annum

3.4.4.2.4 Refining capacity and capacity utilization

The refining capacity, actual crude throughput, and capacity utilization during the past five years are indicated in Table 3.70.

Table 3.70 Refining capacity, actual crude throughput, and capacity utilization during the past five years

MTPA – million tonnes per annum

Particulars	**2000/01**	**2001/02**	**2002/03**	**2003/04**	**2004/05**
Refining capacity (as on 1 April	114.59	114.66	116.96	127.37	127.37
Actual crude throughput (MTPA)	103.10	106.50	10.60	118.70	124.30
Capacity utilization (%)	91.00	93.00	95.00	99.00	

Table 3.71 provides details of the new refineries planned in the Eleventh Five Year Plan

Table 3.71 New refineries planned in the Eleventh Five Year Plan

Name of refineries	Capacity (MTPA)	Expenditure in crore rupees)	Actual/anticipated completion date
IOCL, Paradip	9	8312	March 2010
BPCL, Bina	6	6354	September 2009
HPCL, Bhatinda	9	9806	December 2006

IOCL – Indian Oil Corporation Ltd; BPCL – Bharat Petroleum Corporation Ltd; HPCL – Hindustan Petroleum Corporation Ltd; MTPA – million tonnes per annum

3.4.4.2.5 Hydrocarbon resources (input to the model)

The latest estimates indicate that India has about 0.4% of the world's proven reserves of crude oil. The domestic crude consumption is estimated at 2.8% of the world's consumption. The balance of recoverable reserves as estimated in the beginning of 2001 is 733.70 MT of crude and 749.65 BCM of natural gas. The share of hydrocarbons in the primary commercial energy consumption of the country has been increasing over the years and is presently estimated at 44.9% (36% for oil and 8.9% for natural gas). The demand for oil is likely to increase further during the next two decades. The transport sector will be the main driver for the projected increase in oil demand. Consequently, the import dependency for oil, which is presently about 70%, is likely to increase further during the Tenth and Eleventh Plans.

India has about 0.4% of the world's natural gas reserves. Initially, the gas reserves had been developed largely for use as petrochemical feedstock and for the production of fertilizers, but gas is now increasingly being used for power generation, in industrial applications and, more recently, in the transport sector. Presently, the share of power generation capacity based on gas is about 10% of the total installed capacity. The *India Hydrocarbon Vision 2025* of the government identifies natural gas as the preferred fuel for the future and several options are being explored to increase its supply including building facilities to handle imports of LNG and bringing gas from major gas-producing countries by setting up pipelines. India is also reported to have significant deposits of gas hydrates. However, the true extent of this resource and its potential for commercial exploitation are still being evaluated. In addition, deep-sea gas reserves are unknown and need to be explored.

Table 3.72 Natural gas availability

Particulars	Natural gas availability (MSCMD				
	2006/07	**2011/12**	**2016/17**	**2021/22**	**2026/27**
Total domestic	84	123	125	125	125
Total LNG import	25	65	95	125	135
Trans-national pipelines					
Iran–Pakistan–India	0	30	90	90	90
Myanmar–India	0	0	30	30	30
Total pipelines	025	30	120	120	120
Total imports	109	95	215	245	255
Total		**218**	**340**	**370**	**380**

MSCMD – million standard cubic meter daily; LNG – liquefied natural gas

3.4.4.3 Nuclear energy resources

Nuclear power is an established source of energy to meet base load demand. Nuclear power plants are being set up at locations away from coalmines. Share of nuclear power in the overall capacity profile will need to be increased significantly. Economics of generation and resultant tariff will be, among others, important considerations. Public sector investments to create nuclear generation capacity will need to be stepped up. Private sector partnership would also be facilitated to see that not only targets are achieved but exceeded.

Nuclear energy has the potential to meet the future electricity demand of the country. The country has developed the capability to build and operate nuclear power plants observing international standards of safety. The current installed capacity of nuclear power plants is 2860 MW, accounting for 2.8% of the total installed capacity of the country. The NPCIL (Nuclear Power Corporation of India Ltd) proposes to increase the installed capacity to 9935 MW by 2011/ 12. The future strategies focus on a three stage nuclear power programme for the optimal utilization of the available nuclear energy resources. The first stage of 10 000

MW of nuclear power generation is based on PHWR (pressurized heavy water reactor) technology using indigenous natural uranium resources. The second stage is proposed to be based on FBR (fast breeder reactor) technology using plutonium extracted by reprocessing of the spent fuel obtained from the first stage. In the third stage, the country's vast thorium resources will be utilized for power generation.

Therefore, India needs to adopt a fuel cycle that maximizes the energy yield of the nuclear energy producing ores. The adoption of the three-phase development of nuclear programme in India was envisaged by Dr Homi Bhabha way back in 1944. India is currently in the second phase where the FBRs are to be commissioned.

India's nuclear programme is described below in three stages.

1 *Stage I* construction of natural uranium based, and pressurized heavy-water-moderated and cooled reactors. Spent fuel from these reactors can be reprocessed to obtain plutonium.

2 *Stage II* construction of FBRs fuelled by the plutonium produced in Stage I. These reactors are also to breed U-233 from thorium.

3 *Stage III* power reactors using U-233/ thorium as fuel.

India's uranium resource base can only support 10 000 MW of power generation through the PHWR route, which is the Stage I of India's nuclear programme. Stage II, that is, the FBR route, will require the plutonium derived from the Stage I. This has technological limitations with respect to the production of plutonium by using the fuel in the oxide form. If the FBRs are fuelled by using metallic fuel, the rate of plutonium generation is twice as fast as the MOX (metallic oxide) route, which will generate the required fuel for rapid growth of FBRs. India currently has the experience and capability to use only MOX-derived fuels and it needs to invest in the development of metallic fuel based reactors. Therefore, it currently needs international cooperation to meet its fuel requirements in the Stage II so that the FBRs become self-sustaining.

In the model, nuclear-energy-based power generation has been included as per the government plans. The installed capacity of the nuclear-energy-based power generation in 2001/02 was 2820 MW and increased to 3310 MW as on 31 January 2006. This capacity is expected to increase to 6780 MW by 2010 and 21 180 MW by 2020.we expect 21.18 GW of nuclear energy- based capacity to materialize by 2020 under the baseline as well alternative scenarios. Beyond 2021, in the baseline scenario, we assume that availability of nuclear fuel would be constrained and that the generation capacity would remain constant from 2021 till 2035 in the baseline. However, in the alternative scenario that considers an aggressive pursuit of nuclear-energy-based power generation, we consider the nuclear generation capacity to increase to 70 GW by 2031/32 by being able to import nuclear fuel (enriched uranium) (Table 3.73).

Beyond 2030, enough plutonium is expected to be generated so that the thorium– plutonium fuel cycle (advanced fast breeder reactors) can be commissioned. This could enable a maximum potential generation capacity of about 530 GW (after 2030).

Table 3.73 Installed capacity of nuclear energy based power generation

Expected Installed Capacity (GW)											
Scenario	**2001/02**	**2006/07**	**2011/12**	**2015**	**2016/17**	**2021/22**	**2026/27**	**2030**	**2031/32**	**2036/37**	**2050**
BAU	2.8	3.31	6.78		13.98	21.18	21.18		21.18	21.18	
NUC	2.8	3.31	6.78		13.98	21.18	45.5		70	70	

BAU – business-as-usual; GW – gigawatts; NUC – High nuclear capacity

3.4.4.3.1 High nuclear capacity scenario

Study includes nuclear-energy-based power generation as per government plans. The installed capacity of nuclear power plants was 2.82 GW in 2001/02 and 3.31 GW on 31 January 2006[1]. The nuclear energy- based power generation capacity is expected to increase to 6.78 GW[2] by 2010 and further to 21.18 GW by 2020[3] as per the first stage Indian nuclear power programme. Beyond 2021, in the BAU scenario, the nuclear-energy-based power generation capacity is constrained in view of the non availability of indigenous nuclear fuel and the import restrictions that have several geopolitical dimensions associated with it. The NUC scenario assumes importance in view of the latest development in the nuclear sector due to enhanced international civil nuclear cooperation and the Government of India's initiative in this direction. This scenario considers an aggressive pursuit of nuclear-energy-based power generation whereby the nuclear-energy-based generation capacity is considered to increase to 40 GW by 2021 and 70 GW by 2031/32, driven by the assumption that the country is able to import nuclear fuel (enriched uranium). Table 3.74 presents the expected installed capacity of nuclear-energy-based power generation over the modelling time frame in the NUC scenario vis-à-vis the BAU scenario.

Table 3.74 Installed capacity of nuclear-energy-based power generation

Expected Installed Capacity (GW)										
Scenario	**2001/02**	**2006/07**	**2011/12**	**2015**	**2016/17**	**2021/22**	**2026/27**	**2030**	**2031/32**	**2050**
BAU	2.82	3.31	6.78		13.98	21.18	21.18		21.18	
NUC	2.82	3.31	6.78		13.98	40.0	55.0		70.0	

GW – gigawatts; BAU – business-as-usual; NUC – high nuclear capacity
Note All other assumptions are similar to those in the BAU scenario.

Table 3.75 shows the potential of nuclear energy with domestic resources in the country.

Table 3.75 The approximate potential available from nuclear energy

Particulars	Amount	Thermal Energy		Electricity	
		TWh	GW-year	GWe-Yr.	MWe
Uranium- Metal	61,0000-t				
In PHWR		7,992	913	330	10,000
In FBR		1,027,616	117,308	42,200	5,00,000
Thorium- Metal	2,25,000-t				
In Breeders		3,783,886	431,950	1,50,000	Very Large

Source: Department of atomic energy

Two possible growth paths of nuclear power are summarised in Table 3.76.

Table 3.76 Possible development of nuclear power installed capacity in MW

Year	Unit	Scenarios		Remarks
		Optimistic*	Pessimistic	
2010	GWe	11	9	These estimates assume that the FBR technology is successfully demonstrated by the 500 MW PFBR currently under construction, new uranium mines are opened for providing fuel for setting up additional PHWRs, India succeeds in assimilating the LWR technology through the import and develops the Advanced Heavy Water Reactor for utilizing Thorium by 2020.
2015/16				
2020	GWe	29	21	
2030/31	GWe	63	48	
2040	GWe	131	104	
2050	GWe	275	208	
* It is assumed that India will be able to import 8,000MW of light Water Reactors with fuel over the next ten years.				

Source: Department of atomic energy

3.4.4.4 Uranium & Thorium Resources

India has limited availability of uranium resources (about 70000 tonnes), but has one of the largest resources of thorium in the world, amounting to 360000 tonnes.

3.4.5 Technology description

Efficient technologies, like super critical technology, IGCC etc and large size units would be gradually introduced for generation of electricity as their cost effectiveness is established. Simultaneously, development and deployment of technologies for productive use of fly ash would be given priority and encouragement.

Similarly, cost effective technologies would require to be developed for high voltage power flows over long distances with minimum possible losses. Specific information technology tools need to be developed for meeting the requirements of the electricity industry including highly sophisticated control systems for complex generation and transmission operations, efficient distribution business and user friendly consumer interface.

The country has a strong research and development base in the electricity sector which would be further augmented. R&D activities would be further intensified and Missions will be constituted for achieving desired results in identified priority areas. A suitable funding mechanism would be evolved for promoting R& D in the Power Sector. Large power companies should set aside a portion of their profits for support to R&D.

3.4.5.1 Flue gas desulphurization and de NOx system

Even though SOx emissions from individual stacks, while using low-sulphur coal, are within limits, those from super thermal power stations within a small space may lead to overall high concentration of SOx, leading to acid rain. In such cases, removing SOx by scrubbing off flue gases with lime, known as FGD (flue gas desulphurization), may become necessary. This will lead to an increase in capital and operating cost. Literature survey reveals that the increase in capital cost will be of the order of 15%–20%, and cost of generation may increase by 10%–15%.

The FGD technology is fully established in advanced countries for the past two decades, and can be obtained for applications in India whenever required.

Presence of NOx in the flue gases of pulverized coal-fired boilers can be controlled at the combustion stage (through low-NOx burners/overfire air) or through SCR (selective catalytic reduction). In this process, NOx and NH3 (ammonia) react to form nitrogen and water vapour. The capital cost of SCR system is in the range 90–100 dollars per kW of the installed capacity. The systems can be designed both for high dust applications (before subjecting dust to APH [air pre-heater] and low dust applications (after subjecting dust to ESP). However, India lacks experience with respect to application.

3.4.5.2 Supercritical steam cycle

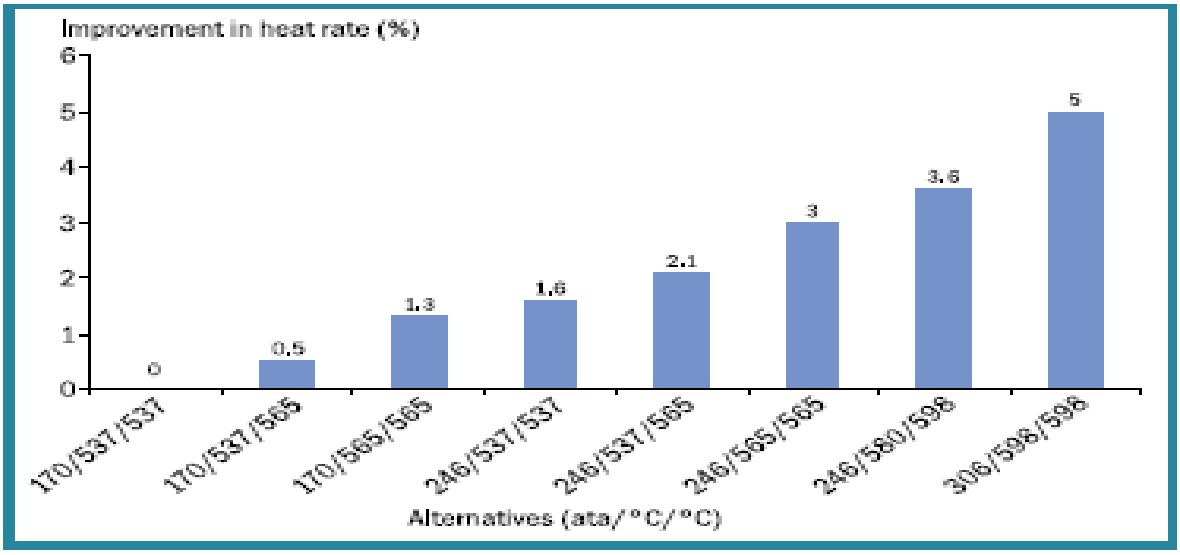
The steam cycle operating at steam pressure above 225.36 ata is called supercritical steam cycle. At this pressure, the density of water and steam is same. Thus, there is no need for a boiler drum that separates steam from water. The boiler used for this application is called once-through unit. The rest of the power plant remains the same, except the number of HP/LP (high pressure/low pressure) heaters chosen to optimize the cycle. The improvement in heat rates while adopting supercritical parameters for Indian ambient conditions is shown in Figure 3.15.

It may be seen from this figure that compared to the base case of steam parameters (170 ata/537 oC/537 oC), the improvement in heat rate will be 2.1% when steam parameters adopted are 246 ata/537 oC/565 oC and 5% when USC (ultra-supercritical) parameters of 306 ata/598 oC/598 oC are adopted. For a pithead 3 × 660 MW supercritical station, the capital cost saving projected in 1999 was about 2.5% as compared to 4 × 500 MW units. In developed countries, where the technologies for supercritical power plants are mature, the capital cost per kW is virtually the same as that of sub-critical plants. Thus, selection of a sub-critical or supercritical unit often depends upon a power producer’s experience and the pressure to reduce fuel consumption (giving benefits of reduction of cost of power generation as well reduced emissions of particulates, SOX, NOX, and CO2).

In terms of operational availability and reliability, the EPRI (Electric Power Research Institute) study of supercritical plants operating in USA has confirmed that outage rates are comparable to drum-type units, after initial period of learning of technology operations.

With the commercial introduction of new steel alloys with higher allowable stresses and longer life at elevated temperatures, a number of power plants with USC parameters (above 280 ata with double reheat or 306 ata/598 oC/598 oC) have come up in advanced countries like Japan, EU, and USA. Based on these successes, researchers continue to improve designs and materials, and it appears that the USC plants with main steam parameters of 357 ata/ 625 oC/625 oC will become fully commercial in the next 5–10 years.

Figure 3.15 Improvement in heat rates with steam parameters



3.4.5.3 Advance class gas turbines

With the increase in the cost of premium fuels like natural gas, naphtha, and LNG, there is an ever-increasing pressure on gas turbine designers and manufacturers of higher efficiency combined cycle systems to produce power at competitive rates compared to coal-fired plants. The improved efficiency obviously leads to reduction in emissions of SOx, NOx, and CO2 also.

Introduction of advance class turbines with inlet temperature in the range 1250– 1350 oC has led to combined cycle power plant efficiency of about 58% on LHV (low heating value) basis and under ISO conditions(Table 3.68). Corresponding value in Indian conditions is in the range 55%– 56.5%. A number of plants are in operation throughout the world. However, there are only a few in India (for example, 2 × 9 FA at Dabhol and 3 × 6 FA at Kovilkallapal, Peringulam, and Dhuvaram). Advance class gas turbines with dry low NOx combustion system using natural gas also generate less than 25 PPM (parts per million) NOx. Further research to improve efficiency is in progress, and gas turbines employing steam injection with gas inlet temperature of 1430 oC and combined cycle efficiency of 60% are available commercially in the UK and USA but not in India

3.4.5.4 Coal-based combined cycle systems

The approach towards further improvement in efficiency of, or reduction of pollution from, coal-based power generation leads to two thermodynamic cycles including gas turbine in topping cycle and a steam turbine in a bottoming cycle, and hence is called combined cycle. However, gas turbines need clean fuel gas or clean flue gas. Therefore, use of coal calls for its conversion to clean combustion products or coal gas at high pressure. Two technologies have been developed: (a) PFBC and (b) IGCC.

Table 3.77 Advance class gas turbines—performance at ISO conditions

Model	ISO rating (MW)	Heat rate (kcal/kWh)	Efficiency (%)	Exhaust flow (kg/s)	GT inlet/exhaust temperature (oC)	CCPP efficiency (%)
V94.3A	278.0	2239	38.4	670.0	1300/582	57.5
9FA	255.6	2331	36.9	641.0	1300/602	57.1
GT26	281.0	2245	38.3	631.7	1280/615	57.8
M701F	270.3	2250	38.2	650.8	1350/586	57.3
M701G	334.0	2180	39.4	736.8	1400/587	58.7

MW – megawatts; kcal – kilocalories; kWh – kilowatt-hour; kg – kilogram; s – seconds; GT – gas turbine; CCPP – combined cycle power plant

3.4.5.5 Pressurized fluidized bed combustion

In the PFBC concept, the conventional combustion chamber of the gas turbine is replaced with PFB combustor (bubbling or circulating) and hot gas clean-up system. The combustion products pass through gas turbine and the heat recovery steam generator. The system is thus a combined cycle, which is capable of giving generation efficiency 5%–6% higher than sub-critical steam cycle plants. Therefore, the system is a strong competitor for USC steam cycle.

The application is generally CHP (combined heat and power). A 360-MW unit based on ABB technology and a 250-MW unit based on Hitachi technology was commissioned in 2003/04 in Japan. The operating experience obtained from these units will have a strong influence on the future of commercial PFBC technology. In India, only BHEL has done R&D work on pilot-scale PFBC, and tested combustion characteristics of few coal types. Recently, they have also tested ceramic-candle-based hot gas clean-up system. The data generated will be useful in designing a demonstration plant in India.

3.4.5.6 Integrated gasification combined cycle

Coal gas can be produced by reacting coal with air/steam or oxygen/steam; the former reaction produces low CV (calorific value) gas whereas the latter reaction produces medium CV gas. For combined cycle operation, it is economical to adopt pressurized gasification. The hot raw gas from the gasifier is cooled by generating steam through HRSG (heat recovery steam generation). This steam is integrated in the combined cycle with the steam produced from HRSG downstream of the gas turbine. Part of the steam produced is used in the gasifier. Thus, the cycle is called IGCC.

Typically, the IGCC efficiency is the product of the gasifier efficiency (achievable 90%) and the combined cycle efficiency (55% with contemporary gas turbines, as explained in Section 4.3), giving a value of 41%–42% compared to 40% achievable through USC steam cycle. This will proportionately reduce CO2 emission. The Sox emission can be brought down to 40–115 mg/Nm3, as the sulphur is removed in the gasification process itself. The NOx emission has also been reported to reduce to levels below 125 mg/Nm3. A number of commercial plants using coal or refinery residues as fuel have come up all over the world (Table 3.78).

The main barriers to widespread adoption of IGCC technologies are: (a) high capital cost compared to pulverized coal plant and (b) demonstration of high availability, at least equal to existing PC plants. However, the costs are coming down. A recent joint study by Texaco, General Electric, and Praxair has shown that for a 550-MW power block, with the introduction of 9H gas turbine technology with firing temperature in the range 1400–1450 0C, the efficiency, capital cost, and cost of generation have significantly improved (Figure 3.14) for the period 1994–2000.

In India, pioneering work has been done on coal-based IGCC by BHEL on a 6.2- MWe pilot plant at Trichy, using both pressurized moving bed gasifier and PFBG.

Table 3.78 Integrated gasification combined cycle experience in the world

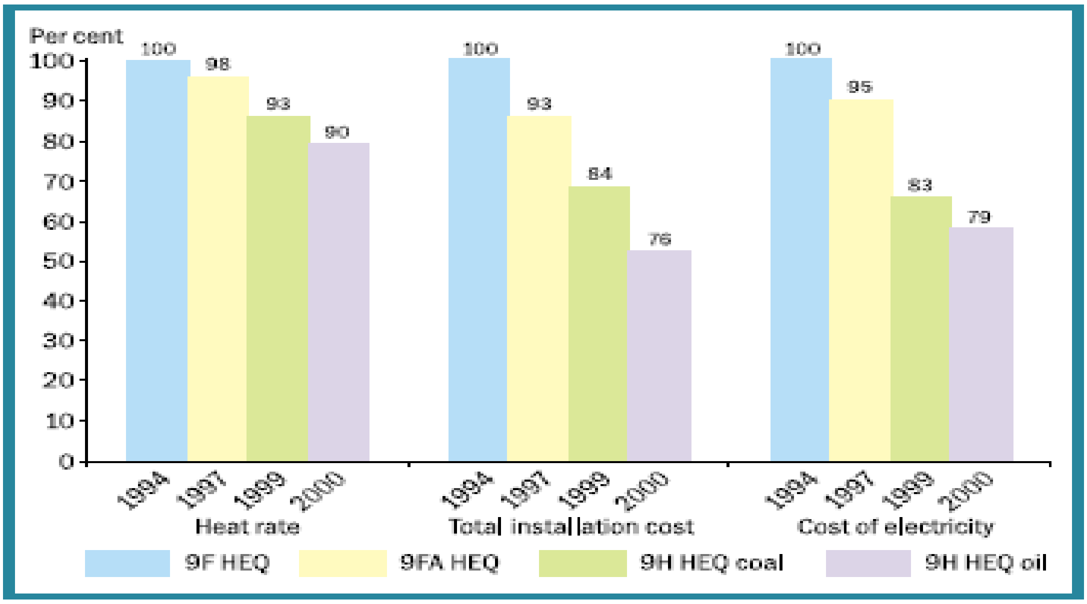
Project	Process	Start-up	Output	Feed	Power block
GSK (Japan)	Texaco	2001	540 MW	VB Tar	2xGE 9EC
Fife Power (Scotland)	BGL	2000	400 MW	Coal/RdF	2xGE 9FA
Shell Pernis (the Netherlands)	Shell	1997	120 MW + H_2	Heavy oil	2xGE 6B
Sierra Pacific (1) (Nevada)	KRW	1998	100 MW	Coal	GE 106 F
Elcogas (Spain)	Pernflow	1998	300 MW	Coal/coke	KWU V94.3
ISE (Italy)	Texaco	2000	520 MW	Asphalt	2xKWU V94.3
SARAS (Italy)	Texaco	2000	550 MW	VB Tar	3xGE 109E
Star (Delaware)	Texaco	1999	240 MW	Petcoke	2xGE 6FA
API (Italy)	Texaco	2000	275 MW	VB Tar	ABB 13 E2
Cool Water (California)	Texaco	1984	120 MW	Coal	GE 107E
Dow Plaquemine (USA)	Destec	1986	220 MW	Coal	GE 107E
Demkolee (the Netherlands)	Shell	1993	250 MW	Coal	KWU V94.2
Tampa Electric (Florida)	Texaco	1996	260 MW	Coal	GE 107 FA
Texaco-Eldorado (Kansas)	Texaco	1996	40 MW	Petcoke	GE 6B
PSI-Wabash (1) (Indiana)	Destec	1996	262 MW	Coal	GE 7FA
Schwarze/Pumpe (Germany)	Noell	1996	40 MW	Coal/oil	GE 6B
Fife Power (Scotland)	BGL	1999	120 MW	Coal/sldg	GE 106FA
Total (France)	Texaco	2004	365 MW	Ref. residue	ABB
EXXON (USA)	Texaco	1999	40 MW	Petcoke	GE 6B
EXXON (Singapore)	Texaco	2000	180 MW	Ref. residue	2xGE 6FA
NPRC (Japan)	Texaco	2003	340 MW	Asphalt	
Repsol (Spain)	Texaco	2004	824 MW	Ref. residue	
CITAGO (USA)	Texaco	2004	350 MW	Petcoke	

MW – megawatts; BGL – British gas Lurgi; KRW – Kellogg–Rust–Westinghouse

Based on this work, design of a 100-MW IGCC demonstration plant with PFBG has been developed. It is learnt that BHEL and National Thermal Power Corporation are jointly working for setting up a plant of this rating. Also a techno-economic feasibility study for a 500-MW IGCC plant is being worked out. The Council of Scientific and Industrial Research has also published in

1992 a feasibility assessment report of IGCC for a 500–600 MW plant with the primary objective of selecting gasification technology for its application for high-ash Indian coal (base case of North Karanpura coal with HHV [high heating value] of 3332 kcal/kg).

Figure 3.16 Economic impacts of integrated gasification combined cycle design study improvements



3.4.6 Emissions from power plants

Conventional power plants typically have the following efficiencies:

Coal 0.38

Lignite 0.37

Oil 0.39

Natural gas 0.40

There are many methods to improve these efficiencies. The possible efficiencies and CO_2 reductions.

Table 3.79 Efficiencies and CO2 emissions of fossil power plants

Technology	Net efficiency (at full load)	CO_2 emissions (kg/kWh)	Specific CO_2 reduction related to conventional system (%)
Hard – coal – fired power plants			
Conventional plant with desulphurization and DENOx	0.38	0.87	
Combined cycle with PFBC	0.415	0.80	8
Integrated gasification combined cycle (IGCC)	0.42	0.79	9
IGCC with hot gas cleaning	0.45	0.73	16
Hybrid combined cycle	0.78	0.69	21
IGCC with natural gas turbine	0.415	0.73	16
In comparison : natural gas combined cycle	0.51	0.37	57
Natural gas – and oil – fired power plants			
Conventional oil – fired power plant	0.39	0.70	-
Oil – fired combined cycle	0.49	0.55	21
Conventional natural – gas – fired power plant	0.40	0.48	-
Natural – gas – fired combined cycle	0.51	0.37	23
82% hard coal, 18% natural gas			

3.4.7 Energy prices

The economic costs of energy resources have been considered in the model. Accordingly, taxes and subsidies are not considered to reflect the price differentiation across various consuming segments/uses. As such, c.i.f. (cost insurance freight) prices are considered for imported fuels while f.o.b. (freight on-board) prices are taken into account for domestic extraction and exports. Owing to large variation in the fuel prices during the past three to four years, we have considered current fuel prices for this analysis. For coal, correction factors are used with f.o.b. price, taking into account different calorific values of domestic coal, and imported and exported coal. For non-coking coal, an import price of 60 dollars per tonne is used. Table 3.80presents the prices considered for different types of coal.

Table 3.80 Prices of different types of coal

Fuel		Current price (dollar/ tonne)	Current price deflated to 2001 (dollar/ tonne)
Non-coking coal	Import Export Domestic	60 41 35	50 34 29
Coking coal	Import Export Domestic	85 59 59	71 49 49
Lignite	Domestic	25	21

1 dollar is 47.7 rupees for 2001 and 43.53 rupees for 2005

Table 3.81 presents the prices considered for crude oil and other key petroleum products.

Table 3.81 Price of crude and other petroleum products

Fuel	f.o.b./ c.i.f.	Unit	Current price	Current price deflated to 2001
Crude oil	f.o.b. c.i.f.	dollars/bbl dollars/bbl	60 62	50 51
HSD	f.o.b. c.i.f.	dollars/tonne dollars/tonne	531 544	443 453
Gasoline	f.o.b. c.i.f.	dollars/tonne dollars/tonne	627 641	523 534
Kerosene	f.o.b. c.i.f.	dollars/tonne dollars/tonne	567 580	472 484
ATF	f.o.b. c.i.f.	dollars/tonne dollars/tonne	567 580	472 484
Naphtha	f.o.b. c.i.f.	dollars/tonne dollars/tonne	544 557	453 464
LPG	f.o.b. c.i.f.	dollars/tonne dollars/tonne	554 873	462 728

HSD – high speed diesel; ATF – aviation turbine fuel; LPG – liquefied petroleum gas;
f.o.b. – freight on-board; c.i.f. – cost insurance freight; bbl – barrel

Table 3.82 presents prices of natural gas considered in this study.

Table 3.82 Prices of natural gas

	Current price ((dollars/ MMBTU)	**Current price deflated to 2001** (dollars/ MMBTU)
Domestic natural gas	3.210	2.68
Import of natural gas by pipelines	3.515	2.93
LNG import by terminal	4.100	3.42

LNG import by terminal 4.100 3.42 LNG – liquefied natural gas; MMBTU – million British thermal unit

3.4.8 Business-as-usual scenario

This scenario is characterized as the most likely path of development in the absence of any major intervention. This scenario incorporates existing government plans and policies. In the BAU, an 8% GDP growth rate (uniform growth rate over the entire modeling time frame, 2001–31) reflects the Government of India's expectations as highlighted in various government policy documents.

With regard to technology penetration in the power sector, limited deployment of clean coal technologies is assumed. The penetration of various renewable energy technologies is considered as per the existing trend and expert opinion. The nuclear-energy- based power generation capacity is constrained to the extent of 21.18 GW (gigawatts) from 2021 onwards in view of the non-availability of indigenous nuclear fuel and import restrictions. The capacity realization of large hydroelectric plants to a maximum level of 150 GW is assumed as per the expectations of the Government of India. Autonomous efficiency improvements are built as per the current technological diffusion in both conversion and end-use sectors.

3.4.8.1 Low-growth scenario

Low-growth scenario assumes a low GDP growth rate of 6.7% relative to the 8% GDP growth rate assumed in the BAU scenario. Thus, the impact of projected GDP growth rates on the future trajectories of energy demand is captured by this scenario.

All other underlying assumptions with respect to resource availability, technology progression, and other parameters are similar to those in the BAU scenario.

3.4.8.2 High-growth scenario

High-growth scenario assumes a very high GDP growth rate of 10% (uniform over the modeling time frame, 2001–31) relative to the GDP growth rate of 8% assumed in the BAU scenario. This scenario paints an optimistic picture of the Indian economy and envisages the ensuing influence a growth rate of such magnitude would have on overall energy consumption in the country.

3.4.8.3 High-efficiency scenario

High-efficiency scenario takes into account the energy efficiency measures spanning across all sectors. On the supply side, advanced gas-based power generation (for example, the H-frame combined-cycle gas turbine) with 60% efficiency is assumed to be commercially available by 2016/17.

The availability factor of wind power plants is assumed to increase from 17.5% in 2001 to 26% in the year 2011 and 35% in 2016 and onwards as compared to the constant figure of 17.5% in the BAU scenario.

On the demand side, efficiency improvements, such as increased share of efficient electrical appliances used to meet the demands for space-conditioning, lighting, and refrigeration in residential and commercial sectors, are considered in various end-use sectors In addition, this scenario also incorporates the faster rate of displacement of in ferior fuels like firewood and kerosene by clean fuels such as LPG (liquefied petroleum gas) vis-à-vis the BAU scenario for cooking in the residential and commercial sectors. Furthermore, energy-efficient measures in transport sectors in the form of policy interventions by the government – such as increased share of rail vis-à-vis road in passenger and freight movement, and promoting public transport – are also incorporated in this scenario.

(**Reference**: power sector, The Gazette of India No 23/40/2004-R & R (Vol. III) Part I Section I, Ministry of power, New Delhi

Power sector, Energy Map for India: Technology Vision, The Energy and Resources Institute, Office of the Principal Scientific Adviser, Government of India 2006, Publishers TERI Press The Energy and Resources Institute and Office of the Principal Scientific Adviser, Government of India)

(Nuclear Energy**,** Integrated Energy Policy, Planning Commission ,Government of India)

(Reference: Efficiencies and CO2 emissions of fossil power plants - Strategies and Technologies for greenhouse gas mitigation - N.K. Bansal)

3.4.4.5 Renewable energy sources

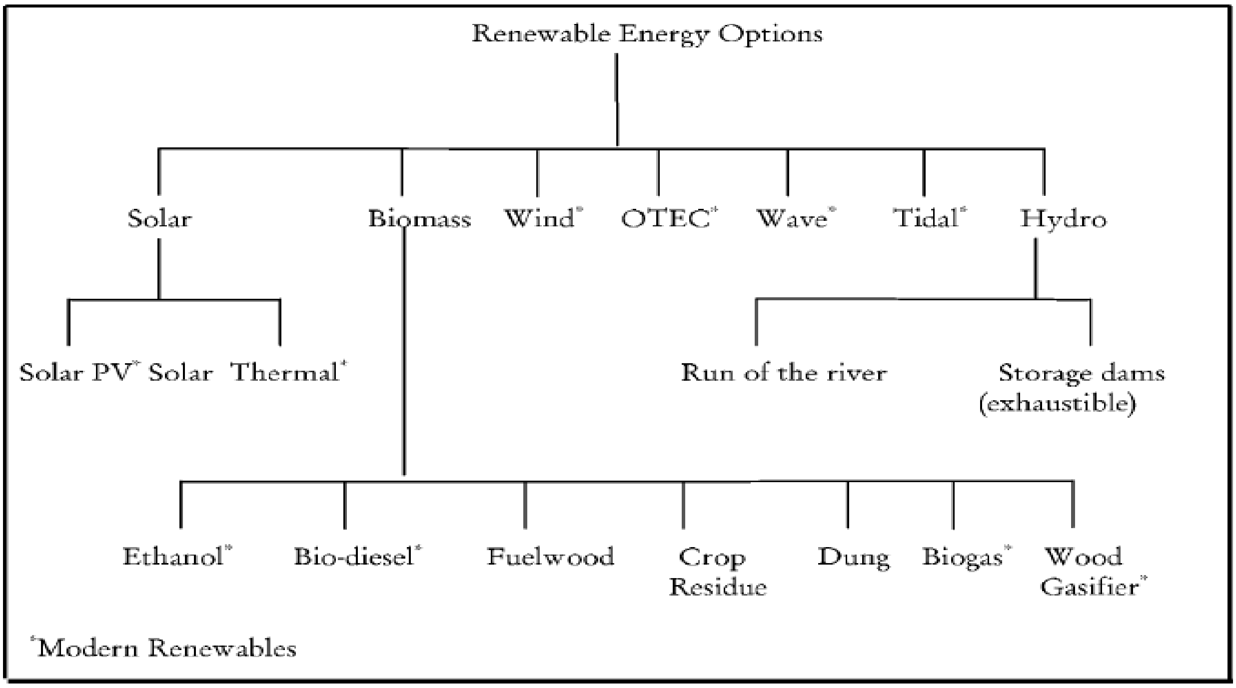
3.4.4.5.1 Introduction

Feasible potential of non-conventional energy resources, mainly small hydro, wind and bio-mass would also need to be exploited fully to create additional power generation capacity. With a view to increase the overall share of non-conventional energy sources in the electricity mix, efforts will be made to encourage private sector participation through suitable promotional measures.

Below Figure 3.17 shows a listing of some of the commonly used renewable options.

Figure 3.17

Renewable Energy Options



Many renewables have high initial costs. Often development efforts have been sub-critical and subsidy driven growth has not provided incentives for technical improvements or cost reduction. There are also externalities of the use of renewables, the benefits of which do not accrue to the user.

Table 3.83 Capital Costs and the Typical Cost of Generated Electricity from the Renewable Options

Sl. No	Source	Capital Cost (Crores of Rs/MW)	Estimated Cost of Generation Per Unit {Rs,/kWh}	Total Installed Capacity (MW) (upto 51,12.2005)
1.	Small* Hydro-Power	5.00-6.00	2.50-3.50	1748
2.	Wind Power	4.00-5.00	3.004.00	4434
3.	Bio mass Power	4.00	3.00-4.00	377
4.	Bagasse Gogenc ration	3.00-3.50	2,00-3.00	491
5.	Biomass Gasifier	2.50-3.00	3.00-4.00	71
6.	Solar Photovoltaic	25-30	15.00-20.00	3
7.	Energy from Waste	5.00-10.00	4.00-7.50	46

*<25 MW

India’s renewable energy resources are summarised in the below Table 3.84. It may be noted that many renewables require land. The potential energy generated is assessed independently for each option. If all such options are developed together the combined potential may be less than the sum due to a paucity of available land for energy generation as other competing land uses may dominate.

Table 3.84

3.4.4.5.1.1 Renewable energy scenario

In this scenario, high penetration of renewable energy is considered. About 4233 potential sites are identified for small hydro power plants in the country. The corresponding capacity is worked out at about 10 GW (MNES 2005a). It is assumed that the maximum identified potential could be tapped by 2016.

3.4.4.5.1.2Cogeneration and Non-Conventional Energy Sources

Non-conventional sources of energy being the most environment friendly there is an urgent need to promote generation of electricity based on such sources of energy. For this purpose, efforts need to be made to reduce the capital cost of projects based on non-conventional and renewable sources of energy. Cost of energy can also be reduced by promoting competition within such projects. At the same time, adequate promotional measures would also have to be taken for development of technologies and a sustained growth of these sources.

The Electricity Act 2003 provides that co-generation and generation of electricity from non-conventional sources would be promoted by the SERCs by providing suitable measures for connectivity with grid and sale of electricity to any person and also by specifying, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution licensee. Such percentage for purchase of power from non-conventional sources should be made applicable for the tariffs to be determined by the SERCs at the earliest. Progressively the share of electricity from non-conventional sources would need to be increased as prescribed by State Electricity Regulatory Commissions. Such purchase by distribution companies shall be through competitive bidding process. Considering the fact that it will take some time before non-conventional technologies compete, in terms of cost, with conventional sources, the Commission may determine an appropriate differential in prices to promote these technologies.

Industries in which both process heat and electricity are needed are well suited for cogeneration of electricity. A significant potential for cogeneration exists in the country, particularly in the sugar industry. SERCs may promote arrangements between the co-generator and the concerned distribution licensee for purchase of surplus power from such plants. Cogeneration system also needs to be encouraged in the overall interest of energy efficiency and also grid stability.

India is endowed with abundant natural and renewable sources of energy like sun, wind, and biomass. The country has been able to achieve significant capacity addition of 1367 MW through wind farms and ranks fifth in the world after Germany, USA, Spain, and Denmark in the generation of wind energy, as per 2004/05 data. The available renewable resources need to be exploited by giving a commercial orientation wherever possible. It may be necessary to continue with subsidies in the case of socially oriented programmes to meet the energy requirements of rural areas, particularly, remote villages, which may be difficult to service through the conventional power grid in the near future. Table 3.72 gives the available potential and the actual potential exploited till August 2001 for various renewable sources of energy as provided by the MNES (Ministry of Non-conventional Energy Sources).

Apart from these resources, the country has significant potential for ocean thermal power, sea wave power, and tidal power, which at this point of time are not expected to be realized due to high cost.

Renewable natural sources, such as biomass, wind, water, and solar energy, have been included in the model. The RETs (renewable energy technologies) are environmentally sustainable and have a vast potential that can be exploited for energy generation in the future.

3.4.4.5.2 Wind energy

Wind-based generation capacity has been rapidly growing in India. The installed wind power capacity increased from 40 MW at the beginning of the Eighth Plan to 992 MW in December 1998 (MNES 2004). The potential of wind farms is estimated at 28 910 MW or 1038 TWh (terawatt-hours) (TERI 1995). Currently, it is claimed that Indian wind farms deliver a capacity factor of about 17% on average. As a first level of approximation, this permits agrid-connected wind capacity estimate of as much as 20,000 MW at the current size of India's grid. The actual grid connected wind capacity, however, is only about 3,600 MW. This reflects both a poor exploitation of claimed potential and, perhaps, the exaggerated claims of capacity factors. Even if one goes by a wind potential of 65,000 MW (as estimated by the Wind Power Society) inclusive of off-shore potential and further assumes that technological innovations will raise capacity factors to 20%, the total contribution of wind energy to India's energy mix will remain below 10 Mtoe. Despite this, wind power, especially at the lagging ends of the grid, provides several benefits and should be pursued wherever it is viable.

Table 3.85 Renewable energy source potential

Source/technology	*Unit*	*Potential/ availability*	*Potential exploited*
Biogas plants	Million	12	3.22
Biomass-based power	MW	19 500	384.00
Efficient wood stoves	Million	120	33.86
Solar energy	MW/km²	20	1.74
Small hydro	MW	15 000	1398.00
Wind energy	MW	45 000	1367.00
Energy recovery from wastes	MW	1700	16.20

MW – megawatts; sq km – square kilometres

3.4.4.5.2.1 Wind energy scenario

Similarly, for wind power generation in India, gross potential is estimated at 49 GW (MNES 2005a). However, the technically feasible potential is reported at 13 GW (MNES 2005a). In the REN scenario, it is assumed that 12 GW of wind capacity could be created by 2036. In this scenario, in addition to the increase in the capacity of wind-based power generation, the availability factor of wind power plants is also assumed to increase from 17.5% in 2001 to 26% in the year 2011 and 35% 2016 onwards.

Table 3.86 present the level of the installed capacity of wind-based power generation.

Lower bound on installed capacity of wind turbine in (GW)										
Scenario	**2001/02**	**2006/07**	**2011/12**	**2015**	**2016/17**	**2021/22**	**2026/27**	**2030**	**2031/32**	**2050**
BAU	1.63	4.23	4.23		4.23	4.23	4.23		4.23	
NUC	1.63	5.00	7.00		8.00	9.00	10.00		11.00	

GW – gigawatts; BAU – business-as-usual; REN – aggressive renewable energy

3.4.4.5.3 Solar energy

Apart from using solar energy for the generation of grid-based power, decentralized solar devices are also included in the model. PV (photovoltaic) systems have emerged as useful power sources for applications such as lighting, water pumping, telecommunications, and power for meeting the requirements of villages, hospitals, lodges, and so on. Based on the reports from the state implementing agencies, 15 206 home-lighting systems, 20 484 solar lanterns, and 437 street lighting systems were installed in 1997/98.

3.4.4.5.3.1 Solar energy scenario

India is blessed with abundant sunshine as most parts of the country have 230–300 sunny days in a year. Average daily solar radiation incident over the land area is in the range of 4–7 kWh/m2 (kilowatt hours per square metre). The potential of SPV (solar photovoltaic) power in India is estimated at 20 MW/km2 (megawatts per square kilometre) (MNES 2005a). The current cost of an SPV cell is 150 rupees/ Wp (watt peak) (MNES 2005b). Because of the high cost of solar cells, the cost of electricity generation from SPV is also very high. For example, the cost of electricity generation from a grid-interactive SPV system without storage is estimated at 20 rupees/kWh (MNES 2005b). For stand-alone systems, the cost of generation is higher due to the additional cost of the battery. However, the *National new and renewable energy policy statement 2005* of the Ministry of Non-conventional Energy Sources reports that the cost of generation is expected to reduce to the level of 4 rupees/ kWh by 2021/22 (MNES 2005b). Because of high capital costs, the current installed capacity of the SPV system is only 2.25 MW (GoI 2005). However, SPV production in the country is increasing by an annual average growth rate of 25%. It is assumed that the installed capacity of an SPV-based power plant will increase up to 20 GW in 2036 in the REN scenario.

Table 3.87 Installed capacity of SPV in aggressive renewable energy scenario

Lower bound on installed capacity										
	2001/02	**2006/07**	**2011/12**	**2015**	**2016/17**	**2021/22**	**2026/27**	**2030**	**2031/32**	**2050**
SPV(GW_P)	0.00	0.05	0.14		0.39	1.04	2.78		7.46	

SPV – solar photovoltaic

3.4.4.5.4 Hydroelectric potential

Hydroelectricity is a clean and renewable source of energy. Maximum emphasis would be laid on the full development of the feasible hydro potential in the country. The 50,000 MW hydro initiatives have been already launched and is being vigorously pursued with DPRs for projects of 33,000 MW capacity already under preparation.

Harnessing hydro potential speedily will also facilitate economic development of States, particularly North-Eastern States, Sikkim, Uttaranchal, Himachal Pradesh and J&K, since a large proportion of our hydro power potential is located in these States. The States with hydro potential need to focus on the full development of these potentials at the earliest.

Hydel projects call for comparatively larger capital investment. Therefore, debt financing of longer tenure would need to be made available for hydro projects. Central Government is committed to policies that ensure financing of viable hydro projects.

State Governments need to review procedures for land acquisition, and other approvals/clearances for speedy implementation of hydroelectric projects.

The Central Government will support the State Governments for expeditious development of their hydroelectric projects by offering services of Central Public Sector Undertakings like National Hydroelectric Power Corporation (NHPC).

Proper implementation of National Policy on Rehabilitation and Resettlement (R&R) would be essential in this regard so as to ensure that the concerns of project-affected families are addressed adequately.

Adequate safeguards for environmental protection with suitable mechanism for monitoring of implementation of Environmental Action Plan and R&R Schemes will be put in place.

India is endowed with economically viable hydro potential. The CEA (Central Electricity Authority) has assessed India's hydro power potential to be about 148 700 MW of installed capacity. The hydroelectric capacity currently under operation is about 26 000 MW and 16 083 MW capacity is under various stages of development. The CEA has also identified 56 sites for pumped storage schemes with an estimated aggregate installed capacity of 94 000 MW. In addition, a potential of 15 000 MW in terms of installed capacity is estimated from small, mini, and micro hydel schemes.

It may be noted that due to lower cost of per unit power generation by large hydro, this option is introduced into the model as an upper bound over the modelling time frame as shown in Table 3.100. Hydro capacity Utilization is assumed to be 32%.

3.4.4.5.4 .1 Small hydel

The total potential for small hydro power up to 3 MW in India has been estimated at about 10 000 MW (MNES 2004/05). The installed capacity of units less than 3 MW was 170 MW in 1997 while an additional 191 MW capacity was under construction. Their installed capacity as on 31 March 1998 was 155 MW. The MNES has identified the potential for small hydel sites of up to 3 MW as 2852 MW and for sites between 3 and 15 MW as 5519 MW (MNES 1999).

3.4.4.5.5 Biomass gasifiers

Biomass is the major domestic fuel used for cooking, and consists mainly of agricultural by-products and gathered wood. Along with dung cakes which provided 30 Mtoe, biomass based fuels provide 81% of domestic energy. Biomass is also used as industrial fuel by small industries in the unorganized sector and by cottage industries. Inclusive of such use biomass along with dung cakes accounts for almost a third of India's total primary energy consumption. This non-commercial energy for the domestic use is essentially managed by women without technology, or investment, and involves unsustainable practices, backbreaking drudgery, health problems especially for women and the girl child and likely environmental damage.

Decentralized biomass-based power plants are ideal in cases where it is either too costly to extend the grid or the power demand is very low. Biomass is produced by numerous small agro-processing industries such as cigarette factories, cashew-processing units, and ayurvedic medicine manufacturing units. The main problem is of collecting and transporting the biomass to places where it may be required.

The biomass yield is estimated at 35 tonnes/hectare/year, and biomass consumption is 1.2 kg/kWh, assuming a PLF of 60% for biogas plants.

Due to the poor quality and unreliability of the grid, industries in many states are forced to switch over to diesel-based captive power generation. The low cost of procuring biomass makes it desirable to couple these gensets with gasifiers. Dual-fuel (gasifier and diesel) electric power generators, therefore, offer a great potential for fuel saving and decentralized power generation.

Till 1998, more than 1000 wood gasifiers have been installed in the country with a generating capacity of 14 MW. A 0.5-MW grid-connected gasifier-based R&D project was also commissioned in 1997.

Biomass can be used as a primary fuel by direct combustion or as a secondary fuel (solid, liquid, and gaseous) by conversion a biological or thermo chemical using process. The main aim of the conversion process is to increase efficiency of utilization for various end-uses. Biomass gasification is basically the conversion of solid biomass into a producer gas, which has carbon monoxide as a combustible gas. Several institutes including TERI are engaged in the R&D of gasifier technology in India. The potential for biomass- based power plants has been estimated to be 16 GW, of which 234 MW has been established so far, and a target of installation of 250 MW of biomass-based power is set for the Tenth Five Year Plan (2002–07). presents the lower bound on the installed capacity of and biomass-based power generation in the REN scenario.

Table 3.88 Installed capacity of biomass-based power generation in aggressive renewable energy scenario

	Lower bound on installed capacity									
	2001/02	**2006/07**	**2011/12**	**2015**	**2016/17**	**2021/22**	**2026/27**	**2030**	**2031/32**	**2050**
Biomass(GW)	0.00	0.25	0.50		1.00	2.00	4.00		8.00	

GW – gigawatts; GWp – gigawatt peak

3.4.4.5.5.1 Biomass consumption

The MNES has already implemented three major BCPPs (biomass-consumption-based power projects). A 6-MW prosopis-based project was set up in the state of Andhra Pradesh in June 1999 and a 5-MW ricehusk- based project in Madhya Pradesh was commissioned in August 1999. A 12-MW cane trash and bagasse-based private sector project, supported by IREDA (Indian Renewable Energy Development Agency), came up in Tamil Nadu.

During 1994–97, 18 BCPPs with a total capacity of 69 MW were installed for supplying power to the grid. So far, over 100 million units of electricity have been fed to the grid from these plants. Seventeen projects aggregating 97 MW are under implementation and once these are commissioned, more than 800 million units will be fed to the grids every year, saving 0.5 MT of coal.

3.4.4.5.5.2 Cogeneration potential from bagasse

The biomass waste generated from the sugar industry has a large potential for generating power. Although the total installed capacity as on 31 March 1998 is only 82 MW, it has been estimated that nearly 3500 MW of power can be generated from this industry if the existing sugar mills adopt modern techniques of cogeneration. High capital investment costs and lack of proper mechanisms for pricing and wheeling of power exported by the co generating industries are the main obstacles to the development of this technology at this stage.

3.4.4.5.6 Biogas

India has a 40 year old biogas programme. The total number of family size biogas plants installed is 3.7 million, though evaluation studies show that only half of these are in use. Community based plants can process dung from households with less than the 3-5 animals that are required for a family sized plant and can also use any excess gas available from family sized plants. Managing acommunity sized plant in an incentive compatible way that ensures voluntary cooperation of all stakeholders is admittedly challenging but is very much possible and worth pursuing (Parikh and Parikh, 1977)3.

3.4.4.5.7 Bio-diesel

It is a natural diesel substitute. While bio-diesel from non-edible oils such as Jatropha, Karanj, Mahua etc., has attracted lot of attention recently, its economic feasibility depends largely on the yields one can get from wasteland and/or the returns one can get from good quality land with irrigation and fertilizer use compared to returns from growing other crops. A number of projects being undertaken now will provide an assessment of these comparative returns in a few years. Bio-diesel also provides decentralised local fuel, which can be used directly without esterification in stationery engines. The process of bio-diesel generation and use can also create significant employment. These benefits should be factored in while assessing the desirability of bio-diesel when the data on land productivity are available.

3.4.4.5.8 Hydrogen

Hydrogen is seen as the new energy carrier. Development of Hydrogen technology is being pursued in many countries. India has also set up a Hydrogen Development Board to promote development of technologies for producing, transporting, storing and distributing hydrogen as well as to explore the field of fuel cells for efficient end-use of hydrogen. Hydrogen can also be burnt directly in internal combustion engines. It can be produced from hydrocarbons and biomass, by splitting water with the use of solar, hydro, wind or nuclear energy, and through certain microbial processes. The overall efficiency of the hydrogen cycle, however, remains in doubt. Hydrogen production, liquefaction or compression, transportation, storage and final dispensation, all entail huge amount of energy consumption and loss. Significant barriers relating to financial and technological viability remain in the widespread use of hydrogen in automotive or stationary applications. Metal hydrides that store hydrogen and release it for direct combustion have been developed for powering two/three-wheelers in the country but the technology has not yet been commercialised. Stationary applications or automotive applications using fuel cells are still relatively uncompetitive.

3.4.4.5.9 Power generation technologies: techno-economic input parameters

Table 3.89 provides the characteristics of all the power-generating technologies input to the model.

Table 3.89 Power-generating technologies

Technology	Availability Factor	Plant characteristics		Capital cost (million rupees / GW)	Annual operation and maintenance cost (million rupees / GW)	Life (Years)	Efficiency (%)
Coal fired plant – old (before 1980)	0.58	Base load	Centralized	Sunk costs	988	10	22.7

Coal – fired plant – old (after	0.58	Base load	Centralized	Sunk costs	988	30	29.5
New coal plant (sub-critical	0.85	Base load	Centralized	39.547	988	30	32.3
Retrofit coal plant (first built before (1980)	0.85	Base load	Centralized	15.000	988	30	30.0
Retrofit coal plant (1980-2000)	0.85	Base load	Centralized	12.500	850	30	32.2
CFBC	0.85	Base load	Centralized	45.653	1141	30	39.0
IGCC (Refinery)	0.85	Base load	Centralized	52.753	1141	30	46.0
IGCC (coal)	0.85	Base load	Centralized	52.753	1141	30	44.0
Coal supercritical	0.85	Base load	Centralized	42.600	1065	30	37.7
Coal pressurized bed combustion	0.85	Base load	Centralized	45.653	1141	30	43.0
Coal ultra-supercritical	0.85	Base load	Centralized	51.120	1331	30	44.0
Lignite Power Plant (existing subcritical tech)	0.58	Base load	Centralized	40.000	988	30	29.5
Small generator set (2 kW)	0.20	Base load	Decentralized	27.000	712.5	10	25.0
Existing open cycle gas based	0.90	Standard	Centralized	Sunk costs	520	20	26.0
Existing combined cycle gas based plant	0.90	Base load	Centralized	Sunk costs	399	25	34.1
New open cycle gas based plant	0.90	Standard	Centralized	15.975	240	20	39.0
NGCC (New)	0.90	Base load	Centralized	22.000	330	25	53.8
NGCC (New high efficiency)	0.90	Base load	Centralized	27.000	405	25	60.0
Hydro reservoir – new	Fixed capacity	Standard	Centralized	40.000	600	50	32.3
Small hydro – grid connected	Fixed capacity	Standard	Centralized	90.000	1350	40	32.3
Heavy water reactor 1 (using natural gas uranium)	0.90	Base load	Centralized	60.000	1500	25	21.4
Light water reactor 1 (using enriched uranium)	0.90	Base load	Decentralized	78.750	1969	25	17.0
Decentralized electricity from fuelwood	0.90	Standard	Decentralized	27.000	713	15	21.7
Solar photovoltaic with battery bank	0.29	Standard	Decentralized	300.000	4500	25	
Solar photovoltaic without battery bank	0.29	Standard	Decentralized	200.000	1000	25	
Grid interactive solar photovoltaic power	Fixed capacity	Standard	Centralized	250.000	1250	25	
Wind turbines	Fixed capacity	Standard	Centralized	38.000	570	20	

CFBC – circulating fluidized bed combustion; IGCC – integrating gasification combined cycle; NGCC natural gas combined cycle; Rs/GW – rupees/ gigawatts; kW – kilowatt

3.4.4.5.9.1Technology forecast till 2030

Stress is mainly on renovation and modification or performance improvement of old power plants to get higher output/PLF from them.

The technology for natural gas-/naphtha fired combined cycle plants will also not undergo much change except that plants with Tech. FA will be introduced at few sites.

The period 2007–12 will see the commissioning of the first thermal plant with supercritical steam parameters, and also setting up of a 100-MW coal-based IGCC plant. This period may also see the introduction of the first combined cycle plant based on gas turbine with Tech. H. Based on the experience gained from the introduction of these new technologies, more plants will come up in the subsequent plan period of 2012–17. During this period, the first commercial IGCC technology will come up.

This will also set up the trend for the refinery rejects—vistar- and petcoke-fired IGCC plants.

During 2017–22, the first coal-fired power plant with ultra-supercritical steam parameters is also likely to come up. This will be followed by the introduction of this technology fully. Then, till 2030, no new technology will be introduced. However, further improvement in steam temperature may be witnessed. This will mainly depend upon the development of high-temperature metallic alloys internationally.

During 2022–27, a demonstration plant for the generation of power using natural gas- based solid oxide fuel cell technology may come up, and the first commercial plant based on this technology will then come up during 2027–32. During this decade, new coal-based plants will be based on ultra supercritical steam parameters.

3.4.4.6.0 Transmission and Distribution

3.4.4.6.0.1 Transmission

The Transmission System requires adequate and timely investments and also efficient and coordinated action to develop a robust and integrated power system for the country.

Keeping in view the massive increase planned in generation and also for development of power market, there is need for adequately augmenting transmission capacity. While planning new generation capacities, requirement of associated transmission capacity would need to be worked out simultaneously in order to avoid mismatch between generation capacity and transmission facilities. The policy emphasizes the following to meet the above objective:

- The Central Government would facilitate the continued development of the National Grid for providing adequate infrastructure for inter-state transmission of power and to ensure that underutilized generation capacity is facilitated to generate electricity for its transmission from surplus regions to deficit regions.
- The Central Transmission Utility (CTU) and State Transmission Utility (STU) have the key responsibility of network planning and development based on the National Electricity Plan in coordination with all concerned agencies as provided in the Act. The CTU is responsible for the national and regional transmission system planning and development. The STU is responsible for planning and development of the intra-state transmission system. The CTU would need to coordinate with the STUs for achievement of the shared objective of eliminating transmission constraints in cost effective manner.
- Network expansion should be planned and implemented keeping in view the anticipated transmission needs that would be incident on the system in the open access regime. Prior agreement with the beneficiaries would not be a pre-condition for network expansion.

CTU/STU should undertake network expansion after identifying the requirements in consultation with stakeholders and taking up the execution after due regulatory approvals.

- Structured information dissemination and disclosure procedures should be developed by the CTU and STUs to ensure that all stakeholders are aware of the status of generation and transmission projects and plans. These should form a part of the overall planning procedures.
- The State Regulatory Commissions who have not yet notified the grid code under the Electricity Act 2003 should notify the same not later than September 2005.

Open access in transmission has been introduced to promote competition amongst the generating companies who can now sell to different distribution licensees across the country. This should lead to availability of cheaper power. The Act mandates non-discriminatory open access in transmission from the very beginning. When open access to distribution networks is introduced by the respective State Commissions for enabling bulk consumers to buy directly from competing generators, competition in the market would increase the availability of cheaper and reliable power supply. The Regulatory Commissions need to provide facilitative framework for non-discriminatory open access. This requires load dispatch facilities with state-of-the art communication and data acquisition capability on a real time basis. While this is the case currently at the regional load dispatch centers, appropriate State Commissions must ensure that matching facilities with technology upgrades are provided at the State level, where necessary and realized not later than June 2006.

The Act prohibits the State transmission utilities/transmission licensees from engaging in trading in electricity. Power purchase agreements (PPAs) with the generating companies would need to be suitably assigned to the Distribution Companies, subject to mutual agreement. To the extent necessary, such assignments can be done in a manner to take care of different load profiles of the Distribution Companies. Non-discriminatory open access shall be provided to competing generators supplying power to licensees upon payment of transmission charge to be determined by the appropriate Commission. The appropriate Commissions shall establish such transmission charges no later than June 2005.

To facilitate orderly growth and development of the power sector and also for secure and reliable operation of the grid, adequate margins in transmission system should be created. The transmission capacity would be planned and built to cater to both the redundancy levels and margins keeping in view international standards and practices. A well planned and strong transmission system will ensure not only optimal utilization of transmission capacities but also of generation facilities and would facilitate achieving ultimate objective of cost effective delivery of power. To facilitate cost effective transmission of power across the region, a national transmission tariff framework needs to be implemented by CERC. The tariff mechanism would be sensitive to distance, direction and related to quantum of flow. As far as possible, consistency needs to be maintained in transmission pricing framework in inter-State and intra-State systems. Further it should be ensured that the present network deficiencies do not result in unreasonable transmission loss compensation requirements.

The necessary regulatory framework for providing non-discriminatory open access in transmission as mandated in the Electricity Act 2003 is essential for signalling efficient choice in locating generation capacity and for encouraging trading in electricity for optimum utilization of generation resources and consequently for reducing the cost of supply.

The spirit of the provisions of the Act is to ensure independent system operation through NLDC, RLDCs and SLDCs. These dispatch centers, as per the provisions of the Act, are to be operated by a Government company or authority as notified by the appropriate Government. However, till such time these agencies/authorities are established the Act mandates that the CTU or STU, as the case may be, shall operate the RLDCs or SLDC. The arrangement of CTU operating the RLDCs would be reviewed by the Central Government based on experience of working with the existing arrangement. A view on this aspect would be taken by the Central Government by December 2005.

The Regional Power Committees as envisaged in section section 2(55) would be constituted by the Government of India within two months with representation from various stakeholders.

The National Load Despatch Centre (NLDC) along with its constitution and functions as envisaged in Section 26 of the Electricity Act 2003 would be notified within three months. RLDCs and NLDC will have complete responsibility and commensurate authority for smooth operation of the grid irrespective of the ownership of the transmission system, be it under CPSUs, State Utility or private sector.

Special mechanisms would be created to encourage private investment in transmission sector so that sufficient investments are made for achieving the objective of demand to be fully met by 2012.

3.4.4.6.0.2 Distribution

Distribution is the most critical segment of the electricity business chain. The real challenge of reforms in the power sector lies in efficient management of the distribution sector.

The Act provides for a robust regulatory framework for distribution licensees to safeguard consumer interests. It also creates a competitive framework for the distribution business, offering options to consumers, through the concepts of open access and multiple licensees in the same area of supply.

For achieving efficiency gains proper restructuring of distribution utilities is essential. Adequate transition financing support would also be necessary for these utilities. Such support should be arranged linked to attainment of predetermined efficiency improvements and reduction in cash losses and putting in place appropriate governance structure for insulating the service providers from extraneous interference while at the same time ensuring transparency and accountability. For ensuring financial viability and sustainability, State Governments would need to restructure the liabilities of the State Electricity Boards to ensure that the successor companies are not burdened with past liabilities. The Central Government would also assist the States, which develop a clear roadmap for turnaround, in arranging transition financing from various sources which shall be linked to predetermined improvements and efficiency gains aimed at attaining financial viability and also putting in place appropriate governance structures.

Conducive business environment in terms of adequate returns and suitable transitional model with predetermined improvements in efficiency parameters in distribution business would be necessary for facilitating funding and attracting investments in distribution. Multi-Year Tariff (MYT) framework is an important structural incentive to minimize risks for utilities and consumers, promote efficiency and rapid reduction of system losses. It would serve public interest through economic efficiency and improved service quality. It would also bring greater predictability to consumer tariffs by restricting tariff adjustments to known indicators such as power purchase prices and inflation indices. Private sector participation in distribution needs to be encouraged for achieving the requisite reduction in transmission and distribution losses and improving the quality of service to the consumers.

The Electricity Act 2003 enables competing generating companies and trading licensees, besides the area distribution licensees, to sell electricity to consumers when open access in distribution is introduced by the State Electricity Regulatory Commissions. As required by the Act, the SERCs shall notify regulations by June 2005 that would enable open access to distribution networks in terms of sub-section 2 of section 42 which stipulates that such open access would be allowed, not later than five years from 27th January 2004 to consumers who require a supply of electricity where the maximum power to be made available at any time exceeds one mega watt. Section 49 of the Act provides that such consumers who have been allowed open access under section 42 may enter into agreement with any person for supply of electricity on such terms and conditions, including tariff, as may be agreed upon by them. While making regulations for open access in distribution, the SERCs will also determine wheeling charges and cross-subsidy surcharge as required under section 42 of the Act.

A time-bound programme should be drawn up by the State Electricity Regulatory Commissions (SERC) for segregation of technical and commercial losses through energy audits. Energy accounting and declaration of its results in each defined unit, as determined by SERCs, should be mandatory not later than March 2007. An action plan for reduction of the losses with adequate investments and suitable improvements in governance should be drawn up. Standards for reliability and quality of supply as well as for loss levels shall also be specified, from time to time, so as to bring these in line with international practices by year 2012.

One of the key provisions of the Act on competition in distribution is the concept of multiple licensees in the same area of supply through their independent distribution systems. State Governments have full flexibility in carving out distribution zones while restructuring the Government utilities. For grant of second and subsequent distribution licence within the area of an incumbent distribution licensee, a revenue district, a Municipal Council for a smaller urban area or a Municipal Corporation for a larger urban area as defined in the Article 243(Q) of Constitution of India (74th Amendment) may be considered as the minimum area. The Government of India would notify within three months, the requirements for compliance by applicant for second and subsequent distribution licence as envisaged in Section 14 of the Act. With a view to provide benefits of competition to all section of consumers, the second and subsequent licensee for distribution in the same area shall have obligation to supply to all consumers in accordance with provisions of section 43 of the Electricity Act 2003. The SERCs are required to regulate the tariff including connection charges to be recovered by a distribution licensee under the provisions of the Act. This will ensure that second distribution licensee does not resort to cherry picking by demanding unreasonable connection charges from consumers.

The Act mandates supply of electricity through a correct meter within a stipulated period. The Authority should develop regulations as required under Section 55 of the Act within three months.

The Act requires all consumers to be metered within two years. The SERCs may obtain from the Distribution Licensees their metering plans, approve these, and monitor the same. The SERCs should encourage use of pre-paid meters. In the first instance, TOD meters for large consumers with a minimum load of one MVA are also to be encouraged. The SERCs should also put in place independent third-party meter testing arrangements.

Modern information technology systems may be implemented by the utilities on a priority basis, after considering cost and benefits, to facilitate creation of network information and customer data base which will help in management of load, improvement in quality, detection of theft and tampering, customer information and prompt and correct billing and collection . Special emphasis should be placed on consumer indexing and mapping in a time bound manner. Support is being provided for information technology based systems under the Accelerated Power Development and Reforms Programme (APDRP).

SCADA and data management systems are useful for efficient working of Distribution Systems. A time bound programme for implementation of SCADA and data management system should be obtained from Distribution Licensees and approved by the SERCs keeping in view the techno economic considerations. Efforts should be made to install substation automation equipment in a phased manner.

The Act has provided for stringent measures against theft of electricity. The States and distribution utilities should ensure effective implementation of these provisions. The State Governments may set up Special Courts as envisaged in Section 153 of the Act.

3.4.4.6.1 Technology and environment policy

Coal is the primary fuel for thermal power generation in India. In the process, it gives rise to atmospheric pollution due to particulate matter, SOx, NOx, and CO2. The use of natural gas for power generation is picking up, the advantages being no particulate matter pollution and reduced CO2 emission per kWh of power generated. The present environment policy defines primarily for particulate matter control, but gives no strict conformance standards for other gaseous pollutants like SOx, NOx, and CO2 (except a gazette notification of the Ministry of Environment and Forests stipulating NOx emissions for gas turbines).

The higher chimney height may disperse SOx and NOx in low concentrations over larger area, but does not reduce/ eliminate their effects. Besides, the international

Table 3.90 Cost comparison of different IGCC technologies (1989 pricing)

Table 3.90 Cost comparison of different IGCC technologies (1989 pricing)

	IGCC plant			PC Plant	
	Entrained bed	Fluidized bed	Moving bed	Without FGD	With FGD
Net Power output (MW)	564.40	496.20	577.20	585.70	549.00
Capital cost ratio	2.17	1.33	1.36	1.00	1.22
Cost of generation ratio	1.94	1.18	1.32	1.00	1.17

MW – megawatts; IGCC – Integrated gasification combined cycle; PC – Pulverized coal; FGD – Flue gas desulphurization

Table 3.91 Achievements in renewable energy sources

Programme	Unit	Achievement
Wind Energy		
Wind farms	MW	733
Wind Pumps	Nos.	3,158
Small hydro		
Mini micro	MW	129
Bio – energy		
Biomass – based cogeneration	MW	29
Biomass combustion power	MW	14
Biomass gasifiers/ Stirling engines	MW	30
Family – sized biogas plants	Nos.	2.3×10^6
Community biogas plants	Nos.	1,623
Improved cook stoves	Nos.	22.6×10^6
Solar Thermal		
Solar Thermal systems		
Collector area	M^2	364,354
Solar cookers	Nos.	406,642
Solar PV		
Power units	KWp	909
Community lights	Nos.	270
TV and community facilities	Nos.	640
Domestic lighting uses	Nos.	37,359
Lanterns	Nos.	81,059
Street lights	Nos.	32,870
Water pumps	Nos.	1,820
Sources : MNES, Government of India		

Recommendations

In order to fully meet both energy and peak demand by 2012, there is a need to create adequate reserve capacity margin. In addition to enhancing the overall availability of installed capacity to 85%, a spinning reserve of at least 5%, at national level, would need to be created to ensure grid security and quality and reliability of power supply.

One of the major achievements of the power sector has been a significant increase in availability and plant load factor of thermal power stations especially over the last few years. Renovation and modernization for achieving higher efficiency levels needs to be pursued vigorously and all existing generation capacity should be brought to minimum acceptable standards. The Govt. of India is providing financial support for this purpose.

For projects performing below acceptable standards, R&M should be undertaken as per well-defined plans featuring necessary cost-benefit analysis. If economic operation does not appear feasible through R&M, then there may be no alternative to closure of such plants as the last resort.

In cases of plants with poor O&M record and persisting operational problems, alternative strategies including change of management may need to be considered so as to improve the efficiency to acceptable levels of these power stations.

A large number of captive and standby generating stations in India have surplus capacity that could be supplied to the grid continuously or during certain time periods. These plants offer a sizeable and potentially competitive capacity that could be harnessed for meeting demand for power. Under the Act, captive generators have access to licensees and would get access to consumers who are allowed open access. Grid inter-connections for captive generators shall be facilitated as per section 30 of the Act. This should be done on priority basis to enable captive generation to become available as distributed generation along the grid. Towards this end, non-conventional energy sources including co-generation could also play a role. Appropriate commercial arrangements would need to be instituted between licensees and the captive generators for harnessing of spare capacity energy from captive power plants. The appropriate Regulatory Commission shall exercise regulatory oversight on such commercial arrangements between captive generators and licensees and determine tariffs when a licensee is the off-taker of power from captive plant

High Voltage Distribution System is an effective method for reduction of technical losses, prevention of theft, improved voltage profile and better consumer service. It should be promoted to reduce LT/HT ratio keeping in view the techno economic considerations.

Effective utilization of all available resources for generation, transmission and distribution of electricity using efficient and cost effective technologies is of paramount importance. Operations and management of vast and complex power systems require coordination among the multiple agencies involved. Effective control of power system at state, regional and national level can be achieved only through use of Information Technology. Application of IT has great potential in reducing technical & commercial losses in distribution and providing consumer friendly services. Integrated resource planning and demand side management would also require adopting state of the art technologies.

Role of private participation in generation, transmission and distribution would become increasingly critical in view of the rapidly growing investment needs of the sector. The Central Government and the State Governments need to develop workable and successful models for public private partnership. This would also enable leveraging private investment with the public sector finances. Mechanisms for continuous dialogue with industry for streamlining procedures for encouraging private participation in power sector need to be put in place.

Energy Conservation

There is a significant potential of energy savings through energy efficiency and demand side management measures. In order to minimize the overall requirement, energy conservation and demand side management (DSM) is being accorded high priority. The Energy Conservation Act has been enacted and the Bureau of Energy Efficiency has been setup.

The potential number of installations where demand side management and energy conservation measures are to be carried out is very large. Bureau of Energy Efficiency (BEE) shall initiate action in this regard. BEE would also make available the estimated conservation and DSM potential, its staged implementation along with cost estimates for consideration in the planning process for National Electricity Plan.

Periodic energy audits have been made compulsory for power intensive industries under the Energy Conservation Act. Other industries may also be encouraged to adopt energy audits and energy conservation measures. Energy conservation measures shall be adopted in all Government buildings for which saving potential has been estimated to be about 30% energy. Solar water heating systems and solar passive architecture can contribute significantly to this effort.

In the field of energy conservation initial approach would be voluntary and self-regulating with emphasis on labelling of appliances. Gradually as awareness increases, a more regulatory approach of setting standards would be followed.

In the agriculture sector, the pump sets and the water delivery system engineered for high efficiency would be promoted. In the industrial sector, energy efficient technologies should be used and energy audits carried out to indicate scope for energy conservation measures. Motors and drive system are the major source of high consumption in Agricultural and Industrial Sector. These need to be addressed. Energy efficient lighting technologies should also be adopted in industries, commercial and domestic establishments.

In order to reduce the requirements for capacity additions, the difference between electrical power demand during peak periods and off-peak periods would have to be reduced. Suitable load management techniques should be adopted for this purpose. Differential tariff structure for peak and off peak supply and metering arrangements (Time of Day metering) should be conducive to load management objectives. Regulatory Commissions should ensure adherence to energy efficiency standards by utilities.

For effective implementation of energy conservation measures, role of Energy Service Companies would be enlarged. Steps would be taken to encourage and incentivise emergence of such companies.

A national campaign for bringing about awareness about energy conservation would be essential to achieve efficient consumption of electricity.

A National Action Plan has been developed. Progress on all the proposed measures will be monitored with reference to the specific plans of action.

Environmental Issues

Environmental concerns would be suitably addressed through appropriate advance action by way of comprehensive Environmental Impact Assessment and implementation of Environment Action Plan (EAP).

Steps would be taken for coordinating the efforts for streamlining the procedures in regard to grant of environmental clearances including setting up of 'Land Bank' and 'Forest Bank'.

Appropriate catchment area treatment for hydro projects would also be ensured and monitored.

Setting up of coal washeries will be encouraged. Suitable steps would also be taken so that utilization of fly ash is ensured as per environmental guidelines.

Setting up of municipal solid waste energy projects in urban areas and recovery of energy from industrial effluents will also be encouraged with a view to reducing environmental pollution apart from generating additional energy.

Full compliance with prescribed environmental norms and standards must be achieved in operations of all generating plants.

All future coal-based thermal power plants of 250 MW and above should have supercritical steam parameters. Immediately, studies should also be initiated for ultra-supercritical steam parameters and the aim should be to establish these plants in next six to seven years.

CFBC (circulation fluidized bed combustion)- based plants of 250 MW, with high sulphur lignite and petcoke, and very high ash coal/washery rejects should be encouraged.

Environment (Protection) Amendment Rules, 1997, for using washed coal for the plants located beyond 1000 km should be enforced without giving further extension. This will definitely reduce the problems related to particulate emissions and fly ash disposal.

All the generating stations should be directed to examine the techno-economic feasibility of using blended coal in a mixture of high-ash and good quality coal from other mines in India or through import of coal. This can be easily established through generation efficiency (specific fuel consumption) tests on an operating station.

Benchmark for the introduction of IGCC technology in India should be seven to eight years. A decision for a 250–300- MW commercial demonstration plant should be taken up immediately.

Regular energy audit of operating plants for generation efficiency should be made mandatory, and the recommendations for improvements should be implemented. This is possible under the Energy Conservation Act, 2001.

The new Electricity Tariff Policy (draft circulated in March 2004) should suitably reward improvements in energy efficiency through sharing the benefits between the power generator and the consumer.

The coal pricing should be linked to the calorific value of the delivered fuel so that supplier has an incentive to improve quality and the power generator gets good and consistent quality of fuel

The development of advanced technology for thermal power generation is very closely linked to the environment policy with respect to emissions of particulate matter, SOx, NOx, and CO2. It takes 10– 15 years for introduction of any new technology. Thus, we must have long-term environment policy to guide the development and introduction of new technologies.

Hydro power is also a preferred option, which reaches the maximum allowed potential over the time period. From ~25 GW (gigawatts) in 2001/02, large hydro power generation capacity increases to 61 GW by 2011/12, 108 GW by 2021/22, and 150 GW by 2031/32. The installed capacity for small hydro is low initially but increases to 8 GW by 2011/12.

Although the percentage share of hydro power in the total power generation capacity is 23% in 2031, its contribution in the total commercial energy mix is as low as 2% due to low PLF (plant load factor) of about 30%.

Renewable Energy Technologies – Potentials, Costs and Emission Savings

The use of renewable energy sources as a replacement for fossil energy sources can contribute significantly to the reduction of CO_2. Though the current non–conventional energy sources account for merely 0.2 per cent of total power generation, their estimated potential is large.

A comprehensive programme to implement renewable energy technologies has been undertaken by the Ministry of Non – conventional Energy Sources (MNES).

Table 3.92 Renewable energy potential in India

Energy source	Estimated potential in MW
Hydro power	84,000
Small hydro	10,000
Ocean thermal power	50,000
Wave power	20,000
Tidal power	10,000
Wind energy	20,000
Solar energy	5×10^{15} kWh/year
Bio energy	17,000
Cogenerating	8,000
Draught animal power	30,000
Energy from waste	1,000

Based on a study by Kolb et al (1989) the specific CO_2 emission for power generation for various technologies are given in the below table 3.93

Table 3.93specific CO_2 emission for power generation for various technologies

Renewable energy technology	CO_2 Emissions	Conventional reference technology	CO_2 Emissions	Savings	
	kg/kWh*		kg/kWh*	kg/kWh*	kg/kWh**
Wind energy converter	0.0	Coal Power Plant	0.92	0.92	0.33
Photovoltaic cell	0.0	Coal power plant	0.92	0.92	0.33
Hydropower plant	0.0	Coal power plant	0.92	0.92	0.33
Electric heat pump	0.26	Oil – fired boiler	0.34	0.08	0.06
Gas heat pump	0.12	Gas – fired boiler	0.24	0.12	0.10
Solar heater	0.0	Oil – fired	0.34	0.34	0.27

		boiler			
Biogas – fired heater	0.51***	Oil – fired boiler	0.34	0.34	0.27
Wood – fired heater	0.48***	Oil – fired boiler	0.34	0.34	0.27
Geothermal system	0.0	Oil – fired boiler	0.34	0.34	0.27

* CO_2 emissions related to energy output

** CO_2 emissions related to fossil primary energy equivalent

*** CO_2 assimilated by growing biomass (assumption)

It would have to be clearly recognized that Power Sector will remain unviable until T&D losses are brought down significantly and rapidly. A large number of States have been reporting losses of over 40% in the recent years. By any standards, these are unsustainable and imply a steady decline of power sector operations. Continuation of the present level of losses would not only pose a threat to the power sector operations but also jeopardize the growth prospects of the economy as a whole. No reforms can succeed in the midst of such large pilferages on a continuing basis.

The State Governments would prepare a Five Year Plan with annual milestones to bring down these losses expeditiously. Community participation, effective enforcement, incentives for entities, staff and consumers, and technological up gradation should form part of campaign efforts for reducing these losses. The Central Government will provide incentive based assistance to States that are able to reduce losses as per agreed programmes.

(**Referenc**e: Achievements in renewable energy sources Source: CO_2 reduction potentials & Strategies and Technologies for greenhouse gas mitigation - N.K. Bansal pg no177)

(Renewable energy sources: Integrated Energy Policy 2006, Planning Commission, Government of India)

(Renewable energy, The Gazette of India No 23/40/2004-R & R (Vol. III) Part I Section I, Ministry of power, New Delhi)

(Renewable energy, Energy Map for India: Technology Vision, The Energy and Resources Institute, Office of the Principal Scientific Adviser, Government of India 2006, Publishers TERI Press The Energy and Resources Institute and Office of the Principal Scientific Adviser, Government of India).

Barriers

The Government of India has initiated several reform measures to create a favourable environment for addition of new generating capacity in the country. The Electricity Act 2003 has put in place a highly liberal framework for generation. There is no requirement of licensing for generation. The requirement of techno-economic clearance of CEA for thermal generation project is no longer there. For hydroelectric generation also, the limit of capital expenditure, above which concurrence of CEA is required, would be raised suitably from the present level. Captive generation has been freed from all controls.

The progress of implementation of capacity addition plans and growth of demand would need to be constantly monitored and necessary adjustments made from time to time. In creating new generation capacities, appropriate technology may be considered keeping in view the likely widening of the difference between peak demand and the base load.

CHAPTER 4

ENERGY EFFICIENCY AND DEMAND SIDE MANAGEMENT

4.1 Introduction

India's conventional energy reserves are limited and we must develop all available and economic alternatives. Simultaneously, a major stress must be laid on energy efficiency and conservation, with particular emphasis on efficiency of electricity generation, transmission, distribution and end-use. Clearly, over the next 25 years energy efficiency and conservation are the most important virtual.

India cannot deliver sustained 8% growth over the next 25 years without energy and water, and these two together shall, in turn, pose the biggest constraints to India's growth. The energy intensity of our growth has been falling and is about half what it used to be in the early seventies but there is significant room to improve. In 2003 India consumed 0.16 kilogram of oil equivalent per dollar of GDP expressed in purchasing parity terms. This compares to 0.23 in China, 0.22 in US and a world average of 0.21. However there are several countries in Europe and Japan at or below 0.15. One should note that cross country comparisons are full of pitfalls. For example, if the share of hydel energy is higher in the total energy mix, energy intensity would be lower. Even then, these comparisons do show that energy intensity can be brought down by 20% in India with commercially viable technologies currently available and in use in the developed countries

The most energy efficient scenario from our model shows an aggregate energy requirement of 1536 Mtoe in 2031. This scenario is 19% more efficient than the most energy intensive scenario. With a projected population of 1.468 billion, the per capita total primary energy supply (TPES) in the most energy efficient scenario comes to 1046 kgoe/year. This is comparable to China's per capita TPES in 2003. Even in the most energy intensive scenario the per capita TPES in 2031-32 is only 1285 kgoe. This compares with the 2003 world average per capita energy consumption of 1688 kgoe. Thus while the projected total energy requirement may look large, it is perhaps not large enough for the GDP growth assumed.

Efficiency of coal power plants themselves can be improved substantially. The average gross efficiency of generation from coal power plants is 30.5%. The best plants in the world operate with super critical boilers and get gross efficiency of 42%. Germany is even claiming gross conversion efficiency of 46%. It should be possible to get gross efficiency of 38-40% at an economically attractive cost for all new coal-based plants. This alone can reduce coal requirement by 111 Mtoe of coal (278 Mt of Indian coal). Thus a very high priority should be given to developing or obtaining the technology for coal-based plants of high efficiency.

If Demand Side Management (DSM) options are pursued to reduce demand for electricity through energy efficient processes, equipment, lighting and buildings so that electricity demand is reduced by 15% by 2031-32, a reduction of 152 Mtoe (381 Mt of Indian coal) in coal requirement takes lace. Studies have shown that economically attractive options of DSM exist to attain such reductions. Energy efficiency and DSM should have a very high priority.

Since domestic oil supply has stagnated at a low level and requirements are growing, oil use efficiency, conservation and substitution by other forms of energy are major options to reduce oil imports. The same is true of gas, though the prospects of finding gas look somewhat brighter. Since no economic substitutes are obvious for the transport sector at least till 2031-32, energy efficiency of vehicles and use of mass transport have to have high priority. If the energy efficiency of all motorized transport vehicles is increased by 50%, (an efficiency level that is already achieved in the world today) our oil requirement will go down by some 86 Mt by 2031-32. If on the other hand railways are able to win back the freight traffic they have lost to trucks and manage to carry 50 percent of freight billion tonne kilometre (Bt-km), then oil requirement can go down by 38 Mt. These two initiatives in the transport sector can, together, reduce our oil requirement by over 25% from the most oil intensive scenario in 2031.

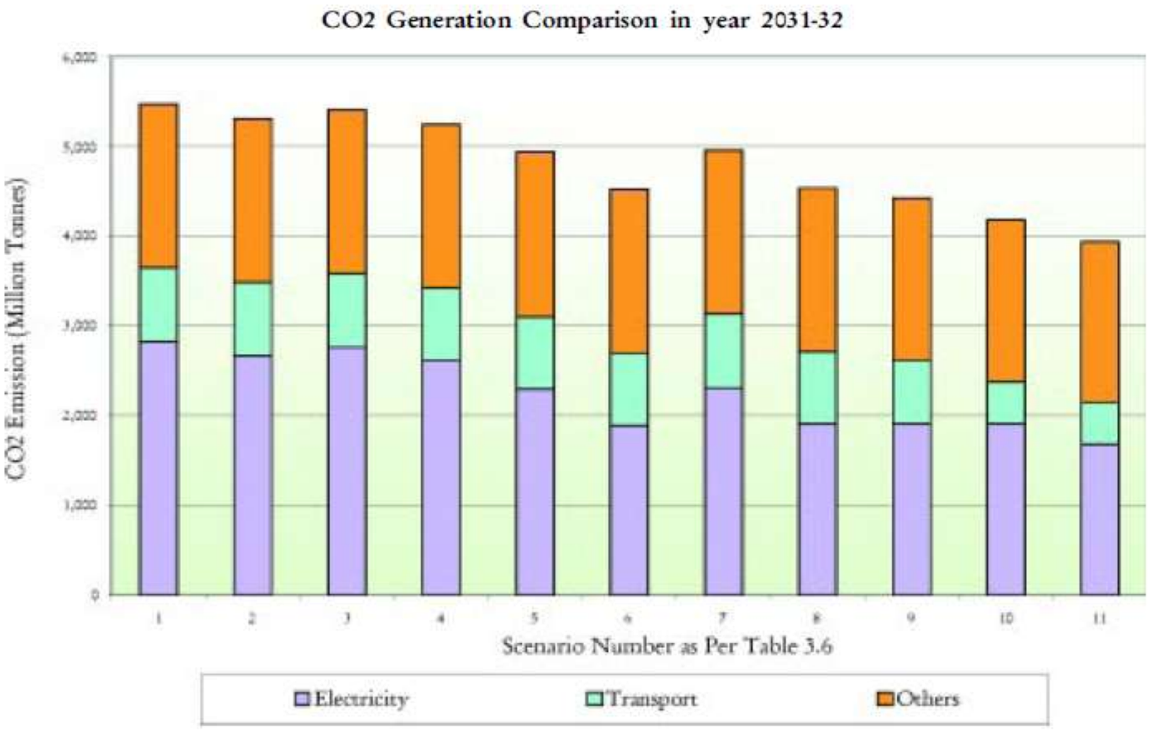
Urban mass transport is much more fuel efficient per passenger kilometer compared to private vehicles. Mass transport also reduces road congestion and air pollution. Thus development of urban mass transport systems of quality and convenience that can attract passengers will contribute significantly to energy conservation.

If both energy efficiency of coal generation and DSM are pursued together along with higher freight share by Railways and a push for renewables, coal demand could come down by over 38% from the coal dominant scenario to 632 Mtoe (1580 Mt of Indian coal).

All of the above recommendations, resulting from an analysis of the scenario s studied, are technologically viable. Pursuing them can lower our energy demand by over19%. Failure to deliver on these recommendations could push India into the international market for coal with a potential demand equal to over 75% of the current level of trade. The short to medium term impact of such an eventuality on coal prices could be disastrous. That being said, there are indications that over the medium term world output of coal and coal trade is set to increase significantly.

4.2 Carbon emissions

Estimates of CO2 generated from energy use in different scenarios are shown in Figure 4.1 between Scenarios 1 (coal dominant scenario) and scenario 11 (with all efficiency and DSM measures and renewables) the difference is nearly 35%.



The carbon emission implications of our scenarios are therefore significant. Annual CO2 emissions could rise from 1 billion tonne at present to 5.5 billion tonnes per year by 2031-32 in the high coal use scenario and 3.9 billion tonnes in the low coal and renewable dominant scenario. In the US, emissions today are in excess of 5.5 billion tonnes of CO2. In per capita terms, however, India's carbon emissions in 2031-32 will be 2.6 to 3.6 tonnes of CO2 compared to the 2004 level of over 20 tonnes in US and a global average of 4.5 tonnes in 2004.

4.3 Implications for investment needs

Apart from the challenges of physically supplying different forms of energy discussed above, the investment requirement also shows a need for purposive action. The electricity generation, transmission and distribution sector alone is estimated to require an investment of at least Rs.60 trillion in 2005 rupees. The total energy sector investment could well amount to Rs.100-110 trillion in 2005 rupees inclusive of related infrastructure.40.

An economy growing at 8% should have little difficulty in mobilising the needed resources particularly with public private partnerships. The main challenge, however, is to create efficient and financially viable energy sub sectors so that investors have the incentives to invest in a competitive set up where consumers interests are simultaneously protected.

Table 4.1 Energy supply by sources for the year 2003-04

Table 4.1

Source		**Domestic**	**Import #**	**Total**
Coal & Lignite	Coal	145.00	14.00	167.00
	Lignite	8.00	-	
Oil & Products	LPG	12.44	0	12.44
	Kerosene	10.69	0.84	11.53
	HSD	40.31	-6.29	34.02
	LDO	1.21	0.00	1.21
	FO	8.36	-0.35	8.01
	LSHS	4.60	0.00	4.60
	MS	8.59	-3.19	5.40
	ATF	2.66	-1.77	6.89
	NAPHTHA	13.59	0.21	13.80
	Bitumen	3.24	0.00	3.24
	Pet Coke	2.80	0.00	2.80
	Lubes etc	1.37	1.53	2.90
	Others *	18.01	0.15	18.16
	TOTAL	127.87	-8.87	119.0
Gas	Gas	29.00	-	29.00
Electricity	Hydel	7.00	-	7.00
	Nuclear	5.00	-	5.00
	TOTAL	12.00	-	12.00
Total Commercial Energy				327.0
Non Commercial	Fuel wood Agro Waste	110.0	-	110.0
	Dung Cake	32.00	-	32.00
	Biogas	1.00	-	1.00
	TOTAL	143.00	-	143.00
Total Energy				**470.00**

* Others include refinery fuel for about 9 Mt
# Net of exports

4.4 Policy for energy efficiency and demand side management

4.4.1 Large potential for saving energy

The importance of energy efficiency and demand side management (DSM) has clearly emerged from the various supply scenarios and is further underlined by rising energy prices. Efficiency can be increased in energy extraction, conversion, transportation, as well as in consumption. Further, the same level of serviceman be provided by alternate means that require less energy. The major areas where efficiency in energy use can make a substantial impact are mining, electricity generation, electricity transmission, electricity distribution, pumping water, industrial production and processes, transport equipment, mass transport, building design, construction, heating ventilation and air conditioning, lighting and household appliances. It may be noted that a unit of energy saved by a user is greater than a unit produced as it saves on production, transport, transmission and distribution losses. Thus a “Negawatt” (a negative Megawatt) produced by reducing energy need saves more than a Megawatt generated.

In the 1990s, several studies have estimated the potential and cost effectiveness of energy efficiency and demand side management (DSM) in India7. Despite these potential studies, actual implementation has been sluggish. The 8th Five Year Plan made a provision of Rs.1,000 crores for energy efficiency to provide targeted energy savings of 5,000 MW and 6 Mt in the electricity and petroleum sectors respectively. There is no clear quantification of the actual costs and savings achieved. The 9th Five Year Plan proposed the passing of the Energy Conservation Act and the setting up of the Bureau of Energy Efficiency.

The 10th Five Year Plan proposes benchmarking of the hydrocarbon sector against the rest in the world. It also suggests demand side management specifically in the transport sector. The target for energy savings in the 10th Plan is 95,000 Million Units which is about 13% of the estimated demand of 7, 19, 000 Million Units in the terminal year of the 10th Plan. However, there is no specific allocation to meet the energy savings targets.

A study prepared for the Asian Development Bank (ADB, 2003) estimated an immediate market potential for energy saving of 54,500 million units and peak saving of 9,240 MW. Though there is some uncertainty in any aggregate estimates, it is clear that cost-effective saving potential is at least 15% of total generation through DSM. Additional savings are possible on the supply side through reduction in auxiliary consumption at generating plants and lowering technical losses in transmission and distribution. At present an estimate of the total volume of the energy efficiency consulting business (audit, performance contracting, engineering, technical assistance and consultancy) is less than 1% of its potential (DSCL, 2004)8.

Bureau of Energy Efficiency (BEE) anodal agency, representing Ministry of New and Renewable Energy, A Government of India body is active in Energy Auditing and implementation of related projects. Details about the organization is given below.

Bureau of Energy Efficiency (BEE)

BEE was established under the Energy Conservation Act, 2001 with effect from 1st March, 2002 to meet the following objectives:

- To exert leadership and provide policy framework and direction to national energy conservation and efficiency efforts and programmes.
- To coordinate energy efficiency and conservation policies and programmes and take it to the stakeholders
- To establish systems and procedures to measure, monitor and verify energy efficiency results in individual sectors as well as at a macro level.
- To leverage multi-lateral and bi-lateral and private sector support in implementation of Energy Conservation Act and efficient use of energy and its conservation programmes.
- To demonstrate delivery of energy efficiency services as mandated in the EC Act through private-public partnerships.
- To interpret, plan and manage energy conservation programmes as envisaged in the Energy Conservation Act.

Actions taken by BEE so far are given below:

- BEE has conducted National Certificate Examinations for selection of Energy Managers and Energy Auditors.
- Energy auditing agencies for accreditation on the basis of their energy auditing capabilities and institutional set-up have been cleared by BEE.
- Draft norms for fixation of specific energy consumption in Cement and Pulp & Paper Industries have been framed and these norms are under discussion prior to finalisation.
- Task forces in 7 Energy Intensive Sectors have been set-up and best practices on energy conservation are being discussed by these task forces.
- Industries are being motivated to take up energy efficiency measures through institution of National Energy Conservation Award Scheme of Ministry of Power.
- Energy Audits for 9 Govt. buildings have been completed that include Rashtrapati Bhawan, Prime Minister's office, South Block (Defence Ministry), Rail Bhawan, Sanchar Bhawan, Shram Shakti Bhawan, Transport Bhawan, R&R Hospital, Delhi Airport and All India Institute of Medical Sciences (AIIMS) and implementation plans have been prepared.
- Energy Conservation Building Code has been prepared and is under review by the stakeholders.

Since Energy Efficiency (EE)/DSM schemes are often cost effective, is it necessary to have policy interventions? In actual practice there are several barriers that constrain the adoption of EE/DSM schemes including high transaction costs, lack of incentives to utilities who perceive DSM as a loss of market base, inadequate awareness, lack of access to capital, perceived uncertainty concerning savings, a high private discount rate, limited testing infrastructure with which to ascertain savings and an absence of a reliable measurement and verification regime. Policy interventions are required to address these barriers

.

To conserve petroleum products, the Petroleum Conservation Research Association (PCRA) was set-up by Ministry of Petroleum and Natural Gas (MOPNG) in 1978. The Bureau of Energy Efficiency (BEE) was established under the Energy Conservation Act, 2001, with effect from 1st March, 2002, under the Ministry of Power (MOP). The mission of BEE is to develop policies and strategies on self-regulation and initiate market interventions aimed at reducing the energy intensity of the Indian economy. While BEE has made a beginning a lot more needs to be done. BEE does not have a fulltime head and, as of September 2005, had only 4 professionals on staff.

Since nearly one third of total energy is used for domestic cooking, efficiency of the cooking process should be given a high priority, particularly since this process is currently marked by poor level of efficiency.

To promote energy efficiency and conservation we need to create an appropriate set of incentives through pricing and other policy measures. Barriers to the adoption of efficient technologies have to be removed and encouragement to develop and deploy more efficient technologies has to be provided. Public policy can set the pace for such development by offering attractive rewards and imposing biting penalties.

An enabling institutional framework is essential to achieve the objectives listed above. Details of such an institutional framework are listed below:

- The BEE should be made an autonomous statutory body under the Energy Conservation Act and be independent of all the energy ministries. It should be funded by the Central Government. A cess on fuels and electricity (adjusted for the cess on fuels used for generating electricity) can be justified as a user charge. BEE staffing should be substantially strengthened.

- Existing national energy efficiency organisations like the Petroleum Conservation Research Association (PCRA) should be merged with the BEE. This will ensure that the BEE is responsible for energy efficiency for all sectors and all end-uses.

- Based on the recommendations of the merged autonomous body the government could directly provide funding support to financial institutions for promoting energy efficiency programmes.

- Energy efficiency and conservation programmes and standards should be established and enforced. The BEE should develop such standards for all energy intensive industries and appliances as well as develop modalities for a system of incentives/penalties for compliance/non-compliance. These standards should be at levels equal to or near current international norms.

- Mechanisms for independent monitoring and verification of achieved energy savings and the cost effectiveness of programmes must be established. Evaluation reports should be quantitative and made publicly available. An annual report of the investments and savings made through specific energy efficiency and DSM programmes should be prepared by the BEE and reported to the Parliament. The feedback from the monitoring exercises should help in modifying programme designs.

- Truthful labelling must be enforced with major financial repercussions if equipment fails to deliver stated efficiencies. In extreme cases, one can resort to black listing errant suppliers at consumer information web sites and on government procurement rosters.
- Verification and labelling requires testing laboratories. A programme for setting up such laboratories in public, private and the NGO sectors is needed.
- National Building Codes should be revised to facilitate and encourage energy efficient buildings.
- Large scope exists to make buildings energy efficient. Construction materials are energy intensive and the use of appropriate materials and design can save a significant amount of energy not only in construction but also during use by building occupants. Innovative and energy efficient building technologies should be widely publicised through an annual prize. Reducing energy needs for heating and cooling by orientation, insulation and using temperature differences in earth or water at some depth could also be significant.
- Improvement in energy efficiency and DSM require actions by a large number of persons and institutions. To mobilize them, the first task is to create awareness of the scope of possibilities and the extent of gains one can make through such measures.
- Promote and facilitate energy service companies (ESCOs) that can identify energy saving options and provide technical support needed for execution to industries and commercial establishments.

Some policy initiatives can yield quick returns with small effort just like plucking low hanging fruits. These could include —

- Regulatory commissions can allow utilities to factor EE/DSM expenditure into the tariff.
- Each energy supply company/utility should set-up an EE/DSM cell. The BEE can facilitate this process by providing guidelines and necessary training inputs. A large number of pilot rogrammes that target the barriers involved and have low transaction costs need to be designed, tested with different institutional arrangements, with different incentives, and with varied implementation strategies. Innovative programme designs can then be rewarded.
- **Implementing Time-of-Day (TOD) Tariffs:** All utilities should introduce TOD tariffs for large industrial and commercial consumers to flatten the load curve. Utilities should support load research to understand the nature of different sectoral load profiles and the price elasticities of these loads between different time periods to correctly assess the impact of differential tariffs during the day. The utility should have focus group meetings with industrial or large commercial consumers, document a few potential case studies illustrating the potential for shifting loads and provide information and analytical support along with implementation of the TOD tariff.
- **Facilitating Grid Interconnection for Co generators**: Enforce mandatory purchase of electricity at fixed prices from cogenerators (at declared avoided costs of the utility) by the grid to encourage cogeneration. The buying/ selling price should be time differentiated and declared by the state regulatory commissions at the time of each tariff notification.
- **Improving Efficiency of Industrial, Municipal and Agricultural Water Pumping**: Institute measures that encourage adoption of efficient pumping systems and shifting of

pumping load to off-peak hours. The public sector should be mandated to do so, and the private sector could be encouraged to do so through time-of day pricing. This will help reduce peak demand and energy demand.

- **Instituting an Efficient Motors Programme:** This initiative should focus on manufacturers/ rewinding shops and target market transformation, by providing incentives to supply energy efficient motors.
- **Instituting an Efficient Boiler Programme:** This initiative should focus on industry and provide incentives for replacement of old inefficient boilers.
- **Promoting Solar Hot Water Systems**: This programme should aim at both industrial and household needs of hot water.
- **Promoting Variable Speed Drives**: All large industries should be required to assess suitability of variable speed drives for their major pumping and fan loads.
- **Undertaking Efficient Lighting Initiative:** Utilities should launch pilot efficient lighting initiatives in towns/ cities (similar to the Bangalore Electricity Supply Company (BESCOM) programme in Bangalore). Features should include warranties by manufacturers and deferred payment through utility bill savings.
- **Improving Cooking Efficiency:** Efficiency of cooking stoves should be improved by targeting manufacturers and requiring them to label stoves so that the consumers know the cost of fuel used. Energy efficient utensils and efficient cooking practices should be promoted as they offer a very large scope for reducing fuel consumption.
- **Making Energy Audits Compulsory For All Loads Above 1 MW:** Energy audits should be done periodically and be made mandatory for public buildings, large establishments (connected load >1 MW or equivalent energy use >1MVA) and energy intensive industries.
- **Reaping Daylight Savings:** Saving daylight by introducing two time zones in the country can save a lot of energy.

11. Medium to long-term initiatives could include

- Adoption of a least-cost planning and policy approach that ensures that energy efficiency and DSM have a level playing field with supply options. The regulatory commissions should invite bids for DSM while approving new capacity additions. Thus, if a state requires an additional peak demand of 1,000 MW over the next five years, the utility can ask for bids from Independent Power Producers (IPPs) as well as Energy Service Companies (ESCOs). For example, an efficient lighting programme may offer to save 150 MW at a cost of Rs.5,000/peak kW saved. This would then become part of the least-cost plan before putting in new power plants that may cost Rs.40,000-50,000/peak kW generated. Similar exercises should be adopted for the oil sector.
- Initiate benchmarking exercises for different industrial sectors, hotels, hospitals, buildings, etc. In each segment, the benchmark would provide the theoretical minimum energy consumption, the best practice and specific steps required to reduce energy consumption. A road map (5-10 years) should be created for energy efficiency improvements in each industry segment. The BEE can catalyse the benchmarking process by bringing together energy auditors, researchers, end-users and providing the required funding.

- The Government (Central/State), Railways, Defence and public sector units constitute a large market segment for energy intensive products. The basis for selecting a vendor is usually only the lowest initial cost (details given in the below table). It is recommended that the procurement process be modified based on the minimum annualised life cycle cost A manual should be prepared establishing the methodology for annualised life cycle costing with a simple spreadsheet package to enable easy implementation. Table 4.2 is given below.

Table 4.2 Initial Cost and Life Cycle Cost

SI. No.	Equipment	Rating	Initial cost (Rs)	Annual Electricity Cost (Rs)	ALCC (Rs)	Cost of electricity as % of ALCC
1.	Motor	20 hp	45,000	600,000	605,720	99.0
2.	EE Motor	20 hp	60,000	502,600	512,700	98.0
3.	Incandescent Lamp	100 W	10	1168	1198	97.5
4.	CFL	11 W	350	128	240	53.6

In many cases of energy equipment the annual costs of operation predominate as compared to the capital cost. However the operating costs are often not considered at the time of the purchase, as they are part of the total electricity bill and recurring maintenance costs. The purchase decision is based on the initial cost. *Table* shows the initial cost and the annualised life cycle cost (ALCC) for some typical energy appliances based only on the annual electricity cost since it is the main cost component for these products.

- Though life cycle costing seems particularly relevant for appliance purchase since appliances are often bought without consideration ofoperating costs, it should be used for all decision-making and alternatives should be compared in terms of expected present discounted values of life cycle cost.
- **Increasing Efficiency of Coal-Based Power Plants:** Require NTPC and SEBs to acquire technology to enhance the fuel conversion efficiency of the existing population of thermal power stations from an average of 30% to 35%. No new thermal power plant should be allowed without a certified fuel conversion efficiency of at least 38-40%. While competitive tariff based bidding can balance fuel efficiency against capital cost and provide ncentives for efficiency improvement; in the absence of such competition the pace of efficiency improvement needs to be forced.
- **Shifting Freight Traffic to Railways:** Improve railway service to win back the long-distance freight traffic carried by trucks today that consume five times as much diesel per net tonne kilometer of freight carried. Construction of dedicated freight corridors and dismantling of the Container Corporation (CONCOR) monopoly are critical measures for this. Already, the railways have permitted private operators. Carrying 3000 billion tonne kilometres (Bt-km) of freight (half of projected freight traffic in 2031) by rail instead of trucks can save approximately 50 Mt of diesel per year. To attract freight traffic, railways must ensure timely and secure delivery. This can be accomplished by operating scheduled container trains and by charging freight on the container, rather than the content, so that the customers can lock and seal it.

- **Promote Waterways:** Water transport is energy efficient. Make investment to provide the needed infrastructure to facilitate water transport.

Promote Urban Mass Transport: Promote urban mass transport by providing quality services which may be partially financed by imposing congestion, pollution and parking charges on those who use personalized motor transport. Plan for future mass transport corridors in smaller cities and acquire the right-of-way. As the city grows, the permissible built up area may be gradually increased. However the additional right to build should remain with the local government, Which it can auction to finance mass transport and other urban infrastructure.

- **Fuel Efficient Vehicles:** Promote hybrid vehicles in India, which are internationally already available commercially. Also promote the already commercial flexi fuel vehicles that can burn varying proportions of ethanol-blended fuels.

At an 8 percent growth rate, we will nearly double our capital stock in nine years. Energy using equipment and appliances will also spread rapidly. Thus, the manufacturers of equipment and appliances should be targeted to force the pace of improvement in energy efficiency. The following steps may be taken to improve efficiency of energy consuming equipment:

- Mandate time bound targets of energy efficiency for industrial equipment, boilers, and appliances such as motor-vehicles, pump sets, refrigerators, water heaters, boilers, etc.
- Create competition among manufacturers to be the first to achieve the target through a "golden carrot" which is a large monetary reward to the first one to commercialize products which provide, say a minimum saving of 20% over the best existing design within a given time frame. The Super Energy Efficient Refrigerator Project in the US is a successful example of such a policy initiative
- Mandate clear and informative labeling in well-designed standardised forms for equipments and appliances. Combine this with consumer awareness programmes that illustrate the savings and possible associated gains.
- Strengthen appropriate labelling by creating regional facilities for testing and certification. Such a labelling/ standards initiative should be supported by analytical studies to establish equipment consumption benchmarks (minimum achievable energy consumption targets).

Industries may need technical support to identify and execute energy saving options. Energy service companies (ESCOs) can provide such support. We need to promote and facilitate ESCOs. Some possibilities include—

- Financing Support – The support for ESCOs could be in the form of payment security mechanisms (this may be required for projects in municipalities, government buildings), partial credit guarantees, or venture capital. Financial institutions may be encouraged to provide these.
- Encouraging different business models

For ESCOs to be successful in India a variety of alternative business models need to be attempted to determine the appropriate ones in the Indian context. The BEE could facilitate 15-20 demonstration ESCO projects in different sectors. These should be well documented, independently monitored and made available to the public. This will encourage more entrepreneurs to invest in ESCOs.

- ESCOs as producers of "Megawatts" may be given the same tax breaks that are available for renewable energy programmes or other energy investments.
- Providing an institutional framework for independent monitoring & evaluation of projects delivered by ESCOs. This would involve independent testing laboratories and setting benchmark standards.

4.5 Recommendations

The Main actions recommended

Comparisons of energy requirements and our resource base suggest that our hydrocarbon resources would be grossly inadequate to meet our needs. From a longer term perspective we need to take a number of actions:

- Relentlessly pursue energy efficiency and energy conservation as the most important virtual source of domestic energy.
- Institute policies that maximize domestic coal production.
- Create coastal infrastructure for import and use of coal.
- Develop coal transportation infrastructure including alternatives such as coastal and river movement.
- Develop fully the nuclear and hydro option.
- Mount R&D efforts to develop commercially viable in-situ coal gasification technology.
- Redouble exploration efforts for oil, gas and coal.
- Raise the level of diplomacy to access hydrocarbon reserves overseas and gas pipelines to India.
- Undertake a technology mission on carbon sequestration.
- Undertake pilot projects to assess the economics and social benefits of biomass plantations and bio-fuels
- Undertake a solar technology mission to make solar power using photovoltaics or solar thermal economically attractive.
- Undertake R&D for exploiting gas hydrates.
- Undertake R&D for fusion to keep open that option for unlimited power.
- Assess off-shore wind power potential.

(**Reference:** Integrated Energy Policy 2006, Planning Commission, Government of India)

CHAPTER 5

CLIMATIC PROJECTIONS

5.1 Introduction

Significant increase of the order of 0.4°C in the past one hundred years in the annual global average surface air temperature has already been observed. While annual average monsoon rainfall at the all-India level for the same period has been without any trend and variations have been random in nature, increase in monsoon seasonal rainfall have been recorded long he west coast, north Andhra Pradesh and north-west India (+10 to +12 per cent of normal/100 years) while decreasing trends have been observed over east Madhya Pradesh and adjoining areas, north-east India and parts of Gujarat and Kerala (-6 to -8 per cent of normal/100 years). Using the second generation Hadley Center Regional Model (Had RM2) and the IS92a future scenarios of increased greenhouse gas concentrations, marked increase in seasonal surface air temperature is projected into the 21st century, becoming conspicuous after the 2040s (Figure 1). Climate projections indicate increases in both maximum as well as minimum temperatures over the region south of 25°N, the maximum temperature is projected to increase by 2-4°C during the 2050s. In the northern region the increase in maximum temperature may exceed 4°C. Model projections also indicate an increase in minimum temperature by 4°C all over the country, which may increase further in the southern peninsula. Little change in monsoon rainfall is projected up to the 2050s at the all-India scale level.However there is an overall decrease in the number of rainfall days over a major part of the country. This decrease is greater in the western and central parts (by more than 15 days) while near the Himalayan foothills (Uttaranchal) and in northeast India the number of rainfall days may increase by 5-10 days. Increase in rainfall intensity by 1-4 mm/day is expected all over India, except for small areas in northwest India where the rainfall intensities may decrease by 1 mm/day.

Figure 5.1: Projections of seasonal surface air temperature for the period 2041-60, based on the regional climate model HadRM2.

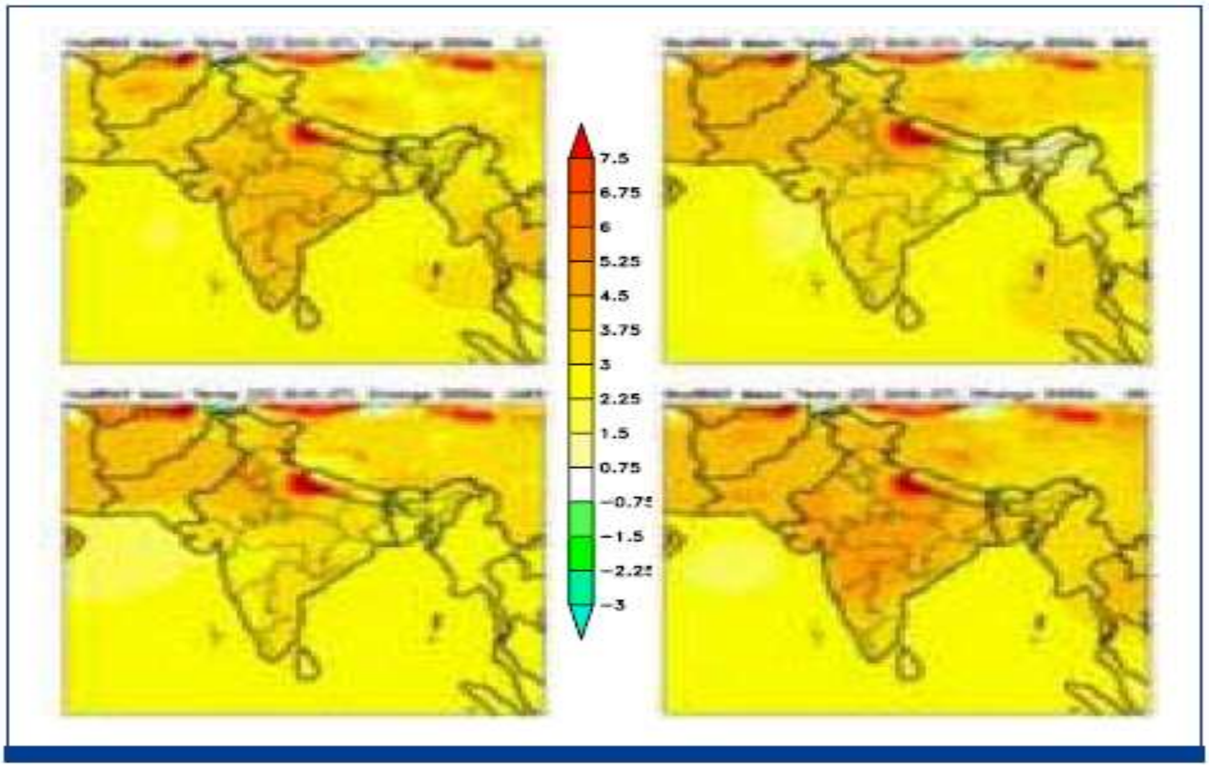
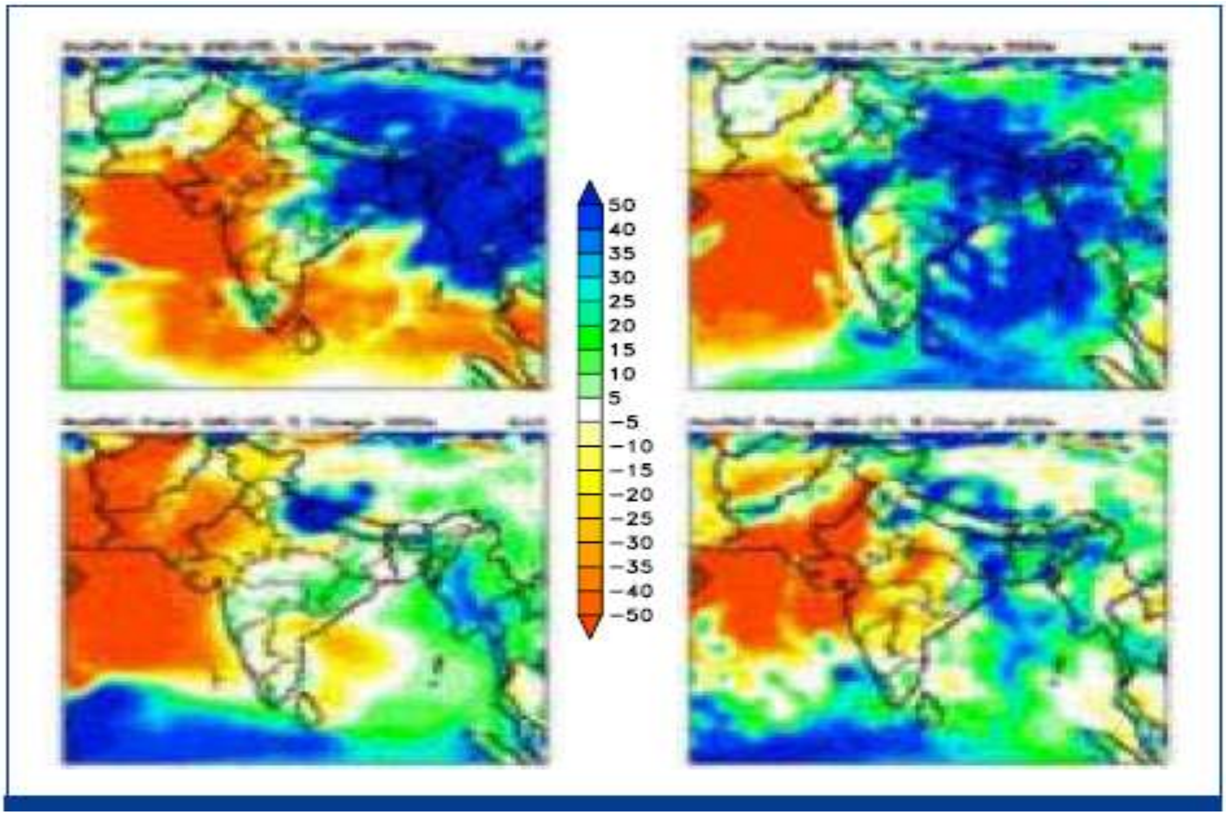


Figure 5.2: Projections of seasonal precipitation for the period 2041-60, based on the regional climate model HadRM2.

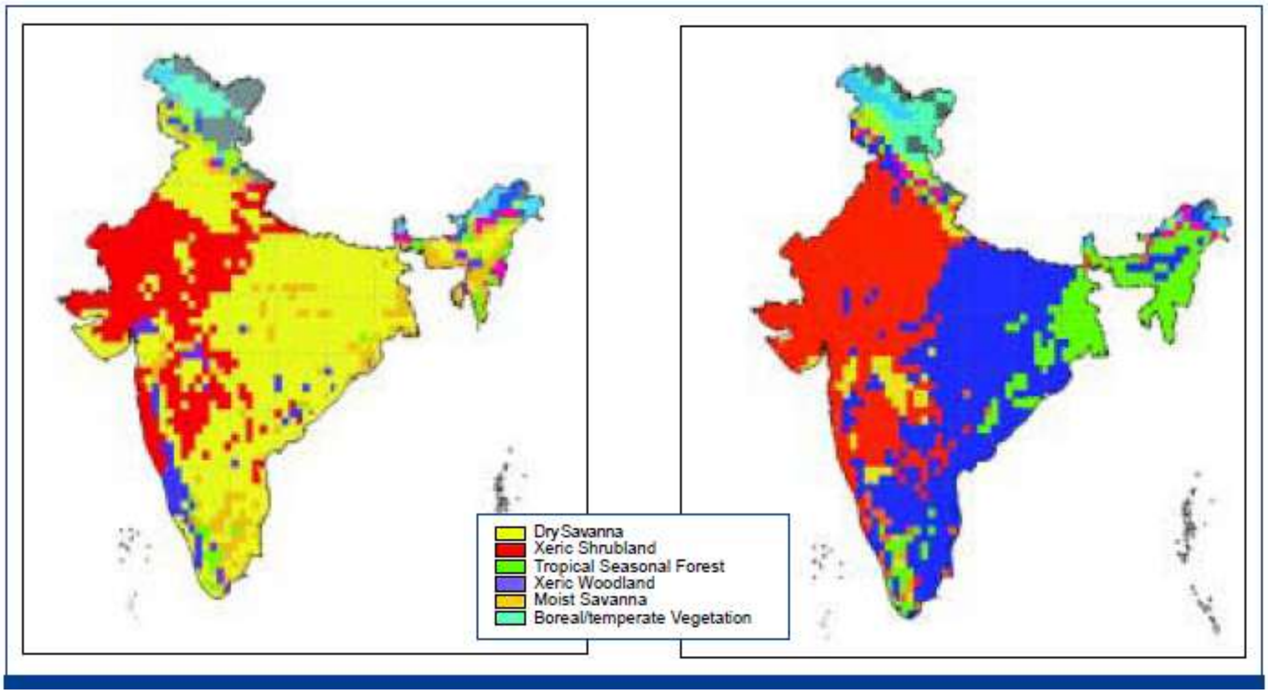


Assessment of the projections of future climate by different GCMs show a consistent rise in temperature across all models, indicating that these predictions are robust. However, the projections of rainfall vary across models. Though the climate models used for assessing future climate have their inherent limitations and uncertainties, the results obtained through these models give an indication of the likely changes in climate in the future. The consequences of these expected changes would vary greatly across the length and breadth of India due to its complex geography and climate patterns. Regional and sectoral variability in levels of social and economic development requires in-depth regional and sectoral assessment of vulnerability due to the projected climate change, and formation of adaptation strategies. The information available for assessments of impact is fragmentary. An effort was made during preparation of the Initial National Communication to undertake modeling and research studies and collate existing information on impact assessment and development strategies which may mitigate some impacts.

The IPCC estimates that have even a 50% chance of making a stabilization target of 2^0 C global temperature increase, will have to peak by2050.In other words, even the WEO,s most optimistic projections take us forcefully in the wrong direction

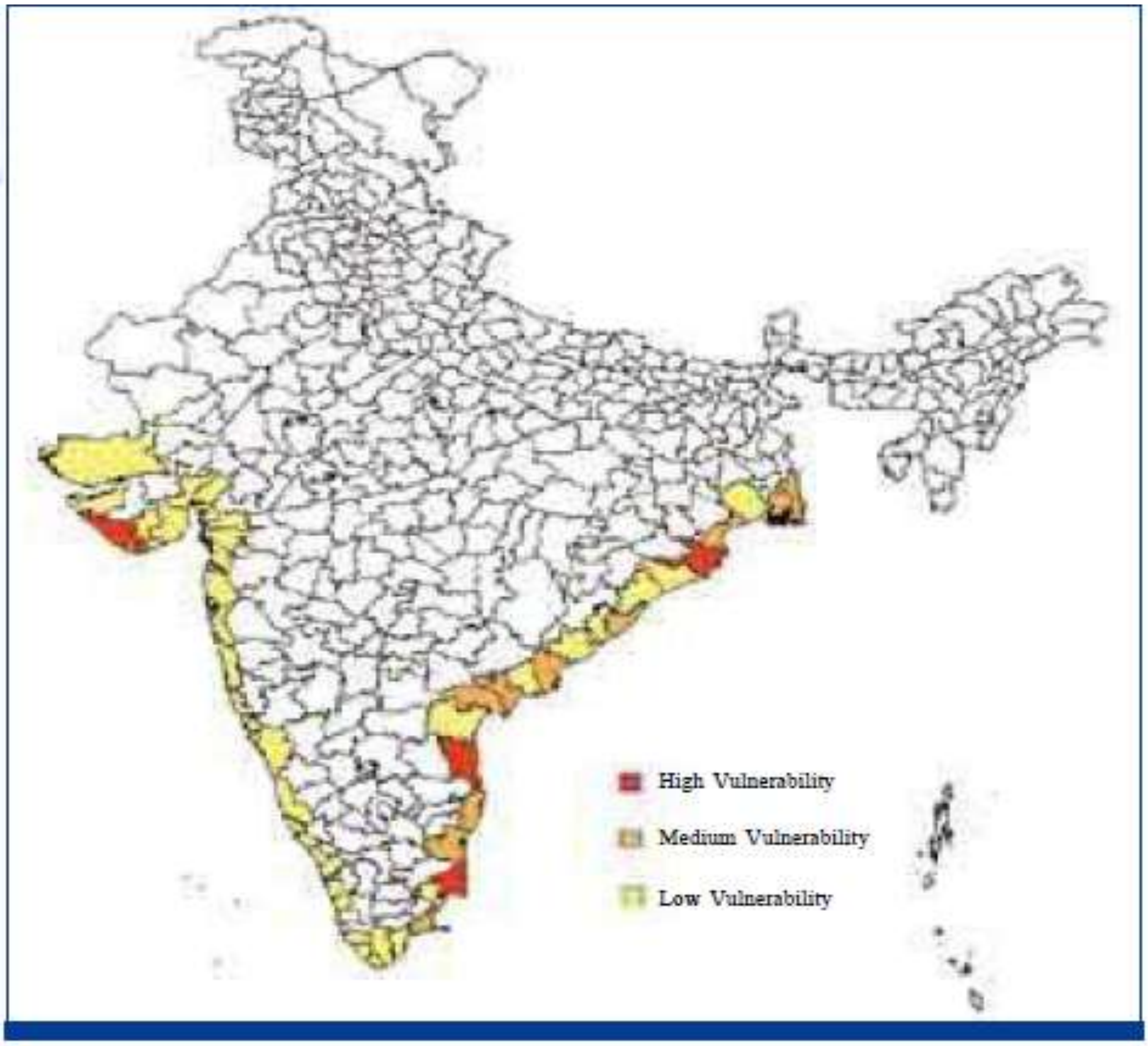
5.1.1 Forest eco-systems: Preliminary assessments using BIOME-3 vegetation response model, based on regional climate model projections (HadRM2) for India show shifts in forest boundary, changes in species-assemblage or forest types, changes in net primary productivity, possible forest die-back in the transient phase, and potential loss or change in biodiversity. Enhanced levels of CO2 are projected to result in an increase in the net primary productivity (NPP) of forest ecosystems over more than 75 per cent of the forest area. Even in a relatively short span of about 50 years, most of the forest biomes in India seem to be highly vulnerable to the projected change in climate (Figure 5.3).

Figure5. 3: Vegetation map for the year 2050 (right) under GHG run of HadRM2 considering all grids of India and potential vegetation (including grids without forests). The control run (without GHG increase) is shown on the left.



5.1.2 Coastal zone*:* The coastal zone is an important and critical region for India. It is densely populated and stretches over 7,500 km with the Arabian Sea in the West and Bay of Bengal in the East. The total area occupied by coastal districts is around 379,610 km2, with an average population density of 455 persons per km2, which is about 1.5 times the national average of 324 persons per km2. Under the present climate, it has been observed that the sea-level rise (0.4-2.0 mm/ year) along the Gulf of Kutchh and the coast of West Bengal is the highest. Along the Karnataka coast, however, there is a relative decrease in the sea level. Future climate change in the coastal zones is likely to be manifested through worsening of some of the existing coastal zone problems. Some of the main climate-related concerns in the context of the Indian coastal zones are erosion, flooding, submergence and deterioration of coastal ecosystems, such as mangroves and salinization.

Figure5.4: Coastal districts vulnerable to climate change.



The diverse impact expected as a result of sea-level rise includes land loss and population displacement, increased flooding of low-lying coastal areas, loss of yield and employment resulting from inundation, and salinization. Damage to coastal infrastructure, aquaculture and coastal tourism, due to the erosion of sandy beaches, is also likely. The extent of vulnerability, however, depends not just on the physical exposure to sea-level rise and the population affected, but also on the extent of economic activity of the areas and capacity to cope with impacts

5.1.3 Human health

Malaria is one such disease in India that has been prevalent over the years, despite government efforts to eradicate it. The climate, vegetation and other socio economic parameters conducive to its prevalence are consistently present in some regions of India. It is projected that malaria will move to higher latitudes and altitudes in India, with 10 per cent more area offering climatic opportunities for the malaria vector to breed throughout the year during the 2080s with respect to the year 2000

5.1.3.1 Climate change impacts on health

Projections of the extent and direction of potential impacts of climate variability and change on health are extremely difficult to make with confidence because of the many confounding and poorly understood factors associated with potential health outcomes. These factors include the sensitivity of human health to elements of weather and climate, differing vulnerability of various demographic and geographic segments of the population, the movement of disease vectors, and how effectively prospective problems can be dealt with.

Table 5.1 Known effects of weather/climate and potential health vulnerabilities due to climate change

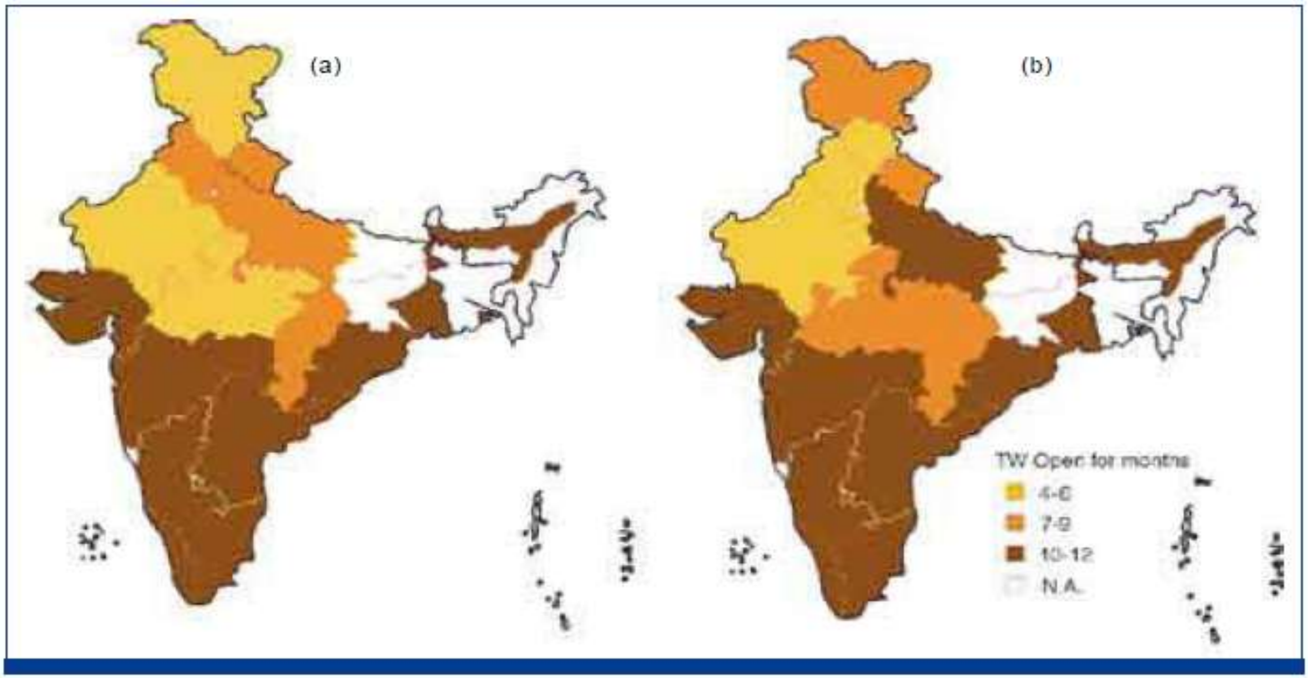
Health Concerns	Vulnerabilities due to climate change
Temperature-related morbidity	Heat- and cold-related illnesses.
	Cardiovascular illnesses.
Vector-borne diseases	Chained patterns of diseases.
	Malaria, Maria, kala-azar. Japanese encephalitis, and dengue caused by bacteria, viruses and other pathogens carried by mosquitoes, ticks, and other vectors.
Health effects of extreme weather	Diarrhea, cholera and poisoning, caused by biological and chemical contaminants in the water (even today about 70% of the epidemic emergencies in India are water-borne).
	Damaged public health infra structure due to cyclones/floods.
	Injuries and illnesses.
	Social and mental health stress due to disasters and displacement.
Health effects, due to insecurity in food production	Malnutrition and hunger, especially in children.

5.1.4 Infrastructure and energy

Large investments are being committed to new infrastructure projects, such as improving drinking water availability, construction of roads and highways, the cost of which runs into billions of US dollars. Infrastructure being long-life assets are designed to withstand normal variability in climate regime. However, climate change can affect both average conditions and the probability of extreme events, temperatures, precipitation patterns, water availability, flooding and water logging, vegetation growth, land slides and land erosion in the medium and long-run which may have serious impacts on infrastructure. These are likely to lead to huge monetary losses, if not taken into consideration while planning. Studies indicate that increased temperatures would increase space-cooling requirements, while enhanced groundwater demand would increase water pumping requirements. These will enhance the electricity demand and add costs to the consumers for maintaining their lifestyles, as well as to the electricity production systems.

The projected variability in precipitation can impact the irrigation needs and consequently increase electricity demand in agriculture sector. This would result in the need for higher power generation capacity. Also, about 1.5 per cent additional power generation capacity would be required for enhanced space cooling requirements as a result of increase in temperature. These additional power requirements are likely to be partly offset by adoption of various energy conservation measures in these areas as the projected energy saving potential in these sectors is very high. However, implementation of energy conservation measures would require substantial investments.

Figure 5.5: Transmission window of malaria in different states of India.(a) for 2000 and (b) under projected climate change scenario during the 2080s.



5.1.5 Technology transfer for power sector

Technology transfer as investment problem the related theme of technology transfer is also attracting an increasing amount of attention. and while the issue of technology transfer has been a negotiating item since the inception of the UNFCCC and, in fact, before, it now occupies a prominence in the negotiations for past 2012 regime that has not been seen here to fore.

In the area of clean energy investment the two agendas come together. The problem of technology transfer can be seen as essentially an investment problem: no enough investment is taking place in transformative technologies that will both provide clean new sources of energy. Successfully addressing the barriers to clean energy investment, making host countries more attractive for the investment, is essential for technology transfer.

In developing countries with a high local consumption, such as China and India's technology transfers could take place by the sale of equipment, licensing, joint ventures, co- operative production. Sub contracting of the manufacture of components, and co-operative research and development. possible forms of co-operation between industrial and developing countries, mounting joint ventures and establishing co-operative production.

At the basic level, technology transfer consists of hard ware (e.g. power generation units of flue gas desulphurization units) and knowledge of operation and maintenance of the technology. In addition, a country like China, for example, is developing its domestic design and manufacturing knowledge and skills for efficient coal based power production technology. The purpose of this kind of technology transfer is to gradually develop domestic manufacturing capacity.

5.1.6 Other barriers: Investors, both foreign and domestic, consider a number of factors when making decisions on clean energy investment. at the general level, investors are wary at the absence of such tings as political and macroeconomic stability, educated work fore, adequate infrastructure, functioning bureaucracy, rule of law and a robust finance sector.

There are also barriers that are specific to clean energy investment. These include a lack of cleaner guidance on future energy policy, monopoly structures for existing producers with lack of purchases agreements of fed in – tariffs for independent producers, lack of fiscal incentives for clean energy production, weak environmental regulation and enforcement, Subsidies for conventional energy sources, and a domestic financial sector that has little experience with new technologies.

The specifics differ fundamentally from country to country, a function of the many factors that shape national energy policies. However, the basic story remains the same, and is repeated in study after study. The being the case, any efforts on clean energy context, and demonstration projects are only useful for technologies at a certain projects are only useful for technologies at certain phase of development.

(Reference: Introduction, Clean Energy Investment as Technology Transfer, Aaron Cosbey, Joint Implementation Quarterly, October 2008

Climatic projections, India's Initial National Communication to the united Nations Framework Convention on Climate Change, government of India)

(Climate Change Impact on health, National Action Plan on Climate Change, Prime Ministers Council on Climate Change, Pg No 115-116)

CHAPTER 6

AVAILABLE ENERGY RESOURCES AND SUPPLY ISSUES

6.1 Introduction

To explore the consequences of different alternatives and their quantitative significance a number of scenarios have been developed using a multi-sectoral, multi period optimising linear programming model 4. These scenarios are described in the Table 6.1 given below. They are designed to assess the importance of critical policy options for meeting energy requirements. These scenarios are designed to map out extreme points of feasible options and none of them should be looked upon as a preferred scenario.

Table 6.1 Some Energy Supply Scenarios for 8% GDP Growth

Scenario		Description
1.	Coal-Based Development	Most electricity generation by the most economical option - which turns out to be primarily coal.
2.	Maximise Nuclear	Assumes nuclear development as per the optimistic scenario of Table 3.4.
5.	Forced Hydro	Development of the entire (1,50,000 MW) domestic hydro potential by 2031-32.
4.	Maximise Hydro & Nuclear	Both nuclear and hydro as in 2 and 3.
3,	'4' plus forced Natural Gas	16% of electricity generation from gas. This is comparable to the scenario of Table 2.7 & 2.12.
6.	'5' plus Demand Side Management	Demand side management reduces electricity demand by 15 percent.
7.	'5' plus Higher Coal Power Plant Efficiency	*Thermal Efficiency of future coal power plants increased to 38-40 percent for super critical boilers, from 36 percent for the present 500 MW
8.	'6' plus Coal Power Plant Efficiency	Both DSM and coal efficiency together.
9,	'8' plus higher freight share of Railways	Railways freight share increased from 32 percent to 50 percent.
10.	'9' plus vehicle efficiency increased	Fuel efficiency of all motorized vehicles increased by 50 percent.
11.	'10' plus renewables	30,000 MW wind power, 10,000 MW of solar power, 50,000 MW of biomass power, 10 Mt of bio-diesel, and 5 Mt of ethanol by 2031-32.
* Thermal efficiency of coal-bated plants refers to gross thermal efficiency based on gross generation and is equal to the ratio of gross heat output to gross heat input.		

India's Hydro-Carbon Energy Reserves are summarised in the below table. 6.2

Table 6.2 India's Hydrocarbon Reserves

Resources	Unit	Proved	Inferred	Indicated	Production in 2004-05	Net Imports in 2004-05	Reserve/ Production Ratio	
							P/Q	(P+I)/Q
		(P)	(I)		(Q)	(M)		
Coil (as on 1.1.2005)	Mtoe	38114	48007	15497				
Extractable Coal*	Mtoe	13489	9600-15650		157	16	86	147-186
Lignite (as on 1.1:2005)	Mtoe	1220	3652	5772				
Extractable table Lignite	Mtoe	1220			9	-	136	136

Oil (2009	Mt	786*	-	-	34	87	23	23
Gas (2005)	Mtoe	1101*	-	-	29	3 (LNG)	38	38
Coal Bed Methane	Mtoe	765	-	1260-2340				
In-situ Coal Gasification***		?	?					

* Balance Recoverable Reserves
** Extractable coal from proved reserves has been calculated by considering 90% of geological reserve as mineable and dividing mineable reserve by Reserve to Production ratio (2.543 has been used in 'Coal Vision 2025' for CDL blocks); and range for extractable coal from prognosticated reserves has been arrived at by taking 70% of indicated and 40% of Inferred reserve as mineable and dividing mineable reserve by R:P ratios (2.543 for CIL blocks and 4.7 for non-CIL blocks as per 'Coal Vision 2025').
*** From deep seated coal (not included in extractable coal reserves)

Note: Indicated Gas resource includes 320 Mtoe claimed by Reliance Energy but excludes the 360 Mtoe of reserves indicated by GSPGL as the same have not yet been certified by DGH.

Source : Respective Line Ministries

6.2 Total commercial energy requirements in the business-as usual scenario

TERI report details about BAU and future resources details are given below

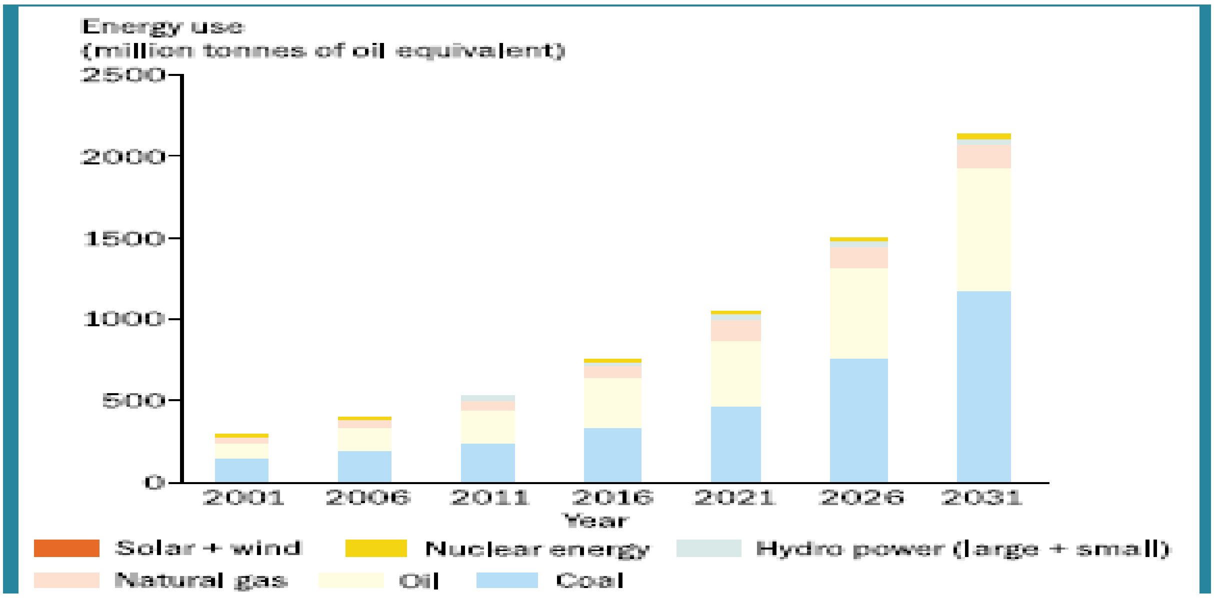
Total commercial energy consumption increases by 7.5 times (6.9% growth rate) over the 30-year period (2001/02–2031/32) in the BAU. Table 6.3 presents the fuel-wise commercial energy requirements. This data is also represented pictorially in Figure 6.1.

Table 6.3 Commercial energy requirements in the BAU (Mtoe)

Fuel	2001/02	2006/07	2011/12	2015	2016/17	2021/22	2026/27	2030	2031/32	2050
Coal	150	193	242		344	466	757		1176	
Natural gas	25	36	51		74	132	136		136	
Oil	101	151	211		298	405	555		757	
Hydro power (Large & small)	7	9	18		24	30	36		40	
Nuclear energy	2	2	4		8	13	13		13	
Renewable energy	0	1	1		1	1	1		1	
Total	285	391	527		749	1046	1497		2123	

BAU – business-as-usual; Mtoe – million tonnes of oil equivalent

Figure 6 .1 Commercial energy uses in the business-as-usual



6.2.1 Nuclear power

The country has a nuclear power programme that is expected to increase the current capacity (2004/05) of 2.7 GW to 6.78 GW by 2011/12 and 21.18 GW by 2021/22 in the BAU scenario. This share is, however, insignificant (0.6%–1.2%) in the total commercial energy mix.

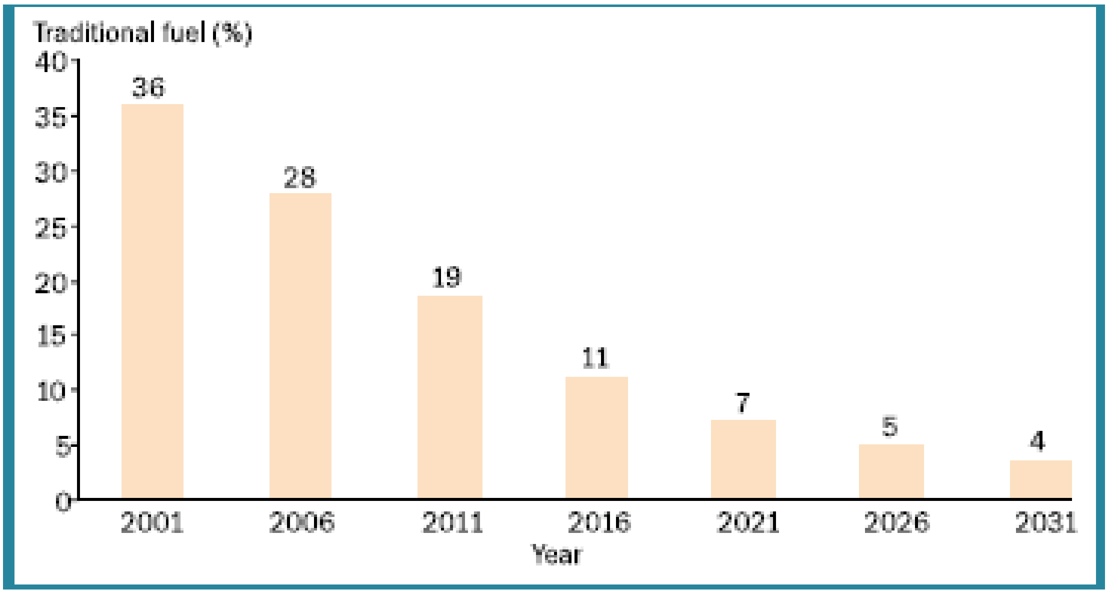
6.2.2 Renewable energy

The share of renewable energy (solar, wind, and bio-diesel) in commercial energy supply remains lower than 1% throughout the modelling time frame. None of the options are preferred in terms of their relative economics.

6.2.3 Traditional fuels

In the BAU, consumption of traditional fuels, such as firewood, crop residue, and dung in the residential and commercial sectors, decreases to half the current level of consumption during the modelling time frame (from 149 Mtoe in 2001 to 73 Mtoe in 2031). The percentage share of the traditional fuels in the total primary energy (commercial and non-commercial) supply decreases from 36% in 2001 to 4% in 2031, as shown in Figure 6.2. This is mainly due to switching over from non-commercial fuels to commercial ones for cooking purposes in the residential sector.

Figure 6.2 Variation in percentage share of traditional fuels in total primary energy supply



6.4 Observation & Understanding of Pricing Different Energy Sources

Energy pricing is a critical element of energy policy/Prices must send the right signal to energy and, where relevant, switch to preferred sources. They must also send signals to producers to invest in the sector. Rational energy pricing also requires that the principles applied to different sources of energy must be common. This is not the case at present because pitches that have evolved over time. The following general principles must guide the evolution of rational energy pricing.

6.4.1 Pricing of tradable energy

As general rule, the prices of all commercial primary energy sources which are tradable i.e. exportable or importable .such as petroleum products, coal and natural gas, should be set at trade party prices at the point of scale. Competitive markets would lead top trade parity prices ensuring that energy use and inter – fuel choices would be economically rational. This means Free-on-board (FOB) price for products for which the country is a next exporter and cost, Insurance and Freight (CIF) prices for which it is a net importer. Pricing a fuel below the import parity price, which at the margin is imported, encourages its domestic consumption beyond the level economically rational discourages domestic production consumption and in effect subsidies fore in producers. The domestic price of a product for which the country is broadly self-sufficient in a competitive market, with many suppliers and buyers, would fluctuate between 6the FOB or CIF limits depending upon the ease of import/export and reliability of suppliers. This is particularly relevant for the petroleum sector where the bulk of the crude oil required is imported and India has also become a net exporter of petroleum products.

To cushion domestic prices against short- term volatility of prices on the international market(FOB or CIF) A variable levy could be used so That domestic prices track median over the previous month or three month period.

6.4.1.1 Import dependency of coal

Although the production of coal nearly doubles over the 30-year period, it reaches its maximum annual production capacity and the economy needs to resort to increasing coal imports, as shown in Table 6.4. The total coal import dependency (percentage of imported fuel to total fuel consumption) increases from 3% to 70% over the modeling time frame.

Import dependency of non coking coal increases very rapidly in the BAU scenario, from almost 0% in 2001 to 71% by 2031. Figure 1.3 and Table 1.2 show variation in production, import, and import dependency of non-coking coal over the modelling time frame in the BAU scenario.

Figure 6.3 show the production, import, and import dependency of coking coal in the BAU scenario over the modelling time frame. Due to the increased steel demand and inadequate availability of coking coal in the country, import dependency increases from 25% in 2001 to 75% by 2031.

Figure 6.3 Production, import, and import dependency of non-coking coal in the business-as-usual scenario

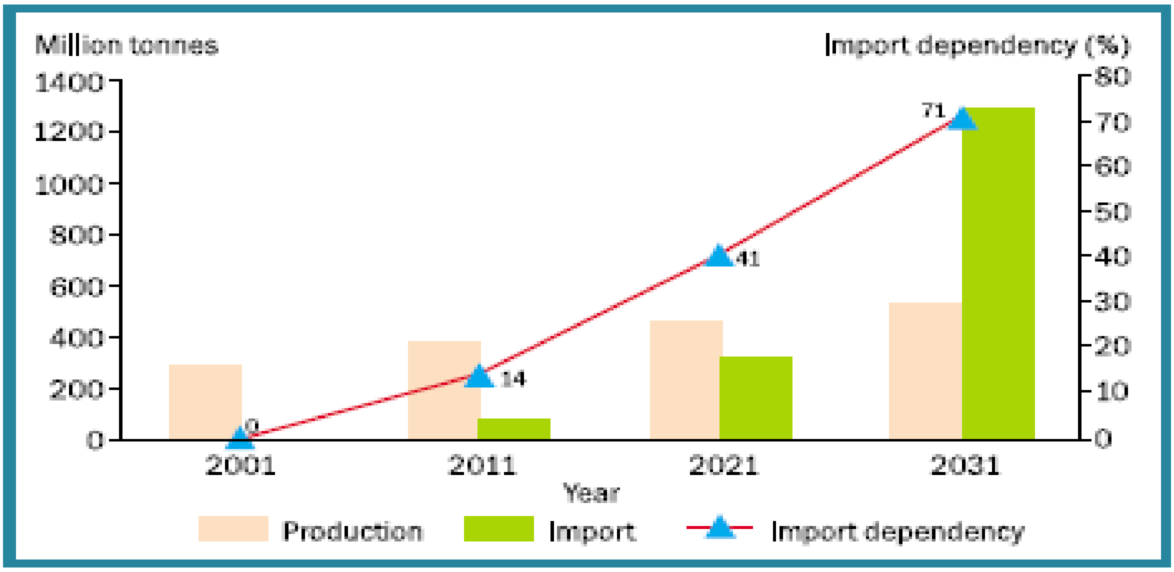
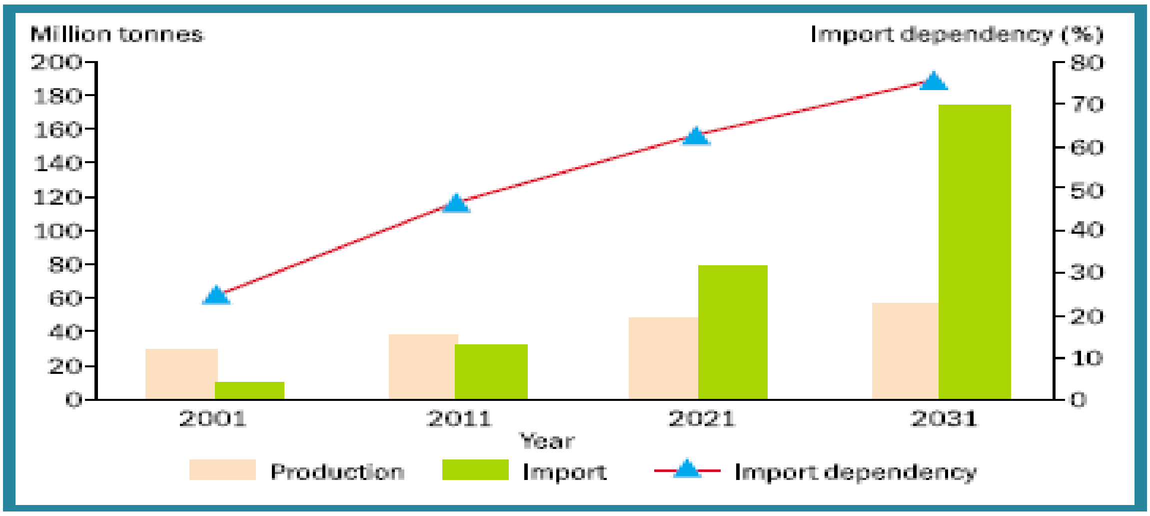


Table 6.4 Annual production, import, and import dependency of coal

Particulars	2001/02	2006/07	2011/12	2015	2016/17	2021/22	2026/27	2030	2031/32	2050
Production (million tones)	343	396	440		485	530	574		619	
Import (million tones)	10	45	92		223	384	811		1438	
Total (million tones)	353	440	532		708	913	1385		2057	
Import dependency (%)	3	10	17		31	42	59		70	

Figure 6.4 Production, import, and import dependency of coking coal in the business-as-usual scenario



Figures 6.5 and 6.6 shows the import dependency of coking and non-coking coal respectively, in 2011 and 2031 across various scenarios. The coking coal import dependency in the HYB and HHYB scenarios is higher than that in the BAU scenario. For non-coking coal, the import dependency is the lowest in the HYB scenario but similar in the HHYB and the BAU scenarios.

Figure 6.5 Import dependency of coking coal across various scenarios for 2011 and 2031

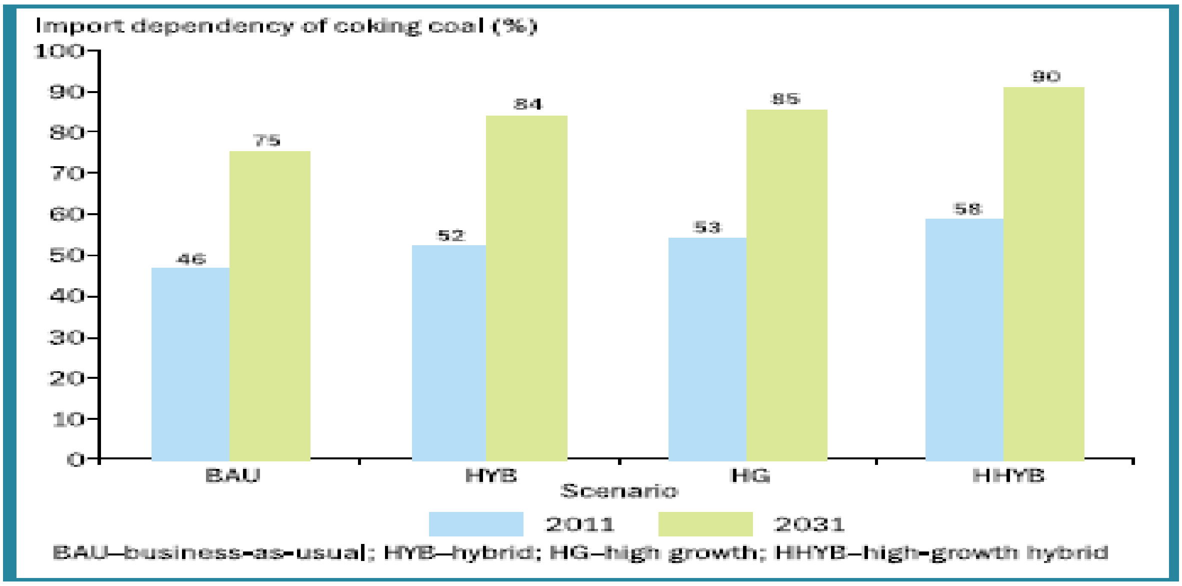
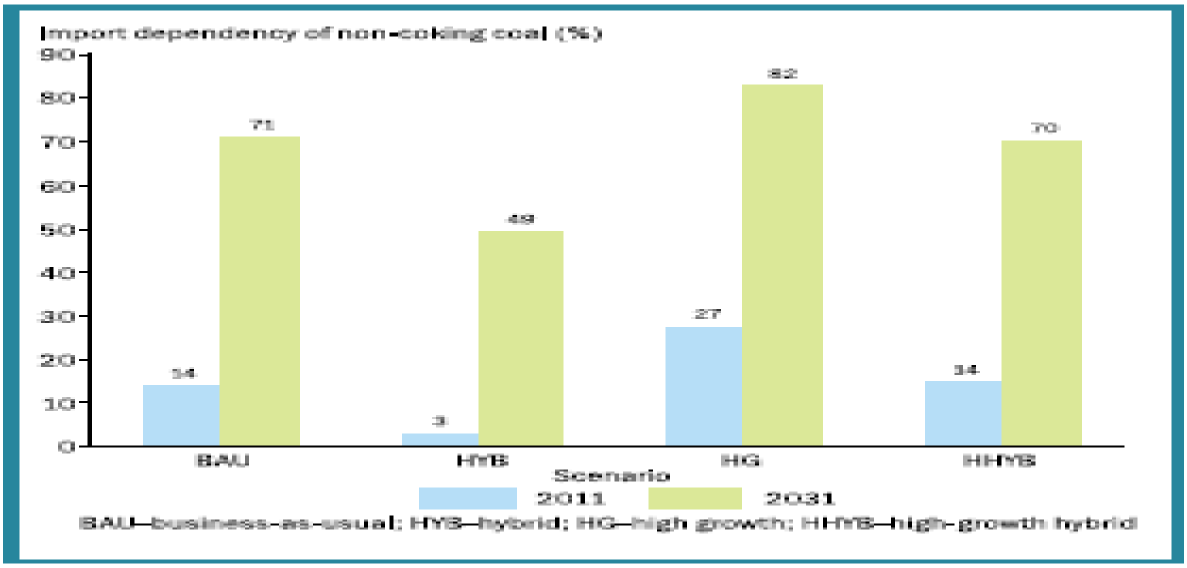


Figure 6.6 Import dependency of non-coking coal across various scenarios in 2011 and 2031



6.4.1.1.1 Coal supply scenario

Proved reserves of coal, the most abundant energy resource, at the current level of consumption can last for about 80 years. I all the inferred reserves also materialise then coal and lignite can last for over 140 years at the current rate of extraction. Of course, coal and lignite consumption will increase in the future and the reserves would last for far fewer years. If domestic coal production continues to grow at 5% per year, the total (including proven, indicated and inferred) extractable coal reserves will run out in around 45 years. However, only about 45% of the potential coal bearing area has currently been covered by regional surveys. Further, it is felt that both regional as well as detailed drilling can be made more comprehensive. Covering all coal bearing areas with comprehensive regional and detailed drilling could make a significant difference to the estimated life of India's coal reserves. The problem with coal remains finding a way to raise the proportion of extractable reserves, ensure adequate production and take care of the environmental impact of production and use.

6.4.1.1.2 Pricing of coal: Coal prices should ideally be left to the market and trading of coal, nationally and inter nationally and inter nationally should be free. At present market determined prices for coal apply only to the coal sold in e- auction and the prices emerging from this process are to 30% higher than official price.

Only a comparative free market can do an efficient job of price determination. However, a truly comparative

Market requires that three are multiple producers and that there are no entry barriers to new producers or to imports. This is not possible at present because coal production is nationalised. While it will take time to establish truly competitive conditions some steps can be taken immediately. Coal prices should be made fully variable based on Gross Calorific Value(GCV)and other quality parameters instead of the current system of pricing on the basis of broad bands of useful heat value.

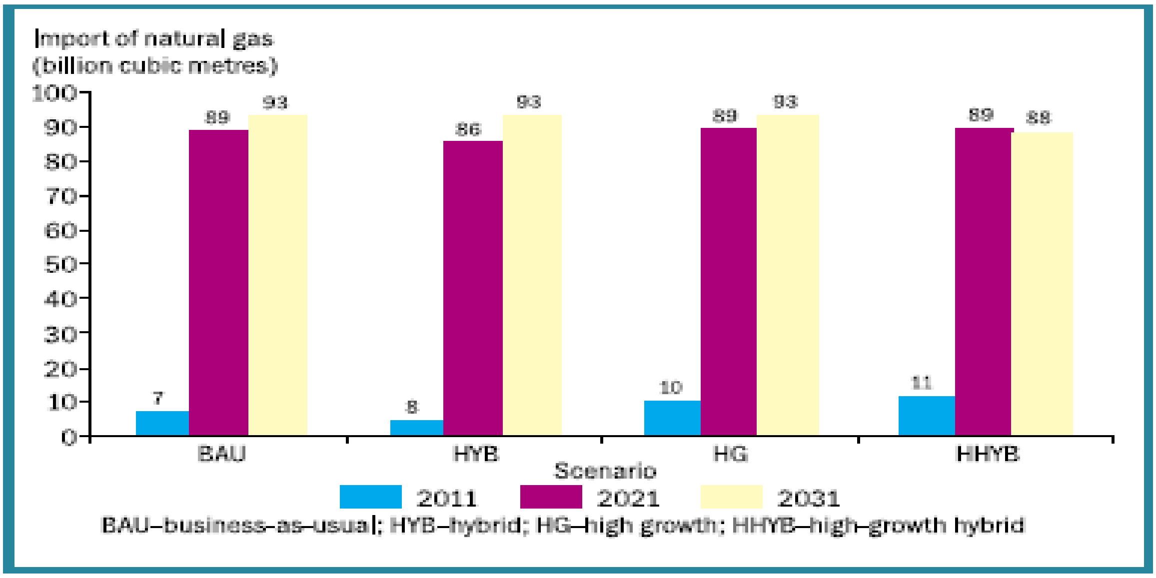
6.4.1.2 Import dependency of natural gas

Gas is being targeted as the future fuel and it is likely that its use would be more widespread. Large-scale investments would be required to enable gas import, handling, and transportation. As observed in Figure 6.7, the import dependency of gas in the BAU scenario increases from almost negligible levels in 2001 to 66% by 2021. In 2031, as per the model, it hovers at about 66%–67% due to constraints imposed on infrastructure

(LNG [liquefied natural gas] terminals and pipelines), but is likely to be higher if adequate facilities for the import and distribution of gas are made available. Natural gas is a preferred fuel for power generation at current prices as compared with coal and is also more economical for fertilizer production.

Figure 6.7shows the import of natural gas in the BAU, HG, and their respective hybrid scenarios for 2011, 2021, and 2031. It can be seen that the imports in the BAU and the HG scenarios for 2021 and 2031 are the same.

Figure 6.7 Import of natural gas across various scenarios for 2011, 2021, and 2031



6.4.1.2.1Oil and Gas supply scenario

The reserves of crude oil are merely 786Mt. These can sustain the current level of production for 23 years and are less than only 7 years worth of our level of consumption in2004-05. There has been no significant step up in crude oil reserves during the last decade in spite of large investments in exploration activities The country has not had any significant oil find since the Bombay High fields, more than 28 years ago. As a result, crude oil production has stagnated and the gap between the demand and domestic availability of crude oil is widening. Import dependence will keep rising, unless dramatic new discoveries are made. Only one third of the potential oil bearing area has been explored so far. The reluctance of international majors to explore in India seen in the past, seems to have hanged following the high success rate in gas discovery achieved by relatively small international players. They have shown much greater interest in the latest round of bidding for exploration blocks under the new exploration licensing policy (NELP). Also, some geologists predict vast amount of undiscovered oil in India. What it may require is development of technology to overcome geological barriers for deep drilling both above ground and under sea. In any case India's supply strategy while stepping up exploration should not rely on the possibility of finding oil domestically Reserves/production of crude oil and natural gas are given below.

Table 6.5 Reserves/Production of Crude oil and Natural gas

Year	Crude oil (Mt)		Natural gas (bcm)	
	Reserves*	**Production**	**Reserves***	**Production**
1970/71	128	6.9	62	1.4
1980/81	366	10.5	351	2.4
1990/91	739	32.2	686	18.0
2000/01	703	32.4	760	29.5
2001/02	732	32.0	763	29.7
2002/03	741	33.0	751	31.4
2003/04	761	33.4	853	32.0
2004/05	739	33.9	923	31.8
2005/06	786	33.2	1101	32.2
2010/11				
2015/16				
2030/31				

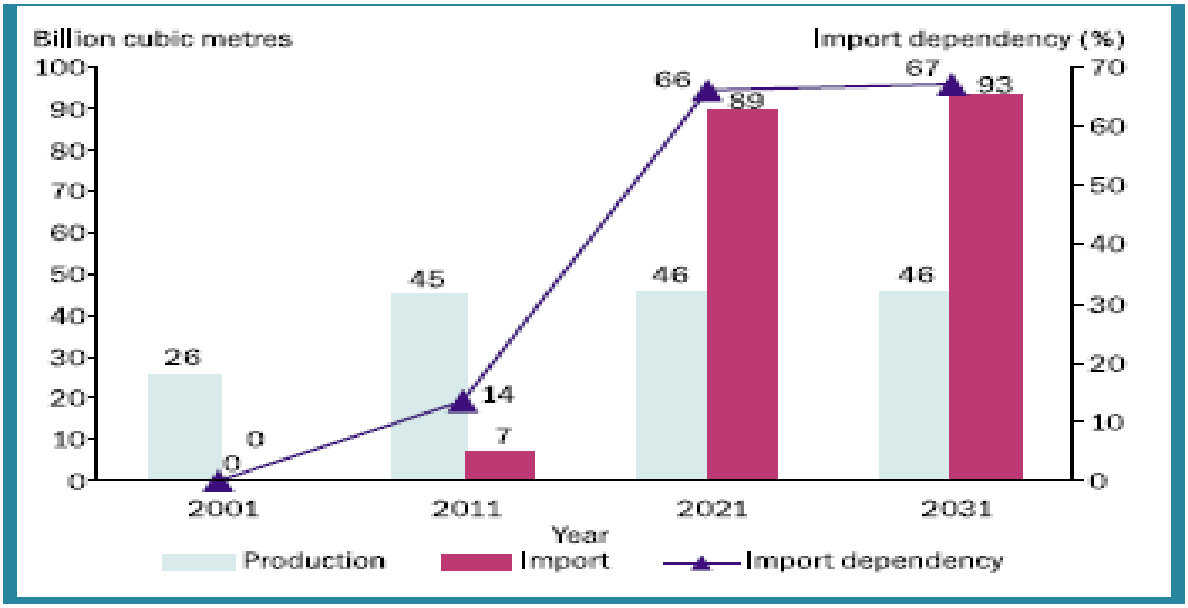
2050				
(p) Provisional				
*Reserve position as on 1st April of commencing year				

Source: Ministry of Petroleum and Natural Gas

6.4.1.3 Import dependency of petroleum products

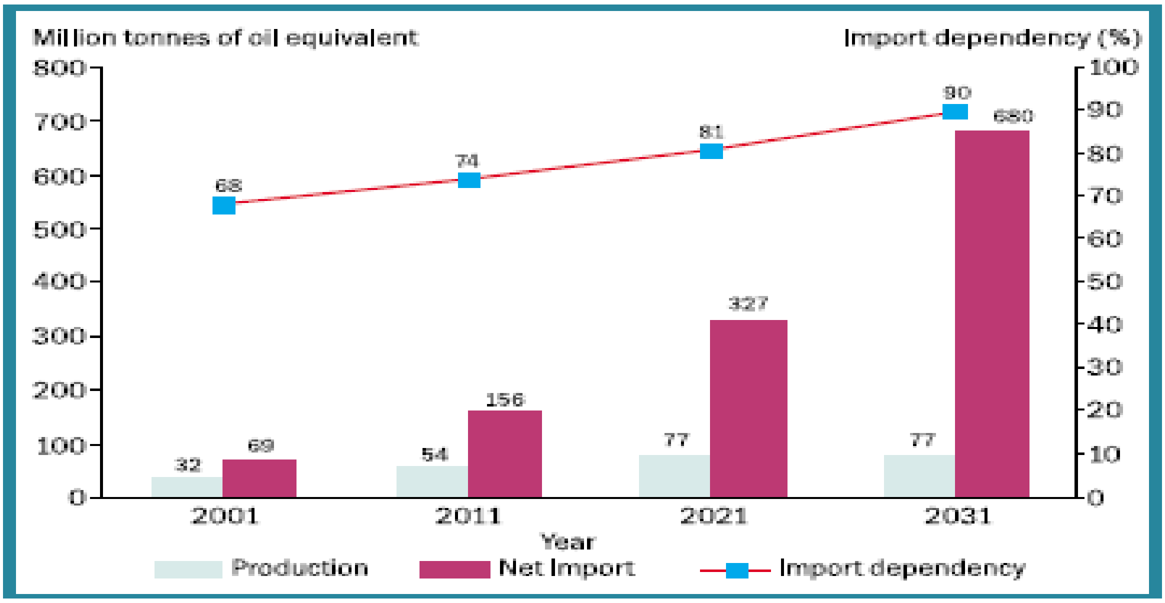
In the BAU scenario, import dependency of oil increases from 68% in 2001 to 90% by 2031, mainly on account of the rapid growth in the transport sector for moving

Figure 6.8 Production, import, and import dependency of natural gas in the business-as-usual scenario



Production, import, and import dependency of petroleum in the business-as-usual scenario is given below.

Figure 6 .9 Production, import, and import dependency of petroleum in the business-as-usual scenario



Figures 6.10 and 6.11 and Tables 6.6 and 1.4 show the net import, import dependency, and production of the petroleum products in the BAU, HG, and their respective HYB scenarios for

2021 and 2031. The import dependency is lowest in the HYB scenario and highest in the HG scenario for all the years. This is primarily due to the fuel demand in the transport sector, details of which are explained under the transport scenario

Table 6.6 Domestic production, net import, and import dependency of petroleum products in 2021

Scenario	Production (Mtoe)	Net import (Mtoe)	Import dependency
BAU	79	330	81
HYB	79	223	74
HG	79	566	88
HHYB	79	299	79

BAU – business-as-usual; HYB – hybrid; HG – high growth; HHYB – high-growth hybrid; Mtoe – million tonnes of oil equivalent

Figure 6.10 Domestic production, net import, and import dependency of petroleum products for 2021

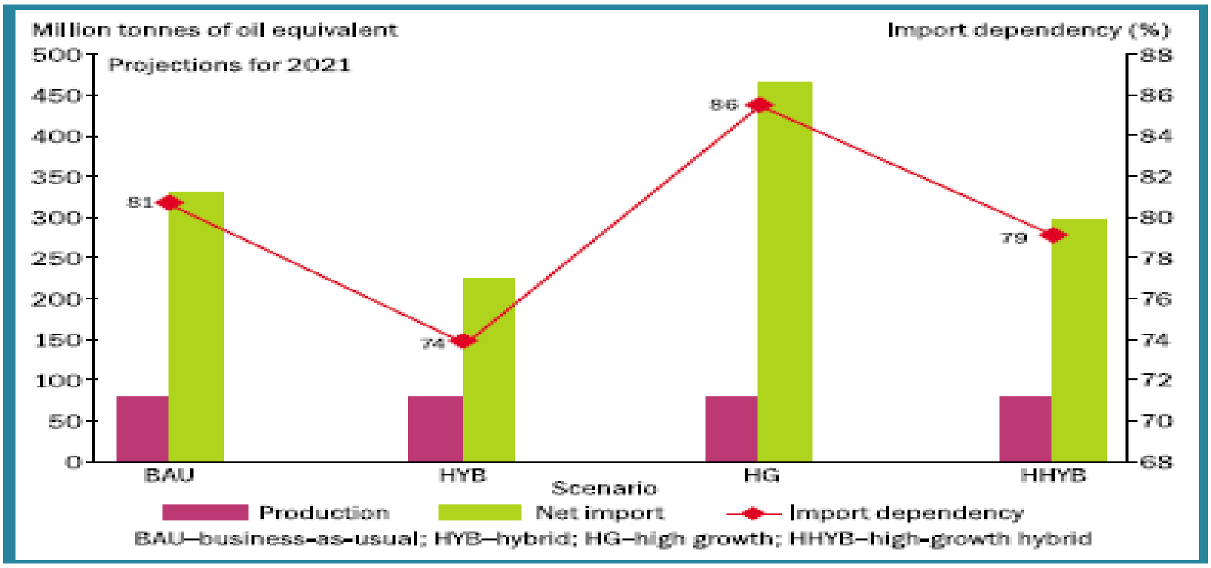


Figure 6.11 Domestic production, net import, and import dependency of petroleum products for 2031

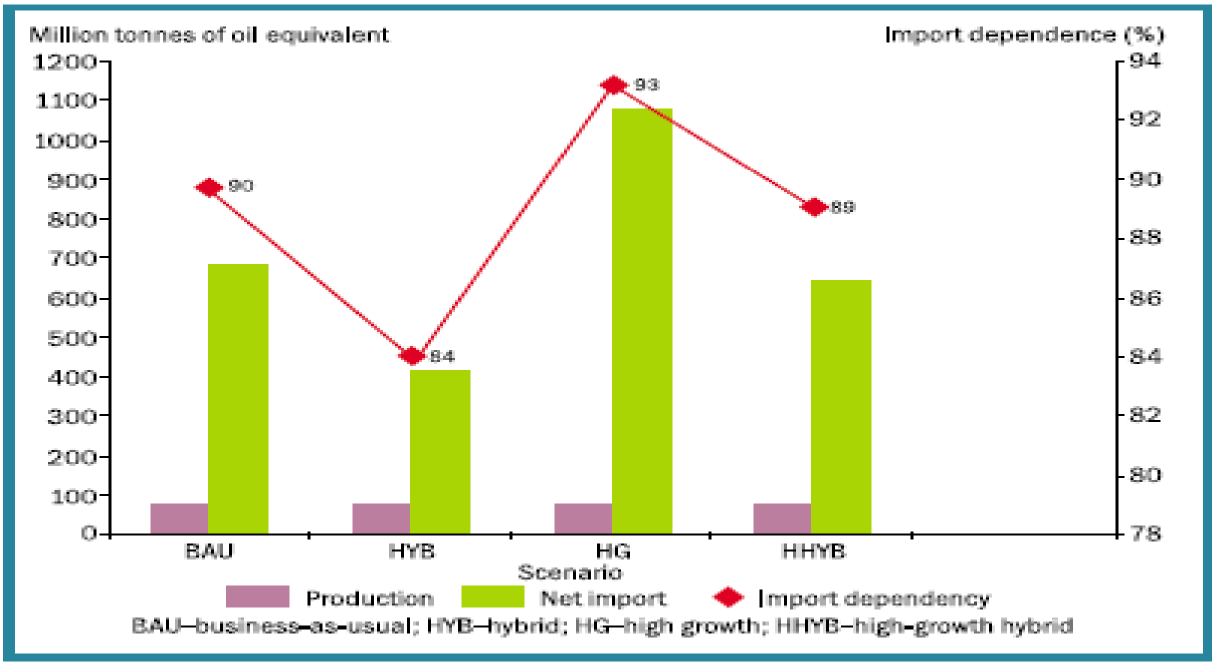


Table 6.7 Domestic productions, net import, and import dependency of petroleum products in 2031

Scenario	Production (Mtoe)	Net import (Mtoe)	Import dependency
BAU	79	688	90
HYB	79	415	84
HG	79	1079	93
HHYB	79	641	89

BAU – business-as-usual; HYB – hybrid; HG – high growth; HHYB – high-growth hybrid; Mtoe – million tonnes of oil equivalent

Table 6.8 presents a comparison of energy intensity of GDP across the eight economy-wide scenarios over the modeling time frame.

Table 6.8 Energy intensity (kgoe/Rs of GDP) for various scenarios

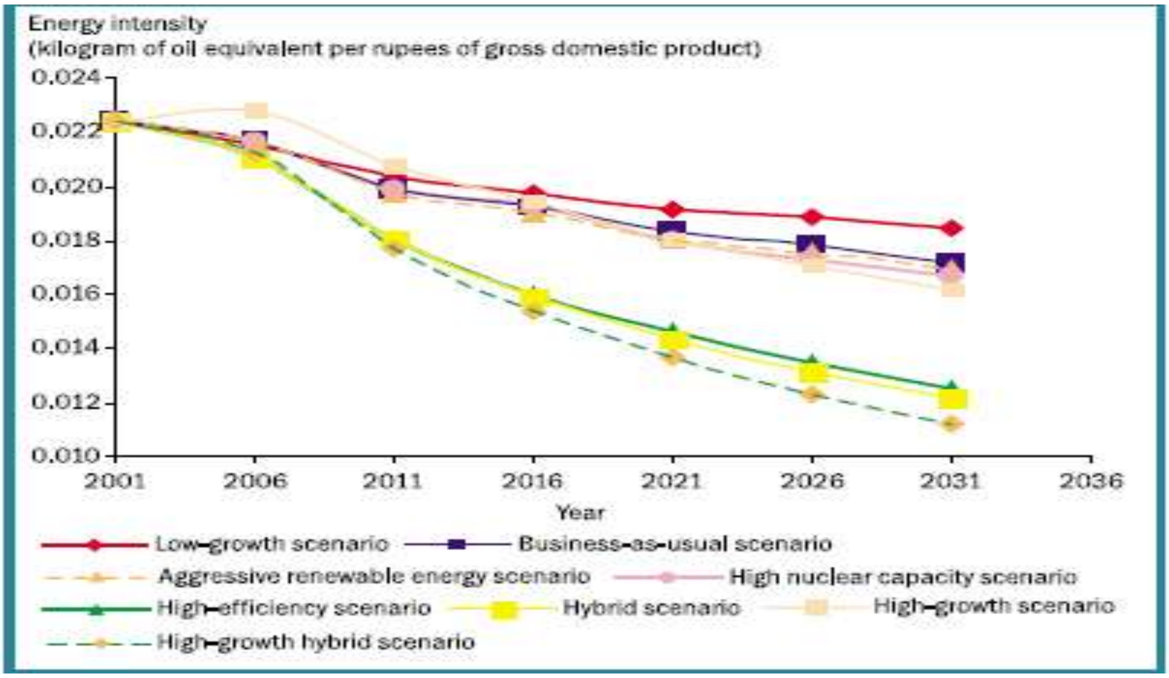
Particulars	**2001**	**2006**	**2011**	**2015**	**2015-16**	**2021**	**2026**	**2030**	**30-2031**	**2050**
LG	0.022	0.022	0.020			0.019	0.019		0.018	
BAU	0.022	0.022	0.020		0.019	0.018	0.018		0.017	
REN	0.022	0.022	0.020		0.019	0.018	0.018		0.017	
NUC	0.022	0.022	0.020		0.019	0.018	0.017		0.017	
EFF	0.022	0.021	0.018		0.016	0.015	0.013		0.012	
HYB	0.022	0.021	0.018		0.016	0.014	0.013		0.012	
HG	0.022	0.023	0.021		0.019	0.018	0.017		0.016	
HHYB	0.022	0.021	0.018		0.015	0.014	0.012		0.011	

LG – low growth; BAU – business-as-usual; REN – aggressive renewable energy; NUC – high nuclear capacity; EFF – high efficiency; HYB – hybrid; HG – high growth; HHYB – high-growth hybrid; kgoe – kilogram of oil equivalent; GDP – gross domestic product

Figure 6.12 presents the trends of energy intensity for various scenarios over the modeling time frame. The figure clearly depicts that the energy intensity exhibits a declining trend from 0.022

kgoe (kilogram of oil equivalent) per rupee of GDP in 2001 to 0.017 kgoe per rupee of GDP in 2031 (a decrease of 23%) in the BAU scenario. It can be inferred that owing to the GDP growth rate of 8% and adoption of government plans and policies, the economy is progressing along an energy-efficient path in the BAU scenario. However, the scenario takes a conservative view with respect to the technology deployment by way of limited penetration of clean-coal technologies, H-frame combined cycle gas turbine, the timing of penetration of efficient power generation technologies, a low degree of penetration of nuclear energy and renewable energy, and so on.

Figure 6.12 Trends in energy intensity across various scenarios, from 2001 to 2031



6.4.1.3.1Pricing of petroleum products

The petroleum and natural gas sector at present suffers from a serious misalignment of prices with domestic prices of many products significantly below any definition of trade party prices. This under pricing is made possible only by placing a large and unsustainable burden on the budget in the form of issue of oil bonds and also under recoveries by the oil companies which puts them at serious financial risk. A phased adjustment of domestic petroleum prices to trade the parity prices must be under taken in a relatively short period.

On the down stream side the pricing of petrol, diesel, LPG, PDS kerosene and a large part of domestic natural gas remain subject to government control and the prices prevailed in 2008 involved huge under pricing of diesel, LPG and kerosene .this has effectively driven out competition from the private sector in marketing despite the presence of a large domestic private player refining and the likely emergence of other private players in the field because the under pricing is not based on transport subsides offered equally to the public sector or the private sector. In fact, the prevailing in pricing and taxation policies and the market structure provide significant protection to the private refineries while imposing a burden on marketing companies.

In general both direct and indirect tax policy should be natural across alternative energy sources except where differences are justified on economic grounds. Taxes and subsidies should be equivalent across fuels in effective calorie terms so that producer and consumer choices as to which fuel and which technology to use are not affected by the taxes and subsidies. However, specifically targeted taxes and subsidies can be justified on socio- economic grounds, e.g. such as employment generation and positive impact on energy security, and also on environmental grounds.

Differential taxes can be justified if they appropriately reflect environmental externalities. A consistent application of the "polluter pays" principle or consumer-pays principle should be made to attain environmental at least – cost

6.4.1.4 Transport sector scenarios

Tables 6.9 – 6.10 present the results for the projected fuel mix in the transport sector across various scenarios for 2011, 2021, and 2031.

Table 6.9 Projected fuel mix in transport sector (in Mtoe) across scenarios for 2011

Fuel	BAU	RAIL – ROAD	PUB-PVT	FUEL-EFF	BIODSL	TPT-HYB
Gasoline	40.00	40.00	40.00	35.00	40.00	35.00
Diesel	60.00	58.00	60.00	53.00	58.00	50.00
Compressed natural gas	2.00	3.00	2.00	2.00	2.00	3.00
Electricity	0.15	0.15	0.15	0.13	0.15	0.15
Bio-diesel	0.00	0.00	0.00	0.00	2.00	2.00
Others	4.00	4.00	4.00	4.00	4.00	4.00

Mtoe – million tonnes of oil equivalent; BAU – business-as-usual

Table 6.10 Projected fuel mix in transport sector (in Mtoe) for various scenarios for 2021

Fuel	BAU	RAIL-ROAD	PUB-PVT	FUEL-EFF	BIODSL	TPT-HYB
Gasoline	74.00	74.00	74.00	57.00	74.00	57.00
Diesel	144.00	135.00	132.00	114.00	135.00	79.00
Compressed natural gas	5.00	6.00	5.00	5.00	5.00	7.00
Electricity	0.15	0.15	0.15	0.11	0.15	9.42
Bio-diesel	0.00	0.00	0.00	0.00	9.00	9.00
Others	9.00	9.00	9.00	9.00	9.00	9.00

Mtoe – million tonnes of oil equivalent; BAU – business-as-usual

Table 6.11 Projected fuel mix in transport sector (in Mtoe) for various scenarios for 2031

Fuel	BAU	RAIL-ROAD	PUB-PVT	FUEL-EFF	BIODSL	TPT-HYB
Gasoline	107.00	107.00	107.00	75.00	107.00	75.00
Diesel	325.00	290.00	300.00	232.00	297.00	138.00
Compressed natural gas	9.00	13.00	9.00	9.00	9.00	17.00
Electricity	0.15	0.15	0.15	0.10	0.15	24.19
Bio-diesel	0.00	0.00	0.00	0.00	28.00	28.00
Others	19.00	19.00	19.00	19.00	19.00	19.00

Mtoe – million tonnes of oil equivalent; BAU – business-as-usual

The inter-scenario comparison of fuel mix in the transport sector is presented pictorially in Figure 6.13

Figure 6.13 clearly indicates that there is a decline in diesel consumption to the extent of 10, 65, and 187 Mtoe for 2011, 2021, and 2031 when the BAU scenario is compared with the TPT-HYB scenario that combines all possible energy-efficient measures induced by policy interventions by the government.

Figure 6.13 Comparison of fuel mix in transport sector across scenarios for 2011, 2021, and 2031

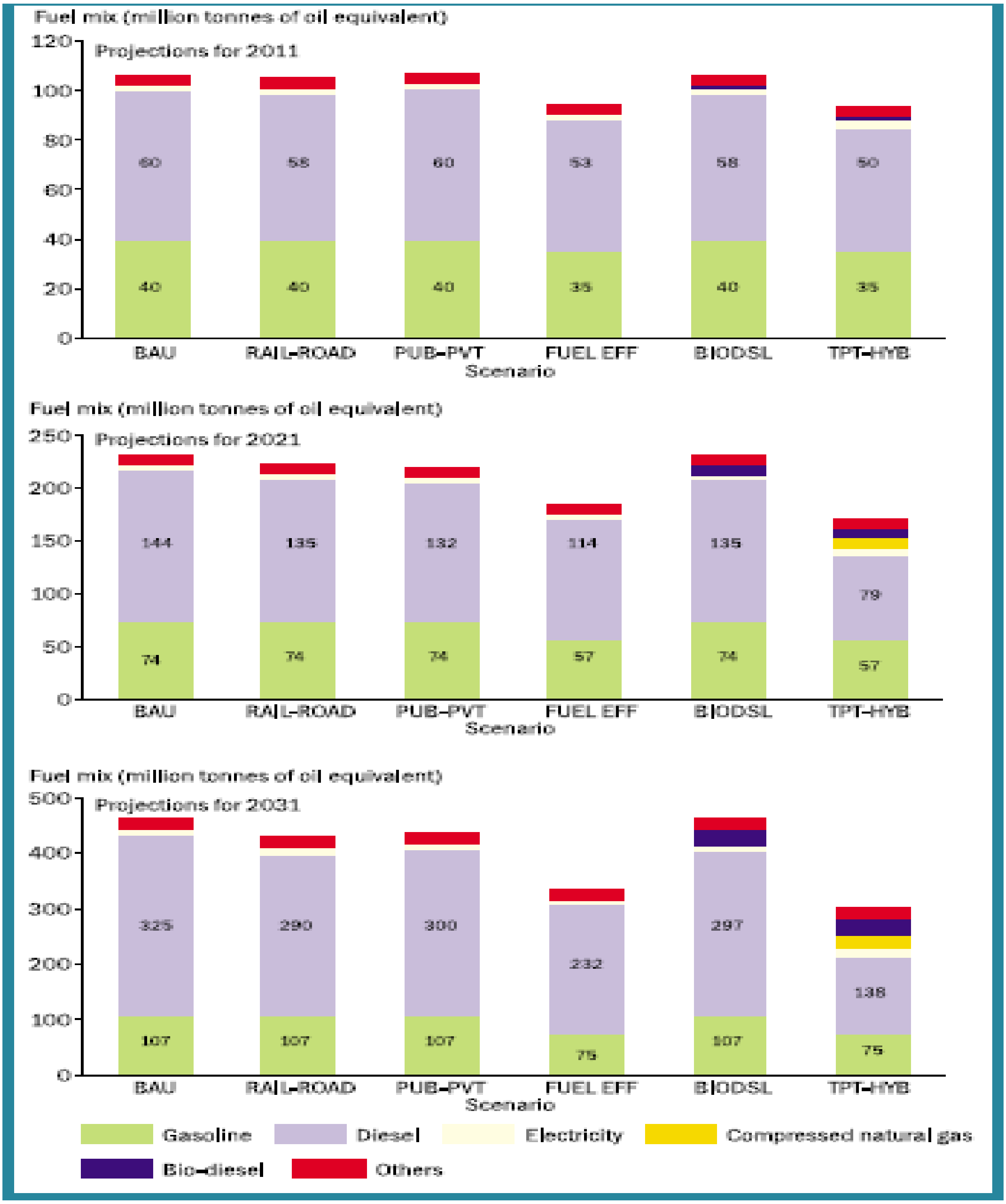


Figure 6.14 presents the comparison of the net import and import dependency of petroleum products across various scenarios for 2011, 2021, and 2031. The figure clearly indicates that if thrust is provided on promoting energy efficiency – thus reducing energy consumption – in the transport sector, the import dependency of petroleum products declines from about 74%, 81%, and 90% in the BAU scenario for 2011, 2021, and 2031, respectively, to 72%, 76%, and 85% in the TPT-HYB for the same time period.

Figure 6.14 Comparison of net import and import dependency of petroleum products across various scenarios for 2011, 2021, and 2031

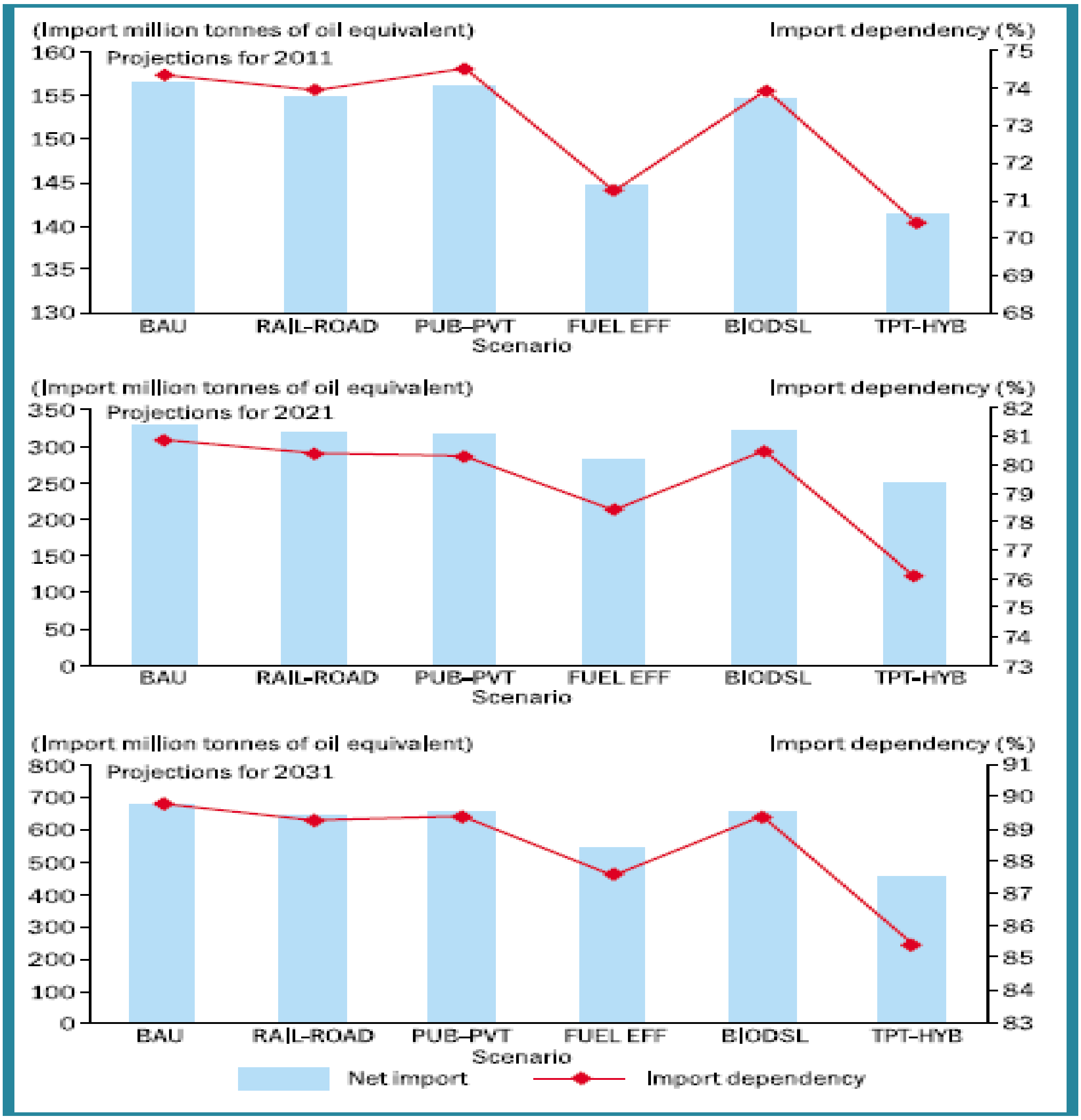
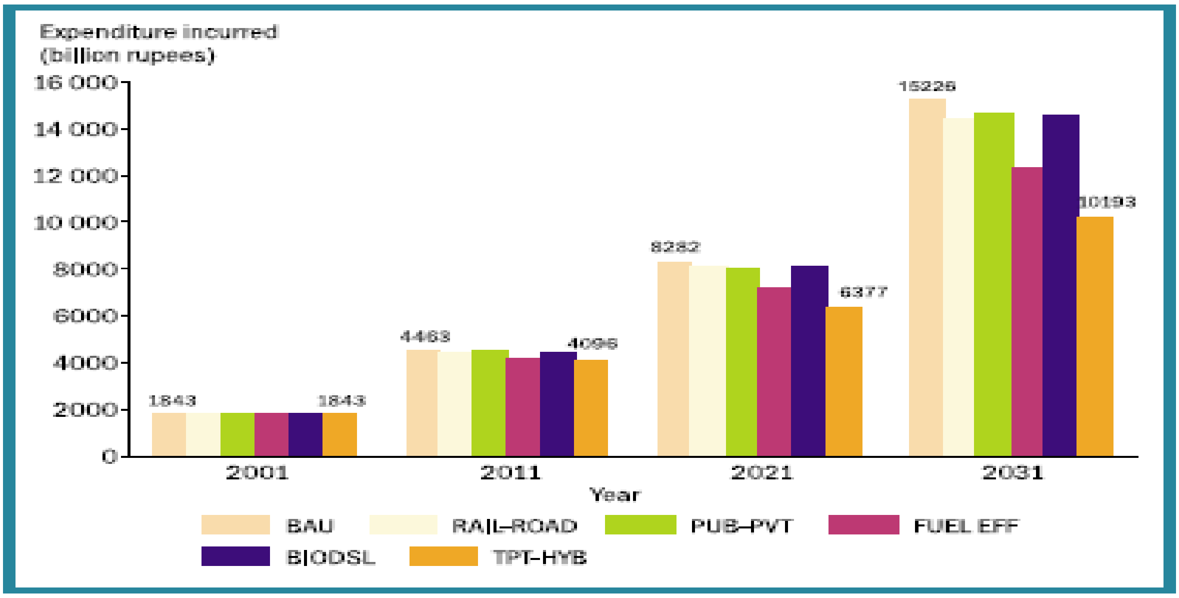


Table 6.12 Summarized the results of all scenarios

Scenario No.	1	2	3	4	5	6	7	8	9	10	11
Scenario Description	**Coal Dominant Case**	**Forced Hydro**	**Forced Nuclear**	**Forced Nuclear Hydro**	**Forced Nuc+ Hyd+Gas**	**Forced Nuc+ Hyd+Gas+ DSM**	**Forced Nuc+Hyd+ Gas+Coal.eff.**	**Forced Nuc+Hyd+ Gas+DSM+ coal. eff**	**Forced Nuc+Hyd+ Gas+DSM+ coal effi. + Rail share up**	**Forced Nuc+Hyd+ Gas+DSM+ coal effi. + Rail share up + Trnsport**	**Scenario 10 + Forced Renewables**
Crude Oil	486	485	486	485	486	486	485	485	447	361	350
Natural Gas	104	105	104	105	197	174	191	171	171	171	150
Coal	1,022	953	998	929	835	715	818	678	701	707	632
Hydro	13	35	35	13	35	35	35	35	35	35	35
Nuclear	76	76	98	98	98	98	98	98	98	98	98
Renewables	2	2	2	2	2	2	2	2	2	2	87
Non-commercial	185	185	185	185	185	185	185	185	185	185	185
Total	1,887	1,840	1,885	1,839	1,837	1,695	1,813	1,673	1,639	1,558	1,536
Total without non – Commercial	1,702	1,655	1,700	1,654	1,652	1,510	1,628	1,488	1,454	1,373	1,351
Crude Oil	25.7%	26.4%	25.8%	26.4%	26.4%	28.7%	26.8%	29.0%	27.3%	23.2%	22.8%
Natural Gas	5.5%	5.7%	5.5%	5.7%	10.7%	10.3%	10.5%	10.2%	10.5%	11.0%	9.8%
Coal	54.1%	51.8%	52.9%	50.5%	45.5%	42.3%	45.1%	41.7%	42.8%	44.4%	41.1%
Hydro	0.7%	1.9%	0.7%	1.9%	1.9%	2.0%	1.9%	2.1%	2.1%	2.2%	2.2%
Nuclear	4.0%	4.1%	5.2%	5.3%	5.3%	5.8%	5.4%	5.9%	6.0%	6.3%	6.4%
Renewables	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	5.6%
Non-commercial	9.8%	10.1%	9.8%	10.1%	10.1%	10.9%	10.2%	11.1%	11.3%	11.9%	12.0%
Total	100	100	100	100	100	100	100	100	100	100	100

Figure 6.15 presents a comparison of expenditure incurred by the economy on the net import of products across various scenarios. As depicted in the figure, the net expenditure on import of petroleum products has increased to 15 226 billion rupees in the BAU scenario, 14 644 billion rupees in the PUB-PVT scenario, 14 423 billion rupees in the RAIL-ROAD scenario, 14 568 billion rupees in the BIODSL scenario, 12 333 billion rupees in the FUEL EFF scenario, and to 10 193 billion rupees in the TPT-HYB scenario in 2031. Thus, a decline to the extent of 33% (that is, by more than one-third) in the import bill of petroleum products can be achieved if all possible energy-efficient measures are undertaken.

Figure 6.15 Expenditure incurred on import of petroleum products



6.4.1.5 Cumulative carbon dioxide emissions

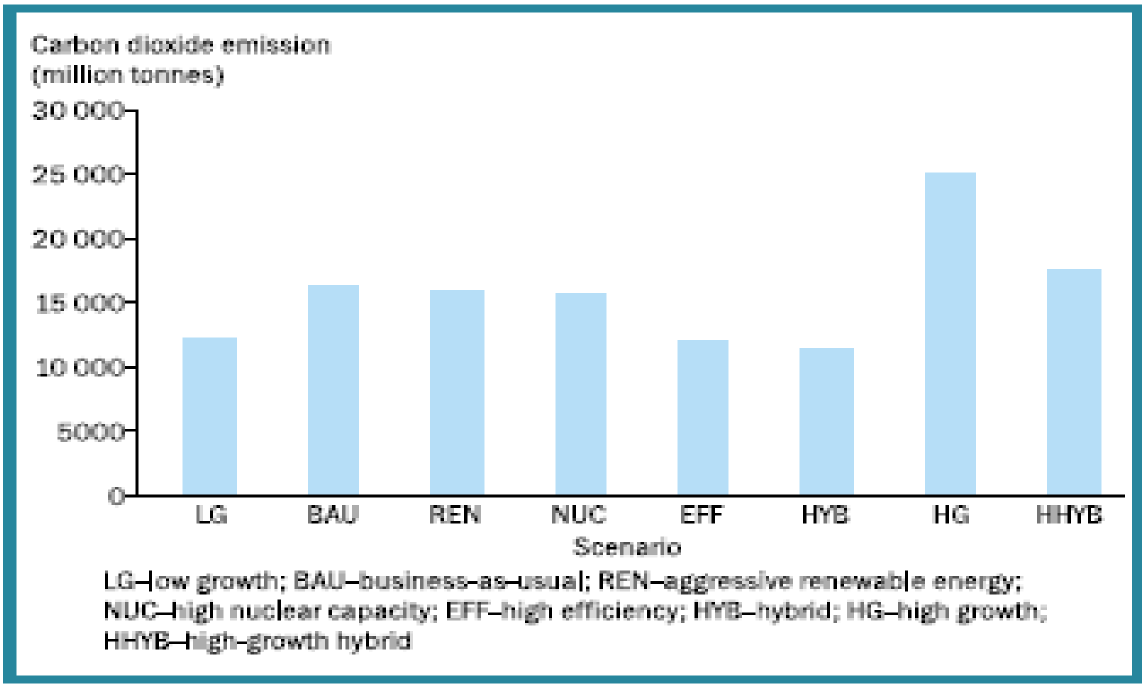
The cumulative CO2 emissions for the period 2001–36 in each of the scenarios are given in Table 6.13 These emissions are significantly lower in the EFF and HYB scenarios: 25% and 29% lower than the emissions in the BAU scenario, respectively. In the HHYB scenario, the CO2 emissions are higher by only 8% compared to those of the BAU scenario. The emissions are also represented in Figure 6.16 to show the magnitude of variations across various scenarios. CO2 emissions are the least in the EFF scenario.

Table 6.13 Cumulative carbon dioxide emissions for different scenarios (from 2001 to 2036)

Scenario	Cumulative CO_2 Emissions (million tones)
LG	12.172
BAU	16.223
REN	15.805
NUC	15.678
EFF	12.113
HYB	11.501
HG	25.004
HHYB	17.553

LG – low growth; BAU – business-as-usual; REN – aggressive renewable energy; NUC – high nuclear capacity; EFF – high efficiency; HYB – hybrid; HG – high growth; HHYB – high-growth hybrid; CO2 – carbon dioxide

Figure 6.16 Cumulative carbon dioxide emissions across various scenarios (2001–36)



(**Reference**: Available Energy Resources And Supply Issues: National Energy Map for India: Technology Vision 2030., The Energy and Resources Institute, Office of the Principal Scientific Adviser, Government of India 2006, Publishers TERI Press The Energy and Resources Institute and Office of the Principal Scientific Adviser, Government of India)

(Energy requirements and supply scenarios, Integrated Energy Policy, Planning Commission, Government of India)

CHAPTER 7

NATIONAL GOALS FOR ENERGY AND CLIMATE

7.1 Introduction

As climate policy India came up with National Action Plan on Climate Change.

India is faced with the challenge of sustaining its rapid economic growth while dealing with the global threat of climate change. This threat emanates from accumulated greenhouse gas emission in the atmosphere, anthropogenic ally generated through long – term and intensive industrial growth and high consumption lifestyles in developed countries. While engaged with the international community to collectively and cooperatively deal with this threat, India needs a national strategy to firstly, adapt to climate change and secondly, to further enhance the ecological sustainability of India's development path.

India needs to sustain an economic growth of at least 9 percent over the next 25 years if it is to eradicate poverty and meet its larger human development goals. Meeting the energy requirements of this growth in a sustainable manner presents a difficult challenge and one that has become more formidable following the steep rise in international energy prices since 2006. It is necessary in this backdrop to evolve an integrated energy policy provides a coherent frame work of policy covering different energy sources in a consistent manner.

Recognizing that climate change is a global challenge, India will engage actively in multilateral negotiations in the UN Framework Convention on Climate Change, in a positive, constructive will be to establish an effective, cooperative and equitable global approach based on the principle of common but differentiated responsibilities and respective capabilities, enshrined in the United Nations Framework Convention on Climate Change (UNFCCC). Such an approach must be based on a global vision inspired by Mahatma Gandhi's wise Dictum – The earth has enough resources to meet people's greed. Thus we must not only promote sustainable production process, but equally, sustainable lifestyles across the globe.

Finally, our approach must also be compatible with our role as a responsible and enlightened member of the international community, ready to make our contribution to the solution of a global challenge, which impacts on humanity as a whole. The success of our national efforts would be significantly enhanced provided the developed countries affirm their responsibility for accumulated greenhouse gas emission and fulfill their commitments under the UNFCCC, to transfer new and additional financial resources and climate friendly technologies to support both adaptation and mitigation in developing countries.

We are convinced that the principle of equity that must underlie the global approach must allow each inhabitant of the earth an equal entitlement to the global atmospheric resources.

In this connection, India is determined that its per capita greenhouse gas emission will at no point exceed that of developed countries even as we pursue our development objectives.

7.2. Principles

Maintaining a high growth rate is essential for increasing living standards of the vast majority of our people and reducing their vulnerability to the impacts of climate change. In order to achieve a sustainable development path that simultaneously advances economic and environmental objectives, the National Action Plan for Climate Change (NAPCC) will be guided by the following principles.

- Protecting the poor and vulnerable sections of society through an inclusive and sustainable development strategy, sensitive to climate change.
- Achieving national growth objectives through a qualitative change in direction that enhances ecological sustainability, leading to further mitigation of greenhouse gas emission.
- Devising efficient and cost-effective strategies for end use Demand Side Management.
- Deploying appropriate technologies for both adaptation and mitigation of greenhouse gases emissions extensively as well as at an accelerated pace.
- Engineering new and innovative forms of market, regulatory and voluntary mechanisms to promote sustainable development.
- Effecting implementation of programmes through unique linkages, including with civil society and local government institutions and through public-private-partnership.

Welcoming international cooperation for research, development, sharing and transfer of technologies enable by additional funding and a global IPR regime that facilitates technology transfer to developing countries under the UNFCCC.

7.3 Approach

The NAPCC address the urgent and critical concerns of the country through a directional shift in the development pathway, including through the enhancement of the current and planned programmes presented in the Technical Document.

The National Action Plan on Climate Change identifies measures that promote our development objectives while also yielding co-benefits for addressing climate change effectively. It outlines a number of steps to simultaneously advance India’s development and climate change-related objectives of adaptation and mitigation.

7.4. The Way Forward Eight National Missions

In dealing with the challenge of climate change we must act on several fronts in a focused manner simultaneously. The National Action Plan hinges on the development and use of new technologies. The implementation of the Plan would be through appropriate institutional mechanisms suited for effective delivery of each individual Mission’s objectives and included public private partnerships and civil society action. The focus will be on promoting understanding of climate change, adaptation and mitigation, energy efficiency and natural resources conservation.

There are Eight National Missions which form the core of the National Action Plan, representing multi-pronged, long-term and integrated strategies for achieving key goals in the context of climate change. While several of these programmes are already not of our current actions, they may need a change in direction, enhancement of scope and effectiveness and accelerated implementation of time – bound plans.

7.4.1 National Solar Mission

A National Solar Mission will be launched to significantly increase the share of solar energy in the total energy mix while recognizing the need to expand the scope of other renewable are non – fossil options such as nuclear energy, wind energy and biomass.

India is a tropical country, where sunshine is available for longer hours per day and in great intensity. Solar energy, therefore, has great potential as future energy sources. It also has the advantage of permitting a decentralized distribution of energy, thereby empowering people at the grassroots level. Photovoltaic cells are becoming cheaper with new technology. There are newer, reflector – based technologies that could enable getting up megawatt scale solar power plants across the country. Another aspect of the Solar Mission would be to launch a major R&D programme, which could draw upon international cooperation as well, to enable the creation of more affordable, more convenient solar power systems, and to promote innovations that enable to storage of solar power of sustained, long – term use.

7.4.2National Mission for Enhanced Energy Efficiency

The Energy Conservation Act of 2001 provides a legal mandate for the implementation of the energy efficiency measures through the institutional mechanism of the Bureau of Energy Efficiency (BEE) in the Central Government and designated agencies in each state. A number of schemes and programmes have been initiated and it is anticipated that these would result in a having of 10,000 MW by the end of 11th Five Year Plan in 2012.

To enhance energy efficiency, four new initiatives will be put in place. These are :

- A market based mechanism to enhance cost effectiveness of improvements in energy in energy – intensive large industries and facilities, through certification of energy savings that could be traded.
- Accelerated the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable.
- Creation of mechanisms that would help finance demand side management programmes in all sectors by capturing future energy savings.
- Developing fiscal instruments to promote energy efficiency

7.4.3 National Mission on Sustainable Habitat

A National Mission on Sustainable Habitat will be launched to make habitat sustainable through improvements in energy efficiency in buildings, management of solid waste and modal shift to public transport. The Mission will promote energy efficiency as an integral component of urban planning and urban renewal through three initiatives.

i. The Energy Conservation Building Code, which addresses the design of new and large commercial buildings to optimize their energy demand, will be extended in its application and incentives provided for retooling existing building stock.

ii. Recycling of material and Urban Waste Management will be a major component of ecologically sustainable economic development. India already has a significantly higher rate of recycling of waste compared to developed countries. A special area of focus will be the development of technology for producing power from waste. The National Mission will include a major R&D programme, focus in on bio chemical conversion, waste water use, sewage utilization and recycling options wherever possible.

iii. Better urban planning and modal shift to public transport. Making long term transport plans will facilitate the growth of medium and small cities in ways that ensure efficient and convenient public transport.

In addition, the Mission will address the need to adapt to future climate change by improving the resilience of infrastructure, community based disaster management, and measures for improving the warning system for extreme weather events. Capacity building would be an important component of this Mission.

7.4.4 National Water Mission:

A National Water Mission will be mounted to ensure integrated water resource management helping to conserve water, minimize wastage and ensure more equitable distribution both across and within states. The Mission will take into account the provisions of the National Water Policy and develop of a framework to optimize water use by increasing water use efficiency by 20% through regulatory mechanisms with differential entitlements and pricing. It will seek to ensure that a considerable share of the water needs of urban areas are met through recycling of waste water, and ensuring that the water requirements of coastal cities with inadequate alternative sources of water are met through adoption of new and appropriated technologies such as low temperature desalination technologies that allow for the use of ocean water.

The National Water Policy would be revisited in consultation with states to ensure basin level management strategies to deal with variability in rainfall and river flows due to climate change. This will include enhanced storage both above and below ground, rainwater harvesting, coupled with equitable and efficient management structures.

The Mission will seek to develop new regulatory structures, combined with appropriate entitlements and pricing. It will seek to optimize the efficiency of existing irrigation systems, including rehabilitation of systems that have been run down and also expand irrigation, where feasible, with a special effort to increase storage capacity. Incentive structures will be designed to promote water – neutral or water – positive technologies, recharging of under-ground water sources and adoption of large scale irrigation programmes which rely on sprinkles, drip irrigation and ridge and furrow irrigation.

7.4.5 National Mission for Sustaining the Himalayan Ecosystem

A Mission for sustaining the Himalaya Ecosystem will be launched to evolve management measures for sustaining and safeguarding the Himalayan glacier and mountain eco-system. Himalayas, being the source of key perennial rivers, the Mission would, inter-alia, seek to understand, whether and the extent to which, the Himalayan glaciers are in recession and how the problem could be addressed. This will require the joint effort of climatologists, glaciologists and other experts. We will need to exchange information with the South Asian countries and countries sharing the Himalayan ecology.

An observational and monitoring network for the Himalayan environment will also be established to assess freshwater resources and health of the ecosystem. Cooperation with neighboring countries will be sought to make the network comprehensive in its coverage.

The Himalayan ecosystem has 51 million people who practice hill agriculture and whose vulnerability is expected to increase on account of climate change. Community-based management of these ecosystems will be promoted with incentives to community organizations and panchayats for protection and enhancement of forested lands. In mountainous regions, the aim will be to maintain two-thirds of the area under forest covers in order to prevent erosion and land degradation and ensure the stability of the fragile eco-system.

7.4.6 National Mission for A Green India

A National Mission will be launched to enhance ecosystem services including carbon sinks to be called Green India. Forests play an indispensable role in the preservation of ecological balance and maintenance of bio-diversity. Forests also constitute one of the most effective carbon – sink

The Prime Minister has already announced a Green India campaign for the afforestation of 6 million hectares. The national target of area under forest and tree cover is 33% while the current are under forests is 23%.

The Mission of Green India will be taken up on degraded forest land through direct action by communities, organized through Joint Forest Management Committees and guided by the Departments of Forest in state governments. An initial corpus of over Rs. 6000 crore has been earmarked for the programme through the Compensatory Afforestaion Management and Planning Authority. (CAMPA) to commence work. The programme will be scaled up to cover all remaining degraded forest land. The institutional arrangement provides for using the corpus to leverage more funds to scale up activity.

7.4.7 National Mission for Sustainable Agriculture

The Mission would devise strategies to make Indian Agriculture more resilient to climate change. It would identity and develop new varieties of crops and especially thermal resistant crops and alternative cropping patterns, capable of withstanding extremes of weather, long dry spells, flooding, and variable moisture availability.

Agriculture will need to be progressively adapted to projected climate change and our agricultural research systems must be oriented to monitor and evaluate climate change and recommend changes in agricultural practices accordingly.

This will be supported by the convergence and integration of traditional knowledge and practice system, information technology, geospatial technologies and biotechnology. New credit and insurance mechanisms will be devised to facilitate adoption of desired practices.

Focus would be on improving productivity of rain fed agriculture. India will spearhead efforts at the international level to work towards an ecologically sustainable green revolution.

7.4.8 National Mission on Strategic Knowledge for Climate Change

To enlist the global community in research and technology development and collaboration through mechanisms including open source platforms, a Strategic Knowledge Mission will be set up to identify the challenges of, and the response to climate change. It would ensure funding of high quality and focused research into various aspects of climate change.

The Mission will also have, on its research agenda, socio-economic impacts of climate change including impact on health, demography, migration patterns and livelihoods of coastal communities. It would also support the establishment of dedicated climate change related academic units in Universities and other academic and scientific research institutions in the country which would be networked. A Climate Science Research Fund would be created under the Mission to support research. Private sector initiatives for development of innovative technologies for adaptation and mitigation would be encouraged through identified centres. The Mission will also focus on dissemination of new knowledge based on research findings.

7.5 Future Plan :

These National Missions will be institutionalized by respective ministries and will be organized through inter-sectoral groups which include in addition to related Ministries, Ministry of Finance and the Planning Commission, experts from industry, academia and civil society. The institutional structure would vary depending on the task to be addressed by the Mission and will include providing the opportunity to compete on the best management model.

Each Mission will be tasked to evolve specific objective spanning the remaining years of the 11th Plan and the 12th Plan period 2012-13 to 2016-17. Where the resource requirements of the Mission call for an enhancement of the allocation in the 11th Plan, this will be suitably considered, keeping in mind the overall resources position and the scope for re-prioritization.

Comprehensive Mission documents detailing objectives, strategies, plan of action, timelines and monitoring and evaluation criteria would be developed and submitted to the Prime Minister’s Council on Climate Change by December 2008. The Council will also periodically review the progress of these Missions. Each Mission will report publicity on its annual performance.

Building public awareness will be vital in supporting implementation of the NAPCC. This will be achieved through national portals, media engagement, civil society involvement, curricula reform and recognition / awards, details of which will be worked out by an empowered group. The Group will also consider methods of capacity building to support the goals of the National Missions.

We will develop appropriate technologies to measure progress in actions being taken in terms of avoided emissions, wherever applicable, with reference to business as usual scenarios. Appropriate indicators will be evolved for assessing adaptation benefits of the actions.

These Eight National Missions, taken together, with enhancement is current and ongoing programmes included in the Technical Document, would not only assist the country to adapt to climate change, but also, importantly, launch economy on a path that would progressively and substantially result in mitigation through avoided emissions.

7.6 Policies:

7.6.1Cola supply related policies

Coal accounts for ever 50% of India’s commercial energy consumption and about 78% of domestic coal production is dedicated to power generation .This domestic coal in India’s energy mix is not likely to change till 2031-32.The coal sector has become profitable in recent years primarily as a result of price increases following decontrol and also the rising share of open cast production .Top priority needs to be given to augment domestic production of coal even while thermal coal imports are freely allowed to meet energy needs. Imported coal is more cost competitive along the western and southern coasts of India compared to domestic coal and if any case imported coal is much more competitiveness in terms of price compared to imported gas at these coastal locations. This cost advantages of imported coal over imported gas is likely to continue for same time in the future.

The following policys initiatives are needed to stimulate coal production

i) The coal mines (Nationalization) Act 1973, should be amended to facilitate: a) private participation in coal mining for purposes other than those specified in the Act and (b) offering of future coal blocks to potential entrepreneurs. Excluding private investment from coal mining is illogical when private exploitation of petroleum, which is a much more scarce resource, is allowed.

The coal is an important initiative, but there is no reason why it should not be opened up for private investment in general. A consensus needs to be build to amend the Act appropriately.

ii)Pending opening of the sector to private production, domestic coal production should be stepped up by allotting coal blocks to central and state public sector units and also private sector units in the form of captive mines for notified end uses eligible for captive mining. Coal blocks held by Coal India Limited (CIL) that cannot be brought into production by 2016 – 17, either directly or through joint ventures, should be made available to other eligible candidates for development and for bringing into production as early as possible.

iii)Simultaneously, the creation of port infrastructure to facilitate thermal coal imports should be encouraged through appropriate policy initiatives. This can be done by inviting PPP projects on a BOT basis, or if it is a dedicated jetty for a particular captive use, then by the establishment of such a facility by the coal using entity itself. This will facilitate coastal power generation capacity based on imported thermal coal will also put desirable competitive pressure on the domestic coal industry to become more efficient and to improve quality.

Iv) Coal companies should be asked to conform to the international practice of preparing coal i.e., sizing, washing etc. prior to its sale. Prepared coal should be the nor and the regulator should insist on it.

projects on a BOT basis, or if it is a dedicated jetty for a" particular captive use, then by the establishment of such a facility by the coal using entity itself. This will facilitate coastal power generation capacity based on imported thermal coal. Imports of thermal coal will also put desirable competitive pressure on the domestic coal industry to become more efficient and to improve quality.

iv) Coal companies should be asked to conform to the international practice of preparing coal *i.e.* sizing, washing etc. prior to its sale. Prepared coal should be the norm and the regulator should insist on it.

v) The system of coal linkages with long-term coal supply agreements with strict penalties for not meeting contracted supplies, quality and off take commitments has been implemented for all but the power sector, and needs to be extended to it.

7.6.2 Oil and Gas Sector Policies

To ensure effective competition in the oil and gas sector it is important to establish independent oversight of both upstream and downstream activities. On the upstream side, Directorate General Hydrocarbons (DGH), an arm of the Ministry, currently oversees allocation and exploitation of oil & gas reserves and enforces profit sharing with exploration & production companies. It is essential for the Directorate General of Hydrocarbons to be strengthened and made independent of the Ministry.

There is an urgent need to have an independent regulator for both upstream and downstream sectors, to ensure that markets function in a competitive manner. The role of the regulator in a competitive market is not to fix prices but to ensure open access to common infrastructure and to regulate user charges for such infrastructure such as gas pipelines, port facilities etc. The regulator must also ensure that oligopolistic power usually found in the upstream sector, is not exploited. The regulator should also ensure that markets such as for city gas distribution are not cornered to prevent competition.

7.7 Electricity

There are several areas where policy initiatives are needed in the electricity sector covering generation, transmission and distribution.

(i) <u>Improving losses in distribution:</u>

6.1.1 The highest priority must be given to reducing technical and. commercial losses of the state transmission and distribution utilities which are very high at present. This is an essential precondition for sustained expansion in power since only financially healthy state power distribution utilities can sustain the growing generation and transmission of Central Power Sector PSUs and State Power Sector Utilities (SPSUs) and provide the needed comfort on payment security to attract private investment in the power sector at internationally competitive tariffs. Several initiatives are needed,

The existing Accelerated Power Development and Reform Programme (APDRP) should be restructured to ensure energy flow auditing at the distribution transformer level through automated meter reading, a geographical information system (GIS) mapping of the network and consumers and the separation of feeders for agricultural pumps. Technical and commercial aspects of power distribution should get audited independently by the electricity regulators. Investment in developing a Management Information System (MIS) that can support a full energy audit for each distribution transformer is essential for reduction in AT&C losses. This will also fix accountability and provide a baseline which is an essential prerequisite to management reform and/or privatisation. The revised APDRP will provide incentives to companies/ undertaking/ retail Supply business that are linked to performance outcomes and will also include incentives to staff for reduction in AT&C losses.

A liberal captive and group captive power generation regime, which is envisaged under the Electricity Act 2003, should be realised on the ground. A liberal captive generation regime will not only derive economic benefits from the considerable scope which exists for distributed generation, but will also set competitive wheeling charges to supply power to group captive consumers. This will also pave the way for open access to distribution networks. Open access is mandatory under the Electricity Act 2003 but is resisted by incumbents as they fear that all the high value paying customers would go away and they would be left with small and subsidised agricultural and domestic customers. Since these customers have strong political constituencies, it may be difficult to raise their tariffs when needed and the incumbent utilities would not remain viable for long. These concerns can be taken care of if the cross-subsidy surcharge, wheeling charge and back-up charge associated with open access are set properly. Unfortunately, many SERCs are not doing it. If these are set too high, open access could be effectively thwarted. These charges need to be periodically revised and independently regulated.

It is essential to separate the cost of the pure wires business (carriage) from the energy business (content) in both transmission and distribution at different voltages. The Electricity Act 2003 recognises such separation for the transmission sub-segment. Separation of content from carriage in the distribution sub-segment, however, is considered only as a means to the provision of open access. The wires business within the distribution sub-segment is also a natural monopoly and must be regulated. Further, introduction of Un-scheduled Interchange Charges for the intra-state sales and the upgradation of State Load Despatch Centres to the technological level of Regional Load Despatch Centres should be realised.

A robust and efficient inter-state and intra-state transmission system with adequate surplus capacity that is capable of transferring power from surplus regions to deficit regions is a must for ensuring optimal operation of the system. An independent transmission corporation without any interest in generation or distribution should do this. Rehabilitation of existing thermal stations could raise capacity at least-cost in the short-run. Similarly rehabilitation of hydro stations could yield much needed peak capacity at negligible cost. Both these steps should be taken up urgently.

(ii) <u>Rationalising Cost of Power:</u>

Power tariffs in India for industry and commerce are among the highest in the world. It is important to reduce the cost of power to increase the competitiveness of the Indian economy, encourage labour intensive industries that use relatively unskilled workers and also to increase consumer welfare.

The Tariff Policy requires that all generation and transmission projects should be competitively built on the basis of tariff-based bidding. Tariff Policy allows, Public Sector Undertakings a 5 year window upto January 19, 2010 or till the time regulatory commission is satisfied wherein projects undertaken by the public sector need not be bid competitively, but they should also be encouraged to participate in such bids.

In cases where tariff continues to be determined on the basis of costs and norms, regulators may either adopt a return on equity approach or return on capital approach, whichever is considered better in the interest of consumers? In deciding the level of return provided, the regulator should *inter-alia* take into account the return available on long-term government bonds adjusted for reasonable risk premiums associated with equity investments.

The current practice of state regulators not allowing state public sector power utilities the same returns as the central public sector utilities should be strongly opposed in the interest of strengthening fair competition which alone will bring down prices in the long-run. This problem would disappear once PSUs are required to do tariff based bidding.

Differential payment security structures for Central Power Sector PSUs and the private sector should be abolished.

Consumer prices for electricity are currently set by State Electricity Regulatory Commissions on cost plus basis. Regulators should set multi-year tariffs and differentiate them by time of day tariff. While some state regulators have done so, the Forum of Regulators should be actively used to encourage others to do so.

An Effective term of loans available to the power sector can easily be extended to 20 years through innovations such as staggered and uneven repayment schedules, refinancing of loans post project completion and refinancing of bullet payments in the 10^{th} or 12^{th} year for a further period of 8-10 years. The Government could seed the market for such instruments by encouraging PSUs such as Power Finance Corporation (PFC) and Rural Electricity Corporation (REC) to introduce such innovative financing instruments.

Distribution should be bid out on the basis of a distribution margin or paid for by a regulated distribution charge determined on a cost plus basis including a profit mark up similar to that paid for generation as recommended above.

(iii) <u>Ensuring Availability of Gas for Power Generation:</u>

The total gas based generation capacity was 15,860 MW as on 31.3.2008 based on gas and liquid fuels, The bulk of this capacity is used for base load under combined cycle operation. However, because gas supplies to these plants have not materialised as expected, capacity utilisations have been restricted and the overall utilisation was at only 58.2%. In 2007-08 a significant part of this capacity was realised under the earlier liquid fuel policy while the rest has been built based on fuel supply agreements that have proved to be unenforceable. These would have been unbankable in a financially prudent environment but in fact, financing institutions have allowed these capacities to be established. Future policy must be guided by the principle that new gas capacity will not be built without firm and bankable gas supply agreements.

7.8 Energy Efficiency and Demand Side Management:

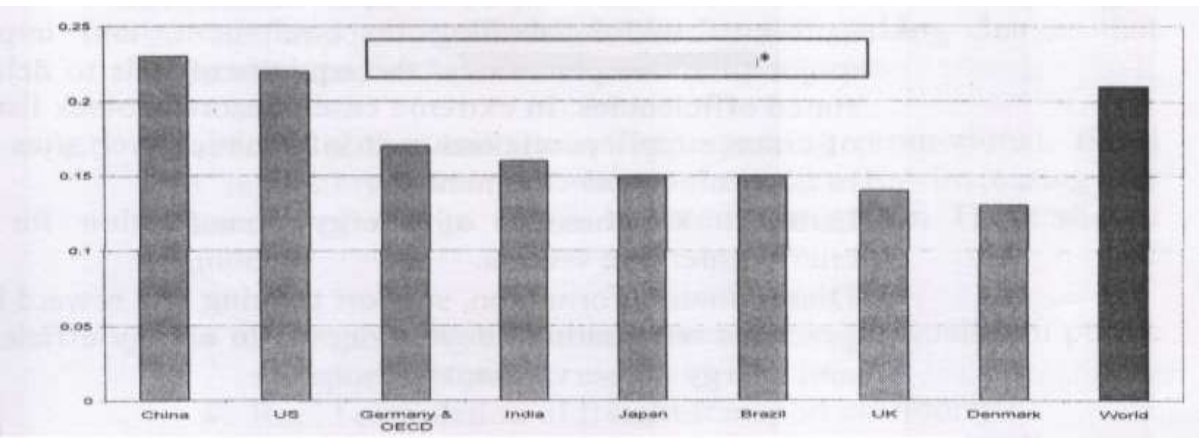
Lowering the energy intensity of GDP growth by achieving higher energy efficiency levels is as important as increasing energy availability and helps ensure energy security. In fact, a "Negawatt", which is conceptually "produced" by a reduction of energy need has more value than a Megawatt generated since it avoids transmission and distribution losses as well as externalities associated with generation and transport of fuel[1]. It is possible as reflected in the lower range of projected energy requirement given earlier to reduce India's energy intensity per unit of GDP by up to 20% from current levels over ten to twenty years through an aggressive pursuit of policies which encourage energy efficiency and conservation.

It is worth noting that the energy intensity of India's growth has been falling and energy intensity today is about half of what it used to be in the early seventies *(See Figure 8.1}*. Currently, we consume 0.16 kg of oil equivalent (kgoe) per dollar of GDP expressed in purchasing power parity terms which is significantly lower than the 0.23 kgoe of China, 0.22 kgoe of the US and a World average of 0.21 kgoe. India's energy intensity is even marginally lower than that of Germany &

[1] Least-cost planning approach could be adopted to provide a level playing field to Negawatts and Megawatts so that electricity regulators permit the same return on the investment needed to save a watt through demand side management as to supply an additional watt. Once tariff based bidding becomes the norm, competitive bids for Negawatt creation through demand side management may be invited by energy distribution companies or State electricity Boards.

OECD at 0.17 kgoe. However, Denmark at 0.13 kgoe, UK at 0.14 kgoe and Brazil & Japan at 0.15 kgoe are ahead of India. Many sectoral studies confirm that energy intensity can be brought down further in India with current commercially available technologies without incurring prohibitive costs.

Table 7.1 Energy Intensity of GDP in 2003 (TPES/GDP(keoe/$-2000PPPl)



* Total Primary Energy Supply in kg of oil equivalent/GDP valued in purchasing power parity adjusted US dollars of 2000

8.3 Efficiency gains can be achieved in the process of energy extraction, in energy conversion, in transportation of goods, as well as in appliances used by final consumers. Further, the same level of output or service can be obtained by alternate means requiring less energy. The major areas where efficiency in energy use can make a substantial impact are mining, electricity generation, electricity transmission, electricity distribution, water pumping, industrial production processes, haulage, mass transport, building design, construction, heating, ventilation, air conditioning, lighting and household appliances. As energy prices are decontrolled, and the Indian economy opens up to international competition, it will have to become more efficient and this means the energy consuming sectors will have to be more energy efficient. This process is already underway , in India's steel and cement industry.

8.4 The following policies should be implemented for raising energy efficiency. Some of these policies can be implemented through voluntary targets undertaken by industry associations as opposed to external dictates and enforcement.

(i) The Bureau of Energy Efficiency (BEE) should be an autonomous statutory body under the Energy Conservation Act. be independent of all the energy ministries and be funded by the Central Government. The new entity should:

- Accelerate the pace of improvement in energy efficiency of energy using appliances, equipment and vehicles, and create "golden carrot" incentives in the form of substantial rewards to the firm which first commercialises equipment that exceeds a prescribed energy efficiency target.

- Enforce truthful labelling on equipment, and impose major financial penalties if the equipment fails to deliver stated efficiencies. In extreme cases, resort to black listing of errant suppliers on consumer information web sites and in government procurement.

- Establish benchmarks of energy consumption for all energy intensive sectors.

- Disseminate information, support training and reward best practices with national level honours in energy efficiency and energy conservation.

(ii) The gross efficiency in power generation should be increased from the current average of 30.5% to 34%. All new plants should be mandated to adopt technologies that improve their gross efficiency from the prevailing 36% to at least 38-40% which would be comparable, given our ambient air temperature, to international standards.

(iii) The government should consciously shift its procurement policies in the public sector to reflect energy use cost by adopting the principle of minimum life cycle cost instead of minimum initial cost in the case of energy using equipment, especially in transport.

(iv) Promote freight movement by energy efficient modes such as railways, coastal and inland shipping instead of by road. This will require that railways provide guaranteed, safe and timely deliveries, infrastructure for shipping is developed and procedures and processes for movement of traffic are simplified.

(v) To make road transport energy efficient, minimum fuel efficiency standards for all vehicles should be prescribed and enforced. In addition standards for road maintenance should also be prescribed and enforced.

(vi) Urban rapid mass transport systems can provide energy efficient transport. In order to promote use of public transport system, it should be a convenient, comfortable and cost-effective alternative. For this, taxes on public transport vehicles should be lower than private transport. At present the tax on public transport, including licence fee per passenger levied by the states, makes public transport more highly taxed. Equally important, the use of private vehicles should be discouraged through imposition of congestion fee and parking charges that reflect the true social cost of land in urban areas.

(vii) Necessary policy initiatives encompassing promotional, fiscal and regulator}' measures should be taken for increasing the efficiency of energy use in the transport sector. These should include:

- Strengthening of and improvement in the quality of public transport system;
- Rapid completion of freight transport corridors;
- Promotion of use of rail, inland waterways and short sea shipping for freight transport;
- Support for non-motorized means of travel such as walking and cycling in urban areas;
- Comprehensive mobility planning and management using intelligent transport systems

(viii) Specialisations in energy efficiency/conservation in technical colleges shall be instituted and certification of such experts should be commenced.

7.8.1 Role of Nuclear Power:

Nuclear energy theoretically offers India the most potent means to long-term energy security, India has to succeed in realising the three-stage development to tap its vast thorium resource to become truly energy independent beyond 2050. The first phase involves setting up of 10,000 MW of power plants using Pressurised Heavy Water Reactors (PHWR) based on domestic uranium. The spent fuel from these plants can be reprocessed to separate Plutonium and the second phase involves use of plutonium and depleted uranium in Fast Breeder Reactors (FBR) which can provide up to 500,000 MW of capacity while also breeding additional plutonium. The third phase involves using the plutonium from fast breeder reactors to converting Thorium to fissile material U_23_3 to run Thorium based reactors. Given India's huge reserves of thorium we have the potential to provide a much larger nuclear power capacity for a few hundred years, in the third phase. This large potential can only be realised over time. With the domestically available uranium and without any additional import beyond Kudankulam I and II plants under construction we can set up no more than 48,000 MW of nuclear plants by 2031 and only about 2,08,000 MW by 2051. With additional import of 30,000 MW of uranium based plants by 2020, we can reach 4, 70,000 MW of nuclear capacity by 2050 if the three-stage programme is fully developed.

Continuing support to the three-stage development of India's nuclear potential is essential. Since India is short of Uranium, the first phase plants cannot exceed 10,000 MW unless imported uranium is available. This would have limited the scale and pace of fast breeder programme and therefore of plutonium production and therefore also the rate at which thorium based nuclear power can be mobilised. Now that NSG restrictions have been lifted we should import uranium and also acquire uranium mining assets abroad. Import of light water reactors would be of considerable importance in the short run as it would allow accelerating the pace of build up of fast breeder reactors. With the success in three stage domestic development, we can also multiply capacity manifold without the need for additional fresh uranium. This would accelerate the pace of development of nuclear power for significantly increasing the role that nuclear energy can play in our long term energy security.

7.8.2 Role of Renewable:

From a longer-term perspective and keeping in mind the need to maximally develop domestic supply options as well as the need to diversify energy sources, renewables remain important to India's energy sector. Solar power could be an important player in India attaining energy independence in the long run. With a concerted push and a 40-fold increase in their contribution to primary energy, currently commercial or near commercial renewables excluding electricity from large hydro plants would account for only 5 to 6% of India's energy mix by 2031-32. While this figure appears small, the distributed nature of renewables can provide many socio-economic benefits.

Subsidies for renewables can be justified on several grounds. A renewable energy source may be environmentally friendly. It may be locally available thereby making it possible to supply energy earlier than in a centralised system. Grid connected renewables could improve the quality of supply and provide system benefits by generating energy at the ends of the grid where otherwise supply would have been lax. Further, renewables may provide employment and livelihood to the poor. However, the subsidies should be given for a well-defined period or upto a well-defined limit.

(i) Incentives for promoting renewables should be linked to outcomes (energy generated) and not just outlays (capacity installed). Even when a capital subsidy is needed, it should be linked to outcomes. For example, capital subsidy could also be given in the form of a Tradable Tax Rebate Certificate (TTRC) that could be based on actual energy generated. The rebate claim would become payable depending upon the amount of electricity/energy certified as having been actually supplied.

(ii) Power Regulators should create alternative incentive structures such as mandated feed-in-laws or differential tariffs or specifying renewable portfolio percentage in total supply to encourage utilities to integrate wind, small hydro, cogeneration etc, into their systems.

(iii) An annual renewable energy report should be published providing details of actual performance of different renewable technologies at the state and national levels. This should include actual energy supplied from different renewable options, availability, actual costs, operation and maintenance problems etc. It should also report on social benefits, employment created, and women's participation and empowerment.

(iv) Policies for bio-fuels, ethanol and biodiesel, requiring blending and providing price support through MSP have already been announced.

(v) Solar energy has a large potential in the country with about 6 kWh/meter^2/day of average solar insolation. This means that just 1% of India's land area even at the present efficiency of photovoltaic cells would suffice to meet her entire projected electrical energy requirements past 2030. However, much of its potential is yet to be exploited. Solar electricity generated through either the thermal route or using photovoltaic cells is an extremely clean form of generation. Solar water heating is cost effective for India even today and can reduce India's demand for oil, gas and coal if pursued to meet the hot water demand in industry and households. Nano-technology holds the hope for making a major breakthrough in solar photovoltaic technology.

Appropriate policies, regulatory systems and fiscal measures duly leveraged by funding available under global climate mechanism should be designed to accelerate the development of solar technology for large-scale deployment, A solar energy

mission has been announced as part of the National Action Plan on Climate Change, to break barriers to wider use of solar thermal and for bringing down the cost of solar photovoltaic by a factor of five as soon as possible. The ultimate objective of the mission would be to develop a solar industry in India that is capable of delivering solar energy competitively against fossil options from kilowatt range of distributed generation to Gigawatt scale of grid interactive power.

(vi) Fuel wood plantations, bio-gas plants, wood gasifier based power plants, bio-diesel and ethanol should be promoted.

(vii) The Indian Renewable Energy Development Agency Ltd (IREDA) should be converted into a national refinancing institution on the lines of NABARD/National Housing Bank (NHB) for the renewable energy sector. IREDA's own equity base should be expanded by the financial institutions of the country instead of continuing the current system of GOI support.

7.9 Ensuring Energy Security:

India's energy security, at its broadest level, is primarily about ensuring the continuous availability of commercial energy at competitive prices to support its economic growth and meet the lifeline energy needs of its households with safe, clean and convenient forms of energy even if that entails directed subsidies. Given the fact that the requirement of energy in the country will rise with development & growth, demand management and increasing efficiency are two very important measures to increase energy security. However, it is also necessary to recognise that India's growing dependence on energy imports exposes its energy needs to external price shocks. Hence, domestic energy resources must be expanded. For India it is not a question of choosing among alternate domestic energy resources but exploiting all available domestic energy resources to the maximum as long as they are competitive. The most critical elements of our energy security, however, remain the measures suggested to increase efficiency, reduce requirements and augment the domestic energy resource base.

Ensuring energy security requires dealing with various risks. The threat to energy security arises not just from supply risks and the uncertainty of availability of imported energy, but also from possible disruptions or shortfalls in domestic production. Supply risks from domestic sources, such as from a strike in CIL or the Railways, also

need to be addressed. Even if there is no disruption of supply, there can be the market risk of a sudden increase in energy price. Even when the country has adequate energy resources, technical failures may disrupt the supply of energy to some people. Generators could fail, transmission lines may trip or oil pipelines may spring a leak. One needs to provide security against such technical risks by building-in redundancy in energy infrastructure.

All risks should be reduced by lowering the requirement of energy by increasing efficiency in production and use; by substituting imported fuels with alternatives such as diesel by electricity in irrigation and transport; by diversifying, fuel choices (gas, ethanol, orimulsion, tar sands etc.) and supply sources; and by expanding the domestic energy resource base.

Supply risks should also be dealt with by increasing the ability to withstand supply shocks for which the following initiatives are recommended:

(i) A reserve, equivalent to 90 days of oil imports should be maintained for strategic-cum-buffer stock purposes and/or buy options for emergency supplies from neighbouring large storages such as those available in Singapore. The buffer stocks should be used to address short-term price volatility. Operating the strategic/buffer reserves in cooperation with other countries who maintain such reserves should also increase their effectiveness.

(ii) A strategic stockpile of nuclear fuel should also be built to counter the risk of disruption of international fuel supply.

(iii) Since 80 percent of global hydrocarbon reserves are controlled by national oil companies controlled by respective governments, oil diplomacy establishing bilateral economic, social and cultural ties could reduce supply risk.

Market risks can be addressed also by—

(iv) Building hard currency reserves to increase the ability to import energy.

(v) Acquiring energy assets abroad of coal, oil, gas, uranium and bio fuel farms. Assets can also be acquired by setting up energy using industries such as fertiliser plants in energy rich countries.

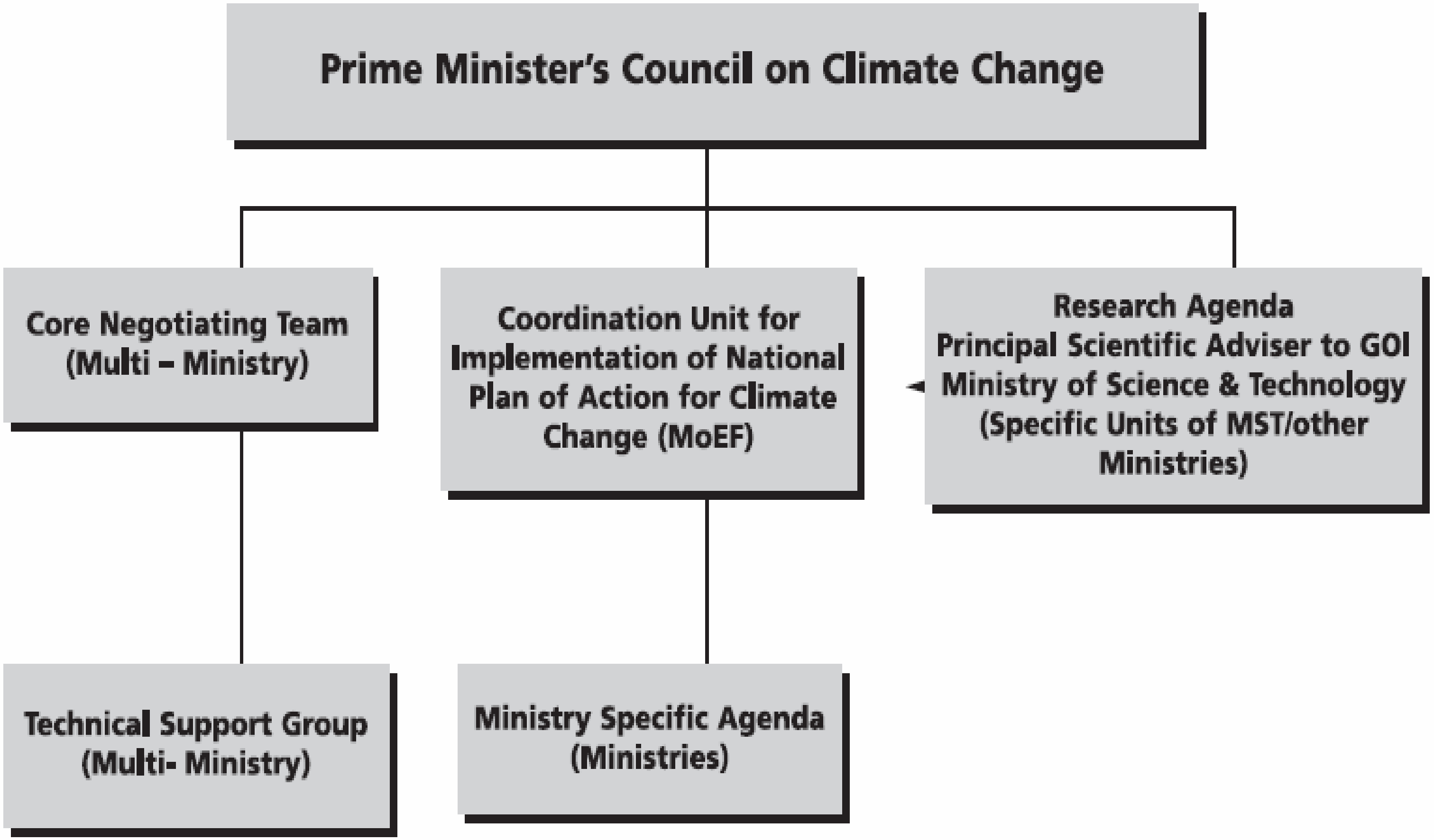
(vi) Building adequate infrastructure facilities for imports.

12.5 For the purpose of providing guidance in coordinating our external interface on energy security matters, an institutional mechanism in the form of a Group of Ministers under the Chairmanship of External Affairs Minister will be constituted, comprising of the Finance Minister, Minister of Petroleum & Natural Gas, Minister of Coal, Minister of Power and the Minister of State for New & Renewable Energy and the Deputy Chairman of the Planning Commission. This mechanism will also provide overall authority for the conduct of structured energy dialogues with selected countries to fulfil the objectives of the integrated energy policy.

(Reference: National Goals for Energy and Climate-India, National Action Plan on Climate Change, Prime Ministers Council on Climate Change, Pg No 1-7)

(Integrated Energy Policy 2006, Planning Commission, Government of India)

Annexure - I


Prime Minister's Council on Climate Change
Core Negotiating Team (Multi – Ministry)
Coordination Unit for Implementation of National Plan of Action for Climate Change (MoEF)
Research Agenda Principal Scientific Adviser to GOI Ministry of Science & Technology (Specific Units of MST/other Ministries)
Technical Support Group (Multi- Ministry)
Ministry Specific Agenda (Ministries)

CHAPTER 8

RESEARCH & DEVELOPMENT REQUIREMENTS

8.1 Boosting Energy Related R&D

India will find it increasingly harder to import its required quantities of commercial energy as her share of the incremental world supply of fossil fuels could rise from a low of 13% in the most energy efficient scenario to a high of 21% in the coal dominant scenario by 2031-32. This assumes that the world's supply of fossil fuels grows by only 2% per annum till 2031-32. The solution for India lies in: (a) reducing requirements by using fuel/energy more efficiently; (b) seeking substitutes to fossil fuels; (c) shifting to fuel efficient modes of transport; (d) augmenting its domestic energy resources; and (e) adopting leading commercial or near commercial low carbon and high-energy-efficiency technologies that extract and use coal, our most abundant primary energy resource, in a more sustainable manner.

Research and Development (R&D) in the energy sector is critical to augment our energy resources, to meet our long-term energy needs and to promote energy efficiency. Such R&D would go a long way in raising our energy security and delivering energy independence over the long-term. R&D requires sustained and continued support over a long period of time. Energy related R&D has not been allotted the resources that it needs. India needs to substantially augment the resources made available for energy related R&D and to allocate these strategically. To take an innovative idea to its commercial application involves many steps. Basic research leading to a fundamental breakthrough may open up possibilities of applications. R&D is needed to develop conceptual breakthroughs and prove their feasibility. This needs to be followed up by a working, laboratory scale model. Projects that show economic potential could then be scaled up as pilot projects, while keeping in mind cost reductions that could be achieved through better engineering and mass production. Demonstrations of such projects, economic assessments and further R&D to make the new technology acceptable and attractive to customers could follow, before finally leading to commercialisation and diffusion.

India has used three approaches; technology development missions that require coordinated research and development of all stages of the innovation chain to reach a targeted goal such as in the departments of atomic energy and space research; technology roll out missions to develop and roll out commercial or near commercial technology such as the missions to provide rural telephony; and broad based R&D support to research institutions, universities and others through project funding.

Technology Missions are the most appropriate mechanism, particularly when it requires coordinated action in a number of different areas, which may involve different government ministries, departments or levels and the private sector. A technology mission whether for development or roll out not only brings a single point focus to dispersed initiatives in the relevant field but also provides support to research projects in universities and research institutions with the aim of delivering the mission objectives. Technology missions must cover areas that are of critical importance to India's long-term energy needs. While coordinated effort is desirable for all R&D in all links of the innovation chain, it becomes critical to place such a coordinating role under a commercially oriented entity, with well identified targets, when one needs to roll out already commercial or near commercial technologies in a time-bound manner. Funding for specific projects to be taken up in universities and R&D institutions as a part of such Programme should be routed through the coordinating agency for time-bound outcomes. In either approach, it is emphasised that R&D requires sustained support over long periods of time.

Some key policy initiatives relevant to energy related R&D is detailed below:

i) A National Energy Fund (NEF) should be set-up to finance energy R&D. Our expenditure on energy related R&D, excepting for atomic energy which currently provides less than 3 percent of our total electrical energy supply, is miniscule compared to what industry and governments spend in developed countries. Firms in developed countries generally spend more than 2 percent of their turnover for R&D. The total expenditure on R&D in the energy sector in India in 2004-05 was Rs.610 crores[2] for Atomic Energy and only Rs.70 crores for Ministry of Power, Coal and Non-Conventional Energy Sources. Even at one-tenth of the rate at which firms in developed countries spend on R&D, *i.e.* 0.2% of the turnover of all energy firms whose turnover exceeds Rs.100 crores a year, we end up with Rs.1000 to Rs.1200 crores per year which would be expected to increase over time. We should be spending much more than this on R&D. R&D can be considered a public good and as such it is ideally financed by the Government out of general reserve. Initially an allocation of Rs.1000 crores should be made for energy R&D excluding atomic energy. To begin with, individuals, academic research institutions, consulting firms, private and public sector enterprise, should all compete for this fund. Firms should also be encouraged to enhance their expenditure on R&D through tax incentives. As this initiative gains momentum there is a case for a cess on energy to fund energy R&D.

The fund should be governed by an Independent Board with representation of Department of Science & Technology (DST), Planning Commission and Energy Ministries. However, a majority should be outside experts. It would support all stages of R&D from basic research to diffusion with appropriate policies, resources and institutions. Each identified technology goal should be broken down into its constituent basic research and applied research. Both types of research should be allowed to access funding from the NEF but all activities must be coordinated to deliver defined goals/ targets/milestones in a time-bound manner.

Each company in the field of energy should be mandated to spend at least 0.4% of its turnover on R&D. Any contribution made by the company to NEF could qualify for full deduction from the income taxes due from the company.

(ii) Energy R&D in the country is currently at a low level of activity. India can not afford to indigenously develop all the required solutions for meeting energy related problems. We need to forge strategic alliances with countries which afford an opportunity for India to jump start our indigenous R&D base. Our international S&T cooperation should be based on strategic alliances and partnerships with 25 year long time horizon.

(iii) The resources devoted to research in different areas depend on the economic importance of that particular area, the availability of technology and the likelihood of success. The latter changes with time as new evolutionary and revolutionary developments in science and technology take place and uncertainties reduce. R&D priorities have to be based on a dynamic strategic vision which is frequently updated. The NEF should encourage and fund research and analysis to outline technology road maps on a regular basis in a number of institutions and should also commission them from experienced and qualified individuals. Such road maps should be widely debated so that they are owned by all stakeholders. The NEF should thus be a gatekeeper of modern technologies.

(iv) The NEF should support energy policy modelling activities in a number of institutions on a long-term basis. The different modellers should be brought together periodically in a forum to address specific policy issues.

(v) A number of technology missions should be mounted for developing near-commercial technologies and rolling out in a time bound manner new technologies that emphasise nationally relevant sources of energy.

The missions must engage industry, academia and India's R&D infrastructure of laboratories and research institutions. The missions identified below exclude nuclear energy as research in that field is progressing well under the various institutions controlled by the Department of Atomic Energy and covers fission, fusion, breeding of fissile material, use of Thorium as also a number of non-energy related fields. The following National Technology Missions are recommended:

8.2 In-Situ Gasification: In-situ coal gasification: Given its vast reserves of relatively poor quality coal which might prove uneconomical for extraction beyond 300 meter depth using convention technologies, India needs to take the lead in developing this technology in order to enhance the life of its most important and dominant energy resource. This technology would extract energy from deep seated coal without the high ash that accompanies Indian coal.

8.3 Integrated gasification combined cycle (IGCC):

It is a clean coal technology that India has been pursuing for some 3 decades. These efforts should be brought under a mission to establish efficacy with Indian coal and likely commercial viability.

8.4 Coal to liquids and/or gasified coal to liquids:

If crude settles at above $45/barrel on a long-term basis, adapting this technology to Indian coal could increase India's energy security. This technology was successfully deployed in South Africa using South African coal. They have tested Indian coal and confirm that the technology works.

8.5 Carbon sequestration; India's energy mix will remain dominated by coal at least to 2031-32 and possibly beyond. In order to grow in a sustainable manner capturing carbon and sequestering it would become critical for India in the years to come. Such technology has already been deployed commercially in conjunction with enhanced oil recovery from adjacent oil fields in three locations worldwide.

8.6 Bio-energy mission: This mission could cover three distinct areas related to bio-energy. These include: (i) Biodiesel from non-edible oils such as Jatropha and Karanj; (ii) Cellulosic ethanol; and (iii) energy plantations.

8.7 Storage technologies: Storage technologies are important for using intermittent sources of power and for the automotive sector. Super conducting storage devices and super battery technology should be focused on, given that cost and higher capacity to weight ratios are still big challenges.

8.7.1 Solar: Solar technology is often seen as relevant for niche applications. Given that solar energy is one of our major energy sources and the only renewable energy source with sufficient potential to meet almost all our energy needs, we should give a high priority to development of solar technology for large-scale deployment. A technology mission should be mounted to break barriers to wider use of solar thermal and for bringing down the cost of solar photovoltaic by a factor of five as soon as possible.

8.7.2 Hydrogen: Development of Hydrogen as an energy carrier is being pursued in many countries. Hydrogen can be used to generate electricity in a fuel cell or it can be burnt directly in internal combustion engines. Hydrogen, however, has to be produced by expanding another primary or secondary form of energy. This can be gas, coal, oil, solar energy, biomass, hydro or nuclear energy. It is also possible to produce it through microbial action. A mission covering all aspects of hydrogen production, storage, transport, deployment and use, can be justified on three considerations:

i) Since many countries are working on hydrogen, the R&D on applications will find international market.

(ii) Some of the R&D for fuel cell based vehicles is common for electric vehicles which may become attractive with advancement of battery technology; and

(iii) If economic production of hydrogen through electrolysis of water using solar energy, and/or nuclear energy or from microbial action materialises, and storage, transportation and distribution of hydrogen becomes economically viable, hydrogen could become a clean and endless energy option.

8.7.3 Gas hydrates: A technology mission for assessment and exploitation of gas hydrates is justified given India's abundant gas hydrate reserves in deep waters.

The Committee has identified the following areas wherein technologies are either fully commercialised elsewhere or are near commercialisation. Even technologies that have been commercialised elsewhere a certain amount of adaptation may be called for. In all these areas, technology roll out missions are proposed. An industry or a group of industries or a commercially oriented agency should be asked to take the role of lead coordinator and seek early acquisition, adaptation and commercialisation. R&D funding for in-house research and directed outsourced research should be provided based on competing offers.

- A number of energy efficiency technologies including DSM technologies. Technology Information, Forecasting & Assessment Council (TIFAC) can be asked to identify specific technologies ready for adaptation and/or commercialisation in India.
- Recovery of coal bed methane and mine mouth methane. Blocks have been allocated already. ONGC and others holding blocks should be asked to indicate firm dates for tapping this energy and identifying any specific hurdles or technology needs.
- Fluidised bed boilers and advanced circulating bed fluidised boilers should be promoted for use with low quality Indian coals and/or washery rejects. BHEL, L&T and others should be asked to take the lead in developing this application and its wider use.
- Washing of Indian coal, requires that a well-established technology be adapted for Indian coals of different quality so that yields and viability can be improved. BHEL and NTPC should lead this effort with the support of the research institutions of the coalindustry.
- Reduction of SOx/NOx and particulate emissions to match global standards. NTPC, private sector and SEBs could compete for taking the lead on this.
- Current practices/technologies for exploration and extraction of coal for adaptation in Indian conditions. Coal India and Neyveli Lignite to be given the lead in this area.

- Increased/enhanced oil and gas recovery and recovery of hydrocarbons from abandoned and isolated fields. ONGC should be given a time-bound programme to acquire and deploy such technologies.

- Fuel-efficient vehicles**:** The automotive industry should be asked to achieve higher fuel efficiency standards in steps so as to reach efficiencies that are at least twice current levels. Companies reaching defined milestones first to be given large cash awards along with fiscal incentives based on outcomes:

8.7.4 Hybrid vehicles and battery operated vehicles. Automotive industry to lead the efforts in commercialising these technologies. Large cash awards and fiscal incentives given based on outcomes.

- Off-shore wind potential to be tapped. Wind mill manufacturers to take lead in delivering a time-bound programme.

GOI to provide fiscal incentives.

- Alternate routes to alcohol such as sweet sorghum should be promoted. Industries such as Praj and industrial alcohol users to compete for R&D funding and fiscal/cash rewards against defined outcomes.
- Promoting community bio-gas plants**.** The real potential of biogas is in community level plants. To have the willing participation of all the cattle owners in the community requires an appropriate operating strategy. Individual and community entrepreneurs should be encouraged to experiment with alternate strategies by providing land and finance. Industries should also be roped in to execute the programme through adoption of villages. Tax rebates to be provided on a graduated scale based on actual outcomes in the field.

The above list is neither a comprehensive list nor a mandatory one. It is an indicative list of technology areas relevant to India's needs. The primary idea is to conduct and fund research that is directed and outcome oriented. All funding made available and fiscal incentives provided should be linked to Achievement of defined outcomes. Finally, a variety of institutions and individuals can be tapped but in a coordinated fashion to deliver defined outcomes.

In addition to the two types of technology missions, the NEF should also provide R&D support for application, innovation of new ideas, fundamental research etc., to researchers from different institution, universities, organisations and even individuals.

Such a R&D programme will require large number of trained researchers. However, a vigorous programme of research and teaching in academic institutions will itself attract students and, over time, relevant expertise will develop. A number of academic institutions should be developed as centres of excellence in energy research. Generous funding for fellowships for energy R&D may be provided to students pursuing post-graduate degrees.

Energy R&D, particularly that devoted to reduce green house gas emissions, has characteristics of global public good. India should link up with other countries and cooperate with international R&D initiatives. India's manpower strength in R&D can then be leveraged to get better results sooner and at lower cost. Joint research with shared IPRs could boost India's R&D efforts significantly. Also, with our growing and diversified energy market, R&D efforts can find quicker returns on successful commercialisation in India. Such a strategy would give India its appropriate place in global energy R&D.

(vi) Coordinated research and development in all stages of the innovation chain to reach a targeted goal (such as that in place in the departments of atomic energy and space research) should be used to develop more efficient industrial plant, machinery & processes, efficient appliances, lignocellulosic ethanol, hybrid cars, super batteries, nuclear technologies related to thorium and fusion, nano technology, biotechnology, ocean technologies, gas hydrates, and hydrogen production, storage, transport and distribution.

(vii) The NEF should provide R&D funding in support of applications, innovative new ideas, fundamental research etc. to researchers in different institutions, universities, organisations and even individuals working independently.

(viii) The currently available institutional mechanisms for energy R&D in the public sector are weak and in the private sector such institutions are even weaker. Therefore, aggressive effort to strengthen the indigenous mechanism for energy R&D is necessary. A number of academic institutions should be developed as centers of excellence in energy R&D. This is critical not only for R&D in the short run but also for nurturing \ human capital in the long run that is critical for successful R&D. Establishment of new institutions in association with some partnering countries and industrial sectors should also be considered.

8.7.5 Household Energy Security - Electricity and Clean Fuels for All

One of the toughest challenges is to provide electricity and clean fuels to all, particularly rural populations many of whom have low paying capacity and also limited availability of local resources for clean cooking energy. The considerable effort spent on gathering biomass and cow-dung and then preparing them for use is not priced into the cost of such energy. These fuels also create smoke and indoor air pollution, are inconvenient to use, and adversely affect the health of people, particularly women and children. Easy availability of a certain amount of clean energy that is required to maintain life should be considered as a basic necessity. Energy security at the individual level implies ensuring supply of such a lifeline energy need. Ensuring this would require targeted subsidies as many households would be unable to pay for safe, clean and convenient commercial energy to meet lifeline needs.

In 2008, consumers paid about 25% of the import parity price for kerosene sold through the Public Distribution System (PDS). The balance 75% of the price was funded largely by oil sector PSUs and the Government through the budget. It is well known that subsidies do not reach the intended beneficiaries due to poor targeting and leakages. The real issue is to improve targeting within the subsidy programme well and ensure that those falling outside the subsidy net pay the full cost of supply. Targeting can be improved by a system of coupons or smart cards that will eliminate dual prices and eliminate the incentive to divert subsidised products. Additionally, a well-targeted subsidy regime may only marginally raise the current subsidy burden.

Action is required in the following:

(i) <u>Electrification of All Households:</u> The Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) was launched to achieve electrification of all rural households. The programme aims to electrify all the villages without electricity by 2009-10 (there were 1, 25,000 such villages in 2003-04) and to connect all the estimated 2.34 crore un-electrified households below the poverty line. The Central

Government provides 90% subsidy on connecting costs and also to augment the backbone network in all the electrified 4.62 lakh villages. The 5.46 crore households above the poverty line which are currently unelectrified, are expected to get electricity connection on their own without any subsidy.

To make RGGVY sustainable, a business plan with a viable revenue model should be elaborated. A clear pricing and subsidy policy and the means of targeting the subsidy should be announced by the government. The centre should provide subsidy for this. Local bodies, panchayati raj institutions, NGOs or even local entrepreneurs should take the franchise to run the local network. Women's self-help groups should also be empowered to do so.

(ii) Till all households are connected and provided with electricity, an accelerated programme to replace kerosene lanterns by solar lamps should be undertaken. The solar lamps can remain in use even after grid based electricity is provided.

(iii) Provision of Cooking Energy: Clean cooking energy such as LPG, NG, biogas or kerosene should be available to all within 10 years. It may be noted that the requirement of cooking energy does not increase indefinitely with income. Thus the total amount of LPG required to provide cooking energy to 1.5 billion persons is around 55 Mtoe. Surplus natural gas (after fulfilling the demand of fertiliser sector & stranded power plants) should be allocated to city gas distribution system. This will release LPG use from those areas which may be used for providing clean cooking fuels to rural and remote areas.

(iv) Other Sources: Fuel wood plantations within one kilometre of all habitations should be promoted. Those who do not have access or cannot afford even subsidised clean fuels, rely on gathering wood. Neighborhood plantations can ease their burden and the time taken to gather and transport wood. Funding to achieve this shall be provided through self-help groups to transform women, who today are only energy gatherers, into micro-entrepreneurs engaged in rural energy markets and energy management. Women's groups can form co-operatives for developing and managing fuel wood or oil seed plantations with the same effort that they put towards searching and gathering fuel wood today.

The best way for providing subsidy for electricity and cleaner fuels, kerosene or LPG is to entitle targeted households to 30 units of electricity per month and LPG, kerosene or bio-gas purchased from a local community size plant equivalent to 6 kg of LPG per month, A system of debit cards should be introduced in phased manner to deliver such a subsidy. The entitlements should only be used for purchase of these products. With modern ICT, debit card readers operated on battery and feeding data using mobile technology, can work in rural areas of the country as well,

(vi) Community Bio-gas Plants: A large scale socio-economic experiment should be financed to operate community sized bio-gas plants as a commercial enterprise either by a community cooperative or by a commercial entrepreneur. Bio-gas plants on this scale could meet the need for clean cooking energy of a sizable segment of the rural population.

(vii) Efficiency of Domestic Chulhas: Even with subsidies for clean fuel, it may not be easy to reach clean fuels to the poor and they may continue to use fuel wood. Thus efficiency of domestic chullahs and lanterns should be improved from the prevailing 10-12% to 20-25%. This is easily attainable and should be accompanied by improved ventilation in the cooking area of the dwellings. The surplus biomass released as a result of better efficiency shall be used in gasifiers for generating electricity.

(viii) Electricity Through Wood Gasifiers: Electricity could be generated through wood gasifiers or by burning surplus bio-gas from the community bio-gas plants. Such distributed generators would be able to take electricity to villages sooner than the grid. This will encourage local generation and could conceivably feed the grid with surplus power at an agreed feed in tariff at a future date, A tariff policy should be formulated for such distributed generation for both household and productive use including agriculture. Such local generation system should not be restricted only to remote villages nor should they disqualify such villages from getting grid connected power.

(ix) Involvement of Organised Sector: The organised sector should be encouraged to adopt rural community/communities in their areas of operation for setting up of off-grid generation facilities.

8.7. 6 Steps for climate change abatement

India is not required to contain its GHG emissions, at present but as a signatory to the UN Framework Convention on Climate Change and a country which has acceded to the Kyoto Protocol, India has been very active in proposing Clean Development Mechanism (CDM) projects?) By September 2008, a total of 358 projects have been approved by CDM Executive Board from India with approximately 31 million tonnes of CO_2 reduction.: Since the impact on the country's poor, due to climate change, could be serious, many of the initiatives recommended as part of the Energy Policy would have the effect of reducing the green house gas intensity of the economy by as much as one third. These include:

Energy efficiency in all sectors

Emphasis on mass transport

Active policy on renewable energy that stipulates renewable portfolio standard

Promotion of bio-fuels and fuel wood plantations

Greening India programme to bring 33 percent of the country's land under forest cover

Accelerated development of nuclear and hydro-electricity

Technology Missions for clean coal technologies

Focussed R&D on many climate friendly technologies

A Solar Technology Mission to make solar power an economic option to coal based power

With these India will be one of the most energy efficient and GHG emission efficient economies in the world with one of the highest | renewable proportion in the energy portfolio.

(**Reference**: Integrated Energy Policy 2006, Government of India)

Chapter 9

CLIMATE CHANGE IMPACTS OF SELECTED SECTORS

9.1 Implementation Infra Structure

The word 'infra' means below and 'infrastructure' means the support services below the real economic structure. Though the concept of infrastructure has been extensively used in the literature of economic development, it has not been explicitly defined in a precise and generally accepted manner. A number of interchangeable terms such as social overhead, economic overhead and basic economic facility have been used to denote services, which are generally identified with infrastructure.

Some of the basic characteristics of infrastructure facilities can thus be defined as:

9.1.1 Essential but not directly productive: Infrastructure facilities are universally required for carrying out any kind of production, yet they themselves do not produce goods for final use. They provide support to the directly productive activities and are, thus, in the nature of overhead costs.

9.1.2 Pre-requisites of development*:* Infrastructure facilities are normally created ahead of demand. Due to their universal requirement they are often considered as necessary pre-requisites of development. The expansion of production activities is unlikely to take place, beyond a level, without these services.

9.1.3 Non-importable: More often than not, the technical nature of these facilities is such that necessitates their creation and supply at the very place of their use. Electricity can be cited as an exception, which can be transported but requires specialized infrastructure in place.

9.1.4 Lumpiness*:* Infrastructure cannot be built in bits and pieces and has to be provided in a minimum size. This feature emanates from what can be described as technical indivisibility. In general, a minimum quantum of investment, which is often large, is required for the creation of infrastructure. A corollary of indivisibility and lumpy investment is that the per unit cost of services generated by infrastructure declines over a very large range of production.

9.1.5 External Economies: Another distinguishing feature of infrastructure is that it generates external economies, i.e., 'services rendered free'. The benefits from infrastructure are sometimes so widespread that it is difficult to identify each and every beneficiary. Hence, it is said that investment in infrastructure is profitable for society as a whole.

9.1.6 Provision by state*:* Due to very high investment involved and inability to generate attractive return to the investor, infrastructure facilities generally require investment by the government. Historically the world over, most of the services have been developed with the initiative of the states. In addition to the above characteristics, infrastructure projects have a long gestation period and a comparatively long life span. Any asset like infrastructure, that has a long life, has a tub-shaped cost curve for repair and maintenance. In the initial stabilization period, it may require frequent maintenance. The maintenance requirement decreases once the system has stabilized it increases again due to wear and tear, as the asset reaches the end of its useful life. Attention to climate change impacts becomes important, since these may be more pronounced in the later part of the 21st century (IPCC, 2001b). These two effects coupled together, would increase the economic impact on infrastructures. Thus, developing countries need to take the investment decisions for infrastructure development very carefully, because these decisions result in long-term irreversible commitment of resources.

9.2 Infrastructure development in India

Economic growth in India demands development of its infrastructure. In the light of the continued need for development of infrastructure in India, successive five-year plans have devoted a large and increasing volume of outlays for the development of economic, social and institutional infrastructure. The following broad generalization can be made about the trend of investment in infrastructure items over the planning period.

The Ninth Plan Working Group on Housing had estimated the investment requirement for housing in urban areas at Rs 526 billion (US$ 11.5 billion). The India Infrastructure Report estimates the annual investment need for urban water supply, sanitation and roa ds at about Rs 280 billion (US$ 6.15 billion)for the next 10 years. The Central Public Health Engineering has estimated the requirement of funds for a 100 per cent coverage of the urban population under safe water supply and sanitation services by the year 2021 at Rs 1,729 billion (US$ 37.9 billion). Estimates by Rail India Technical and Economic Services (RITES) I dicate that the amount required for urban transport infrastructure investment in cities with population 100,000 or more during the next 20 years, would be of the order of Rs. 2,070 billion (US$ 45.4 billion).

Obviously, these massive investments cannot be located from within the budgetary resources of central, state and local governments. Private sector participation and access to international finances are, therefore, required for infrastructure development projects. As a result, investment opportunities are arising in the infrastructure sector, especially in roads, ports, energy, telecommunications and urban services. India may require Rs 9,800 billion during 2001-2006 to meet the projected growth in demand for infrastructure (India Infrastructure Report, 1996).

Some recent initiatives of large-scale infrastructure development in India include the development of the national highways network. Such infrastructure projects require huge investments. The national highways development project for four/ six-laning of around 13,146 km of road network, with another 1,000 km of port and other connectivity, is expected to cost Rs 540 billion (US$ 11.8 billion). More than 2,100 km has already been completed over the last three years and another 5,000 km are under various stages of completion. More than US$ 3.5 billion have been spent and/or committed. The river linking project is estimated to require a Rs. 5,560 billion (US$ 122 billion) investment over next the 10 years. This project has been envisaged in the current climatic regime and assumes the availability of water in the perennial Himalayan rivers. If the climatic changes predicted by international scientific assessment (IPCC, 2001b) were to be realized over the present century, the monsoon and rainfall patterns would alter and the glaciers would recede, thus changing the annual water flow patterns in the sub-continental rivers. This would alter the project's assumptions and the costs and benefits assessment.

9.3 Impact on Transport sector

Climate change impact on transportation infrastructure and the operation of transportation systems may be divided into three categories: the effects of climate on operations; the effects of sea level rise on coastal facilities; and the effects of climate on infrastructure.

A future climate with an increased number of rainy days, rainstorms and higher rainfall intensity may increase vehicular accidents and injuries in accidents, and result in longer travel time and increased delays. The effect of climate change on transport is not very clear. However, transportation by air is known to be sensitive to adverse weather conditions; major system wide effects sometimes follow from flight cancellations, rerouting, or rescheduling. There is a high level of confidence that sea-level rise will increase the cost of protecting infrastructure located in the coastal regions.

Transportation operations are sensitive to local weather conditions. Fog, rain and snow slow down transport movements and increase risks of accidents. In addition, maintenance costs and durability of infrastructure are also dependent on weather events. Changes in frequency and intensity of extreme events such as hurricanes, floods, high-speed winds and cloudbursts may have significant impacts on the safety and reliability of transportation. All these impacts are location-specific and the infrastructure located in different regions will experience different intensity of impacts.

A case study was prepared for climate energy impacts a konkan railway as shown below

Table 9.1: Climate Change Impacts on Konkan Railway.

Climatic Parameter	Impact Parameter	Intervening Parameter	Impact on KRC
Temperature Increase	High evaporation rate	Stability and strength of the building materials	Buildings get weakened. Frequent repair and maintenance
	Surface and ground water loss	Crop productivity in the region may be affected	Agricultural freight traffic
	Need for air-conditioning	Passenger traffic may shift to air-conditioned class	Affects efficiency, carrying capacity and composition.
Rainfall Increase	Ground and surface water-level change	Flooding and water logging, erosion reduces the quality of land cover	Buildings affected, structural damages may take place. Increased maintenance and other related costs
	Improved water availability in the region	Agricultural production	Changes in agricultural freight traffic
	Humidity increase	Uncomfortable climatic conditions, vegetation growth along the track	Passenger traffic affected, increased maintenance cost
Sea-level Change	Land erosion	Tracks tunnels and bridges may be affected	Increased maintenance,
	Flooding	Land instability and land slides	Damage to infrastructure, reconstruction and relocation
	Water logging		Risk of delays increase
Extreme Events	Cyclone and high-velocity winds and storms	Damage to buildings, communication lines, etc	Disruption of services, repair and reconstruction costs
	Cloudbursts	Land erosion, floods, and landslides	Extensive damage to infrastructure, high cost of repair and reconstruction

Every year during the monsoon, train operations are disrupted due to water logging and landslides. There are numerous instances of trains running late due to preventive speed restrictions and disruptions during the rainy season every year. An analysis of the past data indicates that on an average, the operations are suspended for about a week during the monsoons because of such problems along the track. One of the major traffic suspensions was for 14 continuous days between11-25 July 2000, due to land slides at 36 locations caused by more than 300 mm rainfall on a single day. The expected losses were estimated to be about Rs 100 million (US$ 2.2 million).

There were a total of 140 reported incidences of landslides during the entire monsoon season in 2000.

9.4 Impacts on Power Sector and Energy Consumption

The energy sector is highly dependent on temperature conditions and this is probably, where climate change could have very strong direct impacts. The regional temperature would change significantly, thus affecting he future energy consumption behaviour. In the residential and building sector, a major energy demand is expected to be for space cooling and heating. Air conditioning and refrigeration load is closely related to the ambient air temperature and will thus have a direct relation to temperature increase. Temperature increase in the northern mountainous region, where space heating in winter is required, might result in some saving in heating energy. This will be more than compensated by increased energy requirement for space cooling in the plains, thus resulting in a net increase.

Higher income levels will further increase demands for air-conditioning. There are many energy sources for space heating, including coal, biomass and electricity. However, the main source of energy for cooling is electricity. A higher demand for air conditioning will thus result in an increased electricity demand. Similar to the residential sector, the commercial and industrial sector will also experience an increased load for air-conditioning and refrigeration due to temperature rise.

Many sectors affected by climate change will have indirect impacts on the energy sector. A major sector that causes indirect impact on energy is agriculture. Agriculture is very sensitive to any type of climate changes. Climate change in India will result in temperature rise and a changing precipitation pattern. The evaporation rate is also expected to rise because of the temperature increase. This may be countered by increase in rainfall and humidity in some regions. All these put together will affect the water requirement or agriculture which will be grater, resulting in a higher demand of energy for irrigation. The residential after demand is also expected to increase, which would in turn affect the energy required for the after supply system.

Additional electricity generation due to climate change, over and above the electricity generation in 2100, is estimated to be 64 TWh, which is 1.5 per cent of the reference scenario generation for the same year. The domination of coal-based generation continues due to the reliance on domestic resources for energy supply and a major share of this added generation requirement is taken up by the coal-based generation. The economic linkages with coal are also very strong due to the large infrastructure associated ith the mining industry, coal transportation network, generation equipment manufacturers, etc., and coal remains competitive in the long run.

As renewable technologies including hydro, wind, cogeneration, other biomass technologies, solar and geothermal, are expected to reach plateau by this time, fuel-mix changes in the energy sector would largely depend on development of nuclear power and new sources of energy such as fuel cells, fusion etc. over a period of time.

9.5 Risk and Insurance

The insurance sector has participated in covering the risks of the large-scale infrastructure projects against future uncertainties. Climate change increases risks for the insurance sector, but the effect on profitability is not likely to be severe, because insurance companies are capable of shifting changed risks to the insured, provided that they are 'properly and timely informed' on the consequences of climate change. For example, in the event of a catastrophic event, the insurance sector reacts to increased risk and large losses by restricting coverage and raising premiums. It has been shown by various authors that the increased climatic variability necessitates higher insurance premiums to account for the higher probability of damages.

Despite the costs, there has been a great deal of excitement about the potential of insurance and other forms of risk transfer for hedging the risks of extreme weather-related and other disasters facing developing countries. Governments carry a large and highly dependent portfolio of infrastructure assets, some of which are critical for restoring economic growth, and for the same reason, as firms, they may wish to reduce the variance of their disaster losses by diversifying with insurance and other risk-transfer instruments.

Lacking more attractive financing alternatives, the government benefits from risk transfer, since it reduces the variability of its disaster losses, but risk transfer requires resources that could otherwise be invested in the economy. In terms of economic growth, there is thus an inherent trade-off: a reduction in funds spent on current growth permits a government to protect itself against extreme future losses.

9.6 Conclusions

There is a need for building awareness about the potential impacts among the concerned people, and developing good quality databases. Systematic efforts are required to study the impact assessments of different climatic parameters. Studies about future projections of changing regional climate provide insights for methodological developments, including models for integrated assessment and GIS-based computer algorithms for supporting policy assessments at regional levels.

(**Reference**: power sector and energy consumption, India’s Initial National Communication to the United Nations Framework Convention on Climate Change, government of India, pg no 130-131).

CHAPTER 10

REQUIREMENTS FOR FUTURE WORKING CLIMATE CHANGE ADAPTATION AND MITIGATION

10.1 Introduction

India ranks sixth in the world in terms of energy demand, accounting for 3.5 per cent of the world's commercial energy demand in 2001. The world's total primary commercial energy supply (TPCES) grew at a compounded annual growth rate of 2.4 per cent over the period 1965-2002, with the Middle East and the Asia-Pacific regions displaying the highest growth rates. Within the Asia-Pacific region, India has exhibited one of the fastest growth rates in commercial energy supply. On the whole, the share of India in the total world commercial energy supply increased from 1.4 per cent in 1965 to 3.5 per cent in 2001. However, despite achieving such high growth rates in energy consumption, the per capita energy consumption in India is still low according to global standards, and the energy efficiency of the GDP (PPP basis) is among the best. This holds true even if it is compared with other countries at a similar stage of development

10.2 Constraints and Gaps, and Related Financial, Technical and Capacity Needs

The Initial National Communication exercise offered an opportunity to enrich and enhance India's experience in identifying constraints, gaps and related financial, technical and capacity needs to adequately fulfill our obligations under the UNFCCC, including the continuing need for improving the quality of national GHG inventories, regional and sectoral assessment of vulnerabilities and adaptation responses, and the communication of information on a continuous basis.

The data needs for continuous reporting have been identified, taking into consideration the data gaps and constraints experienced during the preparation of the initial national communication Measures for improving the future national communication would include designing consistent data reporting formats for continuous GHG inventory reporting, collecting data for formal and informal sectors of the economy, enhancing data depths to move to a higher tier of inventory reporting, and conducting detailed and fresh measurements for Indian emission coefficients. Several thematic and specific projects are identified for building the research capacity and implementing the climate change project in the country as a part of the preparatory process for national communication. These are representative projects only and do not present an exhaustive elucidation of India's financial and technological needs and constraints. With enhanced scientific understanding and increased awareness, further areas of investigation will be identified.

Capacity building, networking and resource commitment form the core of institutionalizing Indian climate change research initiatives. This involves a shared vision for cooperative research for strengthening and enhancing scientific knowledge and understanding, institutional capacity (instrumentation, modelling tools, and data synthesis and data management), technical skills for climate change researchers, inter-agency collaboration and networking, and medium to long term resource commitment.

Capacities thus strengthened and enhanced can be effectively used for the refinement of GHG inventories, development of climate change projections (with reduced uncertainties and at higher resolutions), long term GHG emission scenarios, detailed impact assessments and formulation of adaptation strategies, developing the capability to undertake integrated impact assessments at sub-regional scales and the diffusion of climate-friendly technologies.

Given the magnitude of the tasks, complexities of technology solutions and diversity of adaptation actions envisaged for an improved and continuous reporting of national communications in the future, the incremental financial needs would be substantial for addressing and responding to the requirements of the Climate Change Convention.

Table10.1: Key Gaps and Constraints for Sustained National Communication Activities.

Gaps and constraints	Description	Potential measures (Illustrative examples)
Data organization	Published data not available in IPCC friendly formats for inventory reporting.	Design consistent reporting formats.
	Inconsistency in top-down and bottom-up data sets for same activities.	Data collection consistency required.
	Mismatch in sectoral details across different published documents.	Design consistent in reporting formats.
Non-availability of relevant data	Time series data for some specific inventory sub-categories, e.g., municipal solid waste sites.	Generate relevant data sets.
	Data for informal sectors of economy.	Conduct data surveys.
	Data for refining inventory to higher tier levels.	Data depths to be improved.
Non-accessibility of data	Proprietary data for inventory reporting at Tier III level.	Involve industry and monitoring institutions.
	Data not in electronic formats.	Identify critical datasets and digitize.
	Lack of institutional arrangements for data sharing.	
	Time delays in data access.	Awareness generation.
Technical and institutional capacity needs	Training the activity data generating institutions in GHG inventory methodologies and data formats.	Arrange extensive training programmes.
	Institutionalize linkages of inventory estimation with broader perspectives of climate change research.	Wider dissemination activities.
Non-representative emission coefficients	Inadequate sample size for representative emission coefficient measurements in many sub-sectors.	Conduct more measurements.
Limited resources to sustain national communication efforts	Research networks.	Collaborative research, GEF/ international funding.
	India-specific emission coefficients.	Conduct adequate sample measurements for key source categories.
	Vulnerability assessment and adaptation.	Sectoral and sub-regional impact scenario generation, layered data generation and organization, modelling efforts, case studies for most vulnerable regions.
	Data centre and website.	National centre to be established

10.3 Reforms and GHG Emissions

The momentous economy-wide reforms initiated in India in 1991 embraced a variety of sectors and activities that emit GHG as well as other pollutants. A significant area in this context is energy, including electricity, hydrocarbons and coal.

10.3.1 Renovation and modernization (R&M), distribution reforms and GHG emissions

To augment T&D networks, system improvements, R&M of old stations for improving efficiency to make investment in energy conservation and environment performance schemes, concerted efforts are on for quite some time at various levels within the system. Reforms in R&M of old thermal power stations will result in improvement in efficiency that is availability of additional power with the same amount of coal burnt and, hence, lower greenhouse gas emissions. Similarly, reduction in technical losses will result in availability of extra power in the grid thereby partially offsetting the new power capacity to be added.

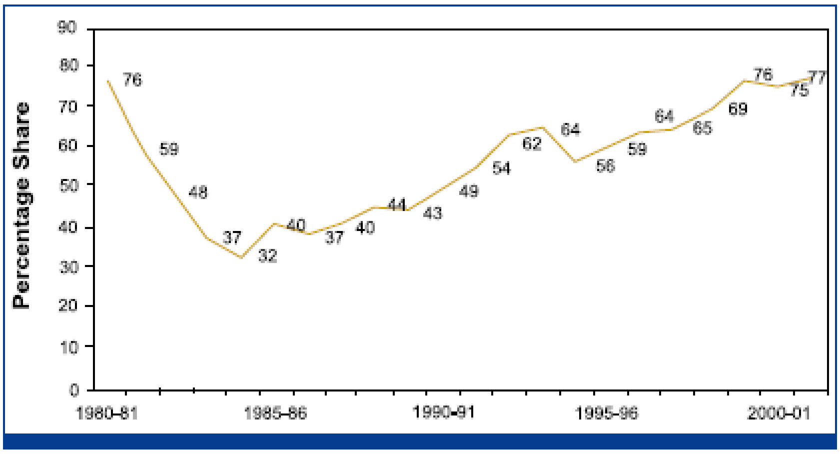
10.4 Reforms in the electricity sector

The Ministry of power has initiated reforms in all aspects of power sector to make the sector viable. To encourage private sector participation with the objective of mobilizing additional resources for the power sector, the 'Private Power Policy' was announced in 1991. The Electricity Regulatory Commission Act was promulgated in 1998 for setting up independent regulatory bodies, both at the central and the state level with an important function of looking into all aspects of tariff fixation and matters incidental thereto to make the sector viable.

10.5 Reforms in the hydrocarbons sector

India imported 77 per cent of her total petroleum consumption in 2001-2002 which required substantial funds. The domestic production failed to keep pace with the domestic requirement, forcing India to import more crude oil and petroleum products. The net imports of both crude oil and petroleum products declined to 32 per cent of total consumption in 1984- 1985 from the high of 76 per cent in 1980-1981 but has risen steadily thereafter to reach 77 per cent in 2001-2002 Few attempts at reforms were taken in the 1980s, when the upstream sector was opened for private participation in order to attract private capital and technology to boost indigenous oil production.

Figure 10.1 Share of petroleum imports in total consumption.



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Economy-wide reforms initiated in 1991 opened up the middle stream refining also for the private sector. The New Exploration and Licensing Policy (NELP) was launched in 1997 and the new format of competitive bidding and relinquishment of blocks by T&D reforms are important components of APDRP. National oil companies made this policy an immediate success. Presently, NELP is due for its fourth round and, until now, a 100 blocks have been awarded to both public and private sector companies. The government remained in control of the hydrocarbons sector in the form of the Administered Pricing Mechanism (APM). Various pool accounts ensured that the oil companies got a fixed return on their investments and the consumers got stable prices. However, mounting concerns about the inefficiency in the sector, the ever-increasing burden of subsidies and crude oil import bills, and sufficient refinery capacity in India propelled the government in 1997 to prepare a road map for dismantling the APM with a step-wise approach, reaching a completely free oil market by 2002. The prices of industrial fuels such as naphtha, fuel oil, bitumen and lubricants, were freed and the national oil companies were allowed to compete in this segment. The last step in dismantling the APM was taken in April 2002, when the Annual Budget 2002-2003 formally announced the move to market-based pricing and, since then, the oil companies, in consultation with the government, have been revising the prices fortnightly in line with the international trend.

10.6 Reforms in the coal sector

Towards reforming the coal sector, the government has recently constituted the Expenditure Reforms Commission (ERC). The major recommendations of the commission are: _ Remove all restrictions on the entry of the private sector in exploration and production of coal by amending the Coal Mines Nationalization Act, 1973. Delhi has world's largest CNG-based public transport fleet.

10.7 The Energy Conservation Act, 2001

The Energy Conservation Act, 2001 was enacted in September 2001 covering all the matters related to the efficient use of energy and its conservation. A Bureau of Energy Efficiency was set up to discharge the activities entrusted under the Act. The Bureau is expected to investigate the energy consumption norms for each energy-intensive industry and encourage the proper labelling of energy consumption indicators on every electrical appliance. The Bureau will also provide guidelines for energy conservation building codes and take measures to create awareness and disseminate information for the efficient use of energy and its conservation. It also aims to strengthen consultancy services in the field of energy conservation and develop testing and certification procedures and promote testing facilities for certification and for energy consumption of equipment and appliances. Various studies estimate that a potential of 23 per cent energy conservation exists in India. Enactment of Energy Conservation Act, 2001 would help in tapping this potential and thus, partially, offsetting the environmental impacts of new capacity addition.

10.8 The Electricity Act, 2003

The Government of India has recently enacted the Electricity Act, 2003. The Act seeks to promote competition in the electricity sector in India by decoupling the generation, transmission, istribution and supply of electricity.

The Act also envisages the preparation of a National Electricity Policy (including tariff) for the development of the power system based on the optimal utilization of natural resources. In consonance with this policy, the central electricity authority will prepare the National Electricity Plan once every five years. The Act has de-licensed the generation of electricity in India. Clause (7) of the Act states that 'any generating company may establish, operate, and maintain a station without obtaining a license under this Act if it complies with the technical standards relating to the connectivity with the Grid'.

The Act has also heralded a move away from the Single Buyer model that was followed during the 1990s. Under this model, private power producers were allowed to sell power to SEBs only. However, the financial difficulties faced by the SEBs proved to be a major constraint for private participation. Under the new Act, the generator and the consumer can individually negotiate the power purchase and use the common access transmission and distribution system to meet the contractual obligations.

Thus, the Electricity Act, 2003 maintains the trend in electricity reforms witnessed the world over by exposing the generation and the supply side of the market to competition, but placing transmission and distribution sections under incentive regulation.

The Act has made the tariff policy one of the cornerstones of the regulatory process. Under the Act, either the state or the central regulatory commission is required to play an important role in tariff setting by the natural monopoly segments of the electricity supply chain, and ensure that such tariff is set through a transparent process of bidding in accordance with the guidelines issued by the central government. The Ministry of Power has recently come out with a discussion paper on the tariff policy. According to the paper, the tariff has to take into account the objectives of: (a) promotion of efficiency; (b) introduction of competition and creating enabling environment for the same; (c) rationalization of electricity tariff; (d) protection of consumer interests; and (e) transparency in subsidy administration (MoP, 2003).

10.9 Petroleum product pipeline policy

The government also announced a new petroleum product pipeline policy on a common carrier principle. The policy promotes the product pipelines originating from refineries, pipelines dedicated for supplying products to particular consumers, and pipelines originating from ports. The policy would reduce road and rail transport and enhance the supply of cleaner fuels and, hence, would reduce emissions of GHG and local pollutants.

10.9.1Auto Fuel Policy

The government announced the Auto Fuel Policy in 2003 to address the issues of vehicular emissions, vehicular technologies and the provision of cleaner auto fuels in a cost-efficient manner, while ensuring the security of fuel supply. These measures would result in the efficient combustion of fossil fuels in the road transport sector resulting in reduced GHG emissions. Transport sector emissions from Delhi are an interesting case in point, where the fuel switch to Compressed Natural Gas (CNG) from diesel in public vehicles has reduced CO2 emissions. Apart from Delhi, CNG in respect of public passenger transport has also been introduced in Mumbai.

10.10 India's details about needs for adaptation to climate change Net consumption to UNFCCC

Reduction of GHG emissions, leading to stabilization of their concentrations in the atmosphere in the long run, will neither altogether prevent climate change, sea-level rise, nor reduce their impacts in the short to medium run. Adaptation is a necessary strategy at all scales, from national to local, to complement climate change abatement efforts; thus, together they can contribute to sustainable development objectives and reduce inequities.

In addition, the development of planned adaptation strategies to address risks and utilize opportunities can complement abatement actions to reduce climate change impacts. However, adaptation would entail costs and cannot prevent all damages. There are many constraints faced by the developing countries such as India while deploying the scarce resources for adaptation measures.

10.10.1 Need for awareness at all levels

There is a need for enhancement of awareness at all levels on adaptation needs. The nature of adaptation needs would differ from location to location and sector to sector in an economy and even at the micro level, across different economic activities in a locality. These also need to consider the stakeholder's perspective and their difference in endowment of resources and capacity.

10.10.2 Need for research on formulating specific adaptation measures for various sectors

Sectoral adaptation measures would depend to a large extent on the awareness and understanding of the climate change impacts. Various sectors like water resources, agriculture, terrestrial and marine ecosystems, human health, human settlements, energy, and industry, have their unique adaptation requirements and there is a need for research to understand the extent of climate change impacts and the possible sectoral adaptation measures.

10.10.3 Need for inter-linkages in adaptation policy and market responses

Adaptation to climate change presents complex challenges, as well as opportunities in many sectors. Policy formulation on adaptation measures has to relate to the complex sectoral interdependence and inter-relationships in climate change impacts. This area has been scarcely researched in the Indian context and information necessary at the local level for adaptation policy planning is generally not available. This in turn also affects coordination with the market responses in adaptation. Market responses would not be forthcoming if there is no clarity in cause-effect. Further in the absence of proper information, the policies do not reflect such clarity and free riding prevails. Developed countries have experienced cases of complacency and mal adaptation fostered by public insurance and relief programmes. The developing countries, which may experience adverse effects of climate change, have to deal with equity issues and development constraints in market responses. Market responses must be matched with extensive access to insurance and more widespread introduction of micro financing schemes and development banking.

10.10.4 Need of resources to implement adaptation measures

The costs of adverse events have risen rapidly despite significant and increasing efforts at fortifying infrastructure and enhancing disaster preparedness in the recent decades. Part of the observed upward trend in disaster losses over the past 50 years is linked to socioeconomic factors, such as population growth and urbanization in vulnerable areas. Moreover, climate change impacts occur in the long term and for sustained level research to enhance preparedness requires enormous resources in developing capabilities in knowledge and infrastructure.

10.10.5 Technological Needs

The Government of India has been promoting low CO2 emission technologies for sustainable development through programmes such as the Integrated Renewable Energy Programme. India has one of the largest programmes for promoting renewable energy in the world, covering all major renewable energy technologies, such as, biogas, biomass, solar energy, wind energy, small hydropower and other emerging technologies. The Ministry of Non-conventional Energy Sources (MNES) is involved in the promotion for development, demonstration and utilization of these technologies, such as, solar thermal; solar photovoltaic; wind power generation and water pumping; biomass gasification/ combustion/co-generation; small, mini, and micro hydro power; solar power; utilization of biomass, biogas, improved cook-stove; geothermal for heat applications and power generation/energy recovery from urban, municipal and industrial wastes; and tidal power generation. The commercialization of several renewable energy systems and products are currently underway. The MNES also deals with other emerging areas and new technologies, such as, chemical sources of energy, fuel cells, alternative fuel for surface transportation and hydrogen energy.

The global thrust on climate-friendly technologies is presently focused on climate change mitigation, such as fuel cell cars, biotechnologies, nano technologies to reduce electricity demand and CO_2 capture and storage. There is a growing need to develop technologies that reduce the vulnerabilities of developing and least developed country populations to adverse impacts of climate change. These technologies have to be low cost and be compatible with local environment and socioeconomic situations for faster adaptation. The revival of and building upon conventional wisdom, such as water management in arid and desert areas, weatherproof low-cost housing, and less water intensive night soil disposal, is also required. Modern technologies should augment the conventional wisdom for adapting to climate change. Various ministries and departments of the Government of India are engaged in technology development on diverse fronts that have been synthesized through the Technology Information, Forecasting and Assessment Council (TIFAC). The continuing work of scientists will remain crucial, generating the knowledge needed to develop effective responses to the challenges of climate change. North-South and South-South cooperation on climate change is a necessity, especially from the developing country perspective, as they need support for adaptation activities, and technology transfer.

10.10.6 Capacity Needs

Beyond the sectoral and scientific or technological capacity needs on climate change, the critical need in India is to integrate the diverse scientific assessments and link them with policy-making. Science has to provide objective scientific and technical advice to the policy-makers, especially for a complex process like climate change. While some experience of using integrated assessment models does exist in India, the capacity building in this area remains a double priority - first, to provide policy orientation to the scientific assessments and second, to provide robust scientific foundation to policy making. The development of assessment tools by interdisciplinary teams within developing countries is crucial. This would need commitment of sustained resources and institutionalization of multidisciplinary and networking efforts, within the scientific and policymaking establishments.

Climate change concerns, assessment challenges and response strategies, for diverse sectors and regions in India require an integrated assessment approach. Integrated assessment is an interdisciplinary process that combines, interprets, and communicates knowledge from diverse scientific disciplines from the natural and social sciences to investigate and understand causal relationships within and between complex systems. Integrated assessment attempts to present the full range of consequences of a given policy— economic or environmental, intended or unintended, prompt or delayed—in order to determine whether the action will make the society better or worse off, and by how much. It must be noted here that, integrated assessment is also not a monolithic, uniform, unique and universal model that can be applied to any context. It indicates an approach to policy-making that has to consider contextual issues and specific nuances of the sector under scrutiny to arrive at integrated policy assessment. For example, in deciding policy for water quality management in a particular place, integrated scientific advice should include the direct and indirect effects of urban development, agricultural run-offs, industrial pollution, and climate change-induced increase in heavy precipitation events on water resources, along with many other factors. Networking is a critical requirement for integrated climate change assessments. The Initial National Communication project has made a beginning where more than a 100 inter-disciplinary research teams spread across the country have been networked together for a shared vision on climate change-related research. Such initiatives have to be strengthened. The Participation of state and UT government departments is to be encouraged in climate change activities. This will build capacities at the state level for implementing policy measures such as those for reducing vulnerability of various sectors and communities, disseminating and promoting climate-friendly technologies and initiatives, adaptation, and energy efficiency improvements. Finally, technology R&D, technology transfer and technology diffusion in India must be promoted. Since there are diverse disciplines involved in climate change, having a unified command and control regime may not be appropriate for these.

10.10.7 Financial Needs

The financial needs arise from the constraints detailed in the previous sections. They are necessary for research and actual projects for implementing climate change related policies and programmes. These cover diverse sectors and require considerable technology transfers and financial resources in terms of Article 4.3 of UNFCCC. Given the magnitude of the tasks, complexities of technological solutions and diversity of actions needed, the resources made available at present are wholly inadequate to address and respond to the requirements of the Convention.

The systems and policies in developing countries are not tuned to handle even the present climate-related stress and climate variability. Income disparities and population growth further constrain the opportunities and equitable access to the existing social infrastructure. The projected climate change could further accentuate these conditions. The challenge then is to identify opportunities that facilitate the sustainable use of existing resources. It entails considerations that make climate-sensitive systems, sectors and communities more resilient to current climate variability. This will pave the way to enhance their adaptive capacity to future climate change. Faster economic development with more equitable income distribution, improved disaster management, sustainable sectoral policies, careful planning of capital intensive and climate-sensitive long-life infrastructure assets are some measures that assist in ameliorating India’s vulnerability to climate change.

10.10.8 Barriers

10.10.8.1 Economics

Capital costs of new conventional power projects are estimated at Rs. 40 million (~ 1 million US $) per MW and the generation cost is estimated at Rs. 2.25 per kWh.

Allocations for renewable energy sources are, however, meager, being only 0.3 per cent of the total plan expenditure for the 8^{th} Plan. For this reason some important future technologies are not taken seriously in the Indian programme. In the long term solar produced hydrogen is a very promising option for CO_2 reduction. This, however, needs serious R&D effort with higher allocation.

10.10.9 Recommendations

The best way for providing subsidy for electricity and cleaner fuels, kerosene or LPG, is to give an entitlement to the targeted households equivalent to 30 units of power and 6 kg. of cooking gas or equivalent amount of kerosene to cover one or both needs. A system of debit cards or smart cards may be introduced whereby the targeted households get a credit of different amounts of cash for the purchase of these entitlements. The available credit on the debit/smart card can only be used for purchase of these entitlements. With modern ICT, card readers operated on battery and feeding data using mobile technology can work in rural areas of the country too.

13. The problem of bogus cards has plagued our public distribution system. How do we ensure that bogus debit cards would not be issued? One way to do this is to put the names of all cardholders on the village board and internet. Another option would be to provide cards with physiological identification.

14. Even if a household decides to sell the entitlement and not use power, LPG and kerosene, it would still be welfare improving. The poor who prefer to sell their entitlement and still gather biomass based fuels would bebetter off as there would be much less competition for it. The effort and time involved mainly of women and girls in gathering fuel would go down. To reduce the adverse impact of indoor air pollution on their health, women should be informed about possible defensive measures, such as ventilating the kitchen by removing a brick or two under the roof, using improved smokeless chulahs, keeping the children away from the stove and minimising the exposure to smoke, etc.

Within this broad strategy the suggested policy actions to provide electricity and cleaner fuels to all are summarised below: _ Provide a monthly entitlement of 30 units of electricity and 6 kg. of LPG or equivalent amount of kerosene for one or both lifeline energy needs through a system of Smart/Debit Cards with varying levels of direct cash support to targeted households as detailed above.

- To facilitate distributed generation under RGGVY to enhance the speed by which we can electrify all households. Revise the scope of RGGVY to cover actual electrification of all households. Most importantly develop a viable revenue model for RGGVY.
- Eventually when the grid supply reaches the villages electrified using DG, the local eneration could feed power price into the grid, at regulated feed-in tariffs, to support the lagging ends of the grid.
- For setting up of off-grid generation facilities in rural areas, encourage the organised sector to adopt rural community/communities in their areas of operation. Even tax rebates may be considered linked to actual outcomes.
- A large-scale socio-economic experiment should be financed to operate community sized biogas plants either by a community cooperative or by a commercial entrepreneur. This should assess various management models in a scientific manner and examine whether the inclusion of the poor and disadvantaged can be guaranteed. Successful management models should be replicated on a largescale.
- Community land should be allocated to women's self-help groups and they should be provided with finance and technical help to develop fuel wood plantations in convenient locations.

(Reference:, India's Initial National Communication to the United Nations Framework Convention on Climate Change, government of India,).

(Introduction, India's Initial National Communication to the united Nations Framework Convention on Climate Change, government of India, pg no 22)

(Constraints and Gaps, and Related Financial, Technical and Capacity Needs National Action Plan on Climate Change, Prime Ministers Council on Climate Change, Pg No XV)

(Indian Petroleum and Natural Gas Statistics, 2003, MoPNG, Government of India.)

(Reforms and GHG emissions, National Action Plan on Climate Change, Prime Ministers Council on Climate Change, Pg No 24 - 28).

(Recommendations, Integrated Energy Policy2006, Planning Commission, Government of India)

CHAPTER 11

CLIMATE CHANGE ROLE OF DEVELOPING COUNTRIES

11.1 Introduction

Climate change, resulting from anthropogenic emissions and increasing concentrations of a suite of gases (called "greenhouse gases" or GHGs) mainly due to fossil fuel use, certain agricultural and industrial activities, and deforestation, has the potential, over the next few generations, to significantly alter global climatic conditions. This would result in large changes in ecosystems, leading to possibly catastrophic disruptions of livelihoods, economic activity, living conditions, and human health. On the other hand, the abatement of GHGs involves significant economic costs.

While climate change is a global environmental issue, different countries bear different levels of responsibility for increases in atmospheric GHG concentrations. Further, the adverse impacts of climate change will fall disproportionately on those who have the least responsibility for causing the problem, in particular, developing countries including India.

Though India is a signatory to the United Nations Framework Convention on Climate Change (UNFCC), she is not required to contain her GHG emissions. India's policies for sustainable development, by way of promoting energy efficiency and the use of renewable energy, changing the fuel mix to cleaner sources, energy pricing, pollution abatement, afforestation, mass transport in and of themselves result in a relatively GHG benign growth path. Have severe adverse impacts on India's precipitation patterns, ecosystems, agricultural potential, forests, water resources, coastal and marine resources, besides the increase in range of several disease vectors. Large-scale resources would clearly be required for adaptation measures for climate change impacts, if catastrophic human misery is to be avoided.

As the global concern vis-a-vis climate change grows and as the threat of climate change is perceived to be real, pressures on India to contain GHG emissions will rise. India should be willing to contain her GHG emissions as long as she is compensated for the additional cost involved. India acceded to the Kyoto Protocol on 26 August 2002. The Government of India established National CDM Authority (NCDMA) in December 2003, with its office in Ministry of Environment and Forests. As of 8th May 2006, a total of 297 projects have been approved by the NCDMA. These projects expect emissions reduction of 236 Million CERs till 2012 at a potential total investment of more than Rs.190 Billion.

India recognizes the possibilities of selling GHG emission reductions. We should choose options that permit doing so at a later date when it is found to be attractive. In any case, for us the imperative is to push energy efficiency, promote modern renewables, develop new technologies that augment our energy supply such as in-situ coal gasification that also provides scope for carbon capture, and emphasise nuclear power. All of these will automatically help reduce the GHG emissions

Below table 11.1 gives the sector-wise break up of approved projects and the total expected reductions.

Table 11.1 India Approved CDM Projects

	No. of Projects	CERs till 2012*	Investment (Rs. Cr)
Energy Efficiency			

Fuel Switching			
Industrial Process			
MSW			
Renewables			
Renewables (Biomass)			
Total			

CER (Certified Emission Reduction) – One Tonne of CO_2 eq. abatement
* Source : India's Initial National Communication to the UN Framework Convention on Climate Change (UNFCCC)

11.2 Concluding Comment

India faces an enormous challenge if it is to meet her energy requirement over the coming 25 years and support a growth rate of 8 percent. This challenge can be met with a coherent approach, which develops all available energy resources. The main areas of action, for which detailed policy recommendations have been made, are as follows:

- Reducing energy requirements through energy efficiency and conservation.
- Augmenting energy resources and supply.
- Rationalisation of fuel prices to mimic free market prices that promote efficient fuel choice and substitution.
- Promoting coal imports.
- Accelerating power sector reforms.
- Cutting cost of power. Encouraging renewables and local solutions.
- Enhancing energy security.
- Promoting and focusing energy R&D.
- Promoting household energy security, gender equity and empowerment through targeted entitlements for the poor.
- Creating an enabling environment and regulatory oversight for competitive efficiency.

The broad policy framework and the development thrusts suggested here need to be made more specific in certain areas. Once the policy framework is accepted, it will be necessary to chalk out roadmaps of development and draft specific policy measures for implementation. With implementation of the recommendations of the Committee, India can meet her energy requirements in an efficient, cost effective way and be on a path of sustainable energy security.

11.3 India's Commitment to Climate Change and Sustainable Development

Though the Government of India has taken many policy decisions that reduce risks and enhance the adaptive capacity of the most vulnerable sectors and groups by promoting sustainable development, considerable scope exists for including more measures to cover the entire range of impacts due to the present climate variability. Currently, income disparities and high population growth constrain the opportunities and equitable access to the existing social infrastructure. The projected climate change could further accentuate these conditions. The challenge then is to identify opportunities that facilitate the sustainable use of existing resources. Faster economic development with more equitable income distribution, improved disaster management efforts, sustainable sectoral policies, careful planning of capital intensive and climate sensitive long-life infrastructure assets, are some measures that will assist India in reducing its vulnerability to climate change.

India accords great importance to climate change and her commitment to UNFCCC is reflected in the various national initiatives for sustainable development and climate change. As a commitment to the UNFCCC, India recently hosted the COP-8 at New Delhi. India has reasons to be concerned about the adverse impacts of climate change, since the vast population depends on climate sensitive sectors. The Government of India makes investments for the promotion of research and development on a continuous basis in diverse areas of the environment, including climate change. Environmental protection and sustainable development have emerged as key national priorities and are manifested in India's approach to socioeconomic development and poverty eradication.

(**Reference**: India's commitment to the climate change, India's Initial National Communication to the United Nations Framework Convention on Climate Change, government of India, pg no xi).)

(Climate change role of developing countries, integrated energy policy2006, Planning commission, Government of India)

<u>APPENDIX 1</u>

<u>SOCIO-ECONOMIC DRIVERS OF ENERGY DEMAND</u>

A1.1 Methodology for estimating income-wise household distribution

The overtime proportion of households in each expenditure class depends on factors such as rate of of population, share of urban population to rural population, household size, and rate of growth of GDP. Given these parameters, distribution of households in various expenditure classes is generated using a lognormal distribution for MPCE (monthly per capita consumption expenditure) data for rural and urban available from NSSO (National Sample Survey Organization) for ‘consumer expenditure rounds; 1993/94 and 1999/2000’

The lognormal distribution of MPCE has probability density function.

$$f(x;\mu,\sigma) = \frac{1}{x\sigma\sqrt{2\pi}} e^{\left(-(\ln x-\mu)^2/2\sigma^2\right)}$$

where, x is the household consumption expenditure for x > 0, where μ and σ are the mean and standard deviation of the MPCE’s logarithm. The expected value is

$$E(X) = e^{\mu+\sigma^2/2} \qquad \textbf{(A-1.1)}$$

and the variance is

$$\mathrm{var}(X) = \left(e^{\sigma^2} - 1\right) e^{2\mu+\sigma^2}$$

The cumulative probability of population below an expenditure level is given by

$$\Phi\left((\ln(L) - \mu)/\sigma\right) \qquad \textbf{(A - 1.3)}$$

where, L is the consumption expenditure level.

In order to forecast the probability of population in an expenditure class, the two unknowns – μ and σ – for the above two equations need to be estimated over the forecast period. σ has been assumed to follow the past rend of decline during 1993/94 to 1999/ 2000 for rural and urban areas. μ , mean expenditure, has been determined by incomes per the Keynesian consumption theory.

Therefore, increase in GDP implies an increase in expenditure thereby implying a rightward shift in the lognormal curve. Private final consumption expenditure has been used for consumption expenditure. Therefore, forecast of growth rate of private final consumption expenditure determines the growth rate of MPCE. The growth rate of private final consumption expenditure has been forecasted using the following equation.

PFCE = 115 235 + 0.54 (Y) (A-1.3)
(-11.79) (20.83)
(Adjusted R_2= 0.953)

where,

PFCE = private final consumption expenditure

and Y = GDP

Coefficient of GDP is the MPC (marginal propensity to consume). In other words, an MPC of 0.54 implies that one rupee increase in income leads to an increase of 0.54 rupee in consumption.

MPCE = PFCE/P

where,

H = population

In India, the per capita income increased from 5823 rupees in 1981 to 12 281 rupees in 2001. Correspondingly, the per capita expenditure increased from 5044 rupees to 8441 rupees during the same time period. This increase in per capita expenditure was at the annual rate of 2.48% during 1981– 2001, when the per capita income growth rate was 3.64%. The same is expected to increase at the rate of 4.8%, 6.0%, and 7.8% with the per capita income growing at the rate of 5.5%, 6.7%, and 8.5% at a GDP growth rate of 6.7%, 8%, and 10% respectively during 2001–36. The NSS (National Sample Survey) data of per capita calorie intake by MPCE classes has been used to find out the monetary cut off corresponding to minimum calorie requirement norm. The national-level official poverty line corresponds to a basket of goods and services, which satisfies the calorie norm of per capita daily requirement of 2400 kcal (kilocalories) in rural areas. Accordingly, people below an MPCE of 525 rupees in rural areas and 575 rupees in urban areas have been considered to be below poverty line (Table A1.1).

For simplifying the analysis, these expenditure classes have been categorized into six expenditure groups namely BPL (below poverty line), L (low), LM (lower middle), M (middle), UM (upper middle), and H (high) in rural and urban areas. MPCE less than or equal to 525–615 rupees is considered to be under the BPL group. For the urban low-income group, the figure is 575– 665 rupees (Table A1.1).

Based on the probabilities computed for rural and urban population under various GDP growth rate scenarios (Tables A1.2– A1.7), the number of households in rural and urban areas is estimated for six expenditure classes.

Table A1.1 **Monthly per capita expenditure and calories intake**

Rural		**Urban**	
Monthly per capita expenditure (in Rs)	**Calorie intake (kcal)**	**Monthly per capita expenditure**	**Calorie intake (kcal)**
0-225	1383	0-300	1398
225–255	1609	300–350	1654
255–300	1733	350–425	1729
300–340	1868	425–500	1912
340–380	1957	500-575	1968
F380–420	2054	575-665	2091
420–470	2173	665–775	2187
470–525	2289	775–915	2297
525–615	2403	915–1120	2467
615–775	2581	1120–1500	2536
775–950	2735	1500–1925	2736
Above 950	3178	Above 1925	2938

Source NSO (2000)

Table A1.2 **Probability of households (rural) 8% GDP**

MPCE (in Rs)	**1993**	**1999**	**2001**	**2006**	**2011**	**20156-16**	**2121**	**2026**	**2030-31**	**2036**	**2050**
0–225	0.101	0.057	0.044	0.012	0.002	0.000	0.000	0.000	0.000	0.000	
225–255	0.048	0.034	0.028	0.010	0.002	0.000	0.000	0.000	0.000	0.000	
255–300	0.083	0.065	0.056	0.025	0.006	0.001	0.000	0.000	0.000	0.000	
300–340	0.079	0.065	0.059	0.031	0.010	0.002	0.000	0.000	0.000	0.000	
340–380	0.077	0.071	0.065	0.038	0.014	0.003	0.000	0.000	0.000	0.000	

380–420	0.075	0.070	0.068	0.046	0.020	0.005	0.001	0.000	0.000	0.000	
420–470	0.084	0.086	0.084	0.063	0.031	0.009	0.001	0.000	0.000	0.000	
470–525	0.082	0.087	0.087	0.073	0.043	0.015	0.003	0.000	0.000	0.000	
525–615	0.106	0.120	0.124	0.121	0.084	0.037	0.009	0.001	0.000	0.000	
615–775	0.122	0.148	0.159	0.188	0.166	0.097	0.032	0.005	0.000	0.000	
775–950	0.070	0.092	0.102	0.148	0.171	0.135	0.064	0.016	0.001	0.000	
950–1200	0.044	0.061	0.072	0.124	0.183	0.195	0.133	0.048	0.009	0.001	
1200–1500	0.019	0.028	0.033	0.069	0.130	0.188	0.181	0.100	0.026	0.002	
1500–2000	0.008	0.013	0.015	0.039	0.094	0.181	0.252	0.218	0.099	0.020	
2000–2800	0.001	0.002	0.003	0.011	0.036	0.100	0.212	0.304	0.250	0.101	
> 2800	0.001	0.001	0.001	0.002	0.008	0.032	0.112	0.308	0.615	0.876	

MPCE – monthly per capita expenditure; GDP – gross domestic product

Table A1.3 Probability of households (urban) 8% GDP

MPCE (in Rs)	1993	1999	2001	2006	2011	2015-16	2021	2026	2030-31	2036	2050
0–300	0.094	0.047	0.035	0.009	0.001	0.000	0.000	0.000	0.000	0.000	
300–350	0.046	0.031	0.025	0.009	0.002	0.000	0.000	0.000	0.000	0.000	
350–425	0.076	0.058	0.050	0.023	0.006	0.001	0.000	0.000	0.000	0.000	
425–500	0.079	0.067	0.061	0.033	0.010	0.002	0.000	0.000	0.000	0.000	
500–575	0.077	0.071	0.067	0.042	0.017	0.003	0.000	0.000	0.000	0.000	
575–665	0.086	0.085	0.083	0.059	0.028	0.008	0.001	0.000	0.000	0.000	
665–775	0.093	0.098	0.098	0.080	0.045	0.015	0.003	0.000	0.000	0.000	
775–915	0.097	0.109	0.111	0.104	0.071	0.030	0.006	0.001	0.000	0.000	
915–1120	0.106	0.125	0.132	0.142	0.119	0.065	0.019	0.002	0.000	0.000	
1120–1500	0.117	0.146	0.158	0.200	0.213	0.164	0.075	0.016	0.001	0.000	
1500–1925	0.064	0.081	0.089	0.134	0.181	0.191	0.131	0.047	0.007	0.000	
1925–2400	0.033	0.043	0.047	0.080	0.130	0.174	0.168	0.092	0.022	0.002	
2400–3200	0.021	0.026	0.030	0.053	0.107	0.183	0.243	0.207	0.088	0.014	
3200–4000	0.007	0.008	0.009	0.021	0.041	0.088	0.158	0.201	0.143	0.042	
> 4000	0.004	0.005	0.005	0.011	0.029	0.076	0.196	0.434	0.739	0.739	

MPCE – monthly per capita expenditure; GDP – gross domestic product

Table A1.4 Probability of households (rural) 10% GDP

MPCE (in Rs)	1993	1999	2001	2006	2011	2015-16	2121	2026	2030-2031	2036	2050
0–225	0.101	0.057	0.004	0.009	0.001	0.000	0.000	0.000	0.000	0.000	
225–255	0.048	0.034	0.028	0.008	0.001	0.000	0.000	0.000	0.000	0.000	
255–300	0.083	0.065	0.056	0.020	0.002	0.000	0.000	0.000	0.000	0.000	
300–340	0.079	0.065	0.059	0.027	0.005	0.000	0.000	0.000	0.000	0.000	
340-380	0.077	0.071	0.065	0.034	0.008	0.001	0.000	0.000	0.000	0.000	
380-420	0.075	0.070	0.068	0.040	0.012	0.002	0.000	0.000	0.000	0.000	
420-470	0.084	0.086	0.084	0.057	0.019	0.002	0.000	0.000	0.000	0.000	
470-525	0.082	0.087	0.087	0.069	0.029	0.005	0.001	0.000	0.000	0.000	
525-615	0.106	0.120	0.124	0.116	0.061	0.015	0.001	0.000	0.000	0.000	
615-775	0.122	0.148	0.159	0.187	0.136	0.047	0.006	0.000	0.000	0.000	
775-950	0.070	0.092	0.102	0.155	0.159	0.084	0.018	0.001	0.000	0.000	
950-1200	0.044	0.061	0.072	0.135	0.195	0.152	0.052	0.006	0.000	0.000	
1200-1500	0.019	0.028	0.033	0.079	0.160	0.187	0.101	0.020	0.001	0.000	
1500-2000	0.008	0.013	0.015	0.047	0.133	0.237	0.216	0.079	0.009	0.000	
2000-2800	0.001	0.002	0.003	0.015	0.062	0.180	0.294	0.215	0.055	0.004	
>2800	0.001	0.001	0.001	0.002	0.017	0.088	0.311	0.679	0.935	0.996	

MPCE – monthly per capita expenditure; GDP – gross domestic product

Table A1.5 **Probability of households (urban) 10% GDP**

MPCE (in Rs)	1993	1999	2001	2006	2011	2015 -16	2021	2026	2030 - 31	2036	2050
0–300	0.094	0.047	0.035	0.007	0.000	0.000	0.000	0.000	0.000	0.000	
300–350	0.046	0.031	0.025	0.008	0.001	0.000	0.000	0.000	0.000	0.000	
350–425	0.076	0.058	0.050	0.019	0.003	0.000	0.000	0.000	0.000	0.000	
425–500	0.079	0.067	0.061	0.028	0.006	0.001	0.000	0.000	0.000	0.000	
500–575	0.077	0.071	0.067	0.037	0.010	0.001	0.000	0.000	0.000	0.000	
575–665	0.086	0.085	0.083	0.054	0.017	0.002	0.000	0.000	0.000	0.000	
665–775	0.093	0.098	0.098	0.074	0.031	0.005	0.000	0.000	0.000	0.000	
775–915	0.097	0.109	0.111	0.099	0.052	0.012	0.001	0.000	0.000	0.000	
915–1120	0.106	0.125	0.132	0.139	0.094	0.032	0.004	0.000	0.000	0.000	
1120–1500	0.177	0.146	0.158	0.204	0.194	0.100	0.021	0.001	0.000	0.000	
1500–1925	0.064	0.081	0.089	0.143	0.188	0.149	0.053	0.006	0.000	0.000	
1925–2400	0.033	0.043	0.047	0.088	0.151	0.170	0.095	0.018	0.001	0.000	
2400–3200	0.021	0.026	0.030	0.064	0.141	0.224	0.201	0.073	0.007	0.000	
3200–4000	0.007	0.008	0.009	0.022	0.062	0.137	0.190	0.119	0.024	0.001	
> 4000	0.004	0.005	0.005	0.014	0.050	0.167	0.435	0.783	0.968	0.999	

MPCE – monthly per capita expenditure; GDP – gross domestic product

A. 1.2 Rationale for choice of 8% gross domestic product growth rate

The Tenth Five Year Plan covering the period 2002–07 prepared by the Planning Commission, GoI Government of India) aims at achieving an average growth rate of real GDP of 8% per annum over the period 2002–07. The 8% average growth rate target set for the Tenth Plan appears quite optimistic when compared with the short-term GDP growth rate forecasts of other organizations. However, the rationale behind targeting 8% GDP growth rate is doubling the per capita incomes over the next decade with a more equitable regional distribution. This would bring about substantial improvement in the welfare of the entire population. Furthermore, the Tenth Five Year Plan has been prepared against the backdrop of the performance of the Indian economy during the Eighth and the Ninth Plan periods. During these plan periods many of the commonly held beliefs regarding the potentialities and constraints that govern the operation of the economic system have been questioned and highlighted.

There are three major experiences from the previous plan periods, as highlighted in the Tenth Five Year Plan that lay down the guidelines for setting the growth targets for the future.

Firstly, the growth rate of the Indian economy is no longer constrained by the availability of savings or investible resources. Thus, it can be stated that the availability of investible resources was not the primary constraint to growth and investment in India.

Secondly, the growth rate of an economy is not wholly determined by the level of investment activity. The Tenth Five Year Plan highlights the fact that the rate of real investment as a percentage of GDP was higher during the Ninth Five Year Plan as compared to the previous plan period. The Ninth Five Year Plan recorded a real investment rate of 26.3% of GDP as compared to 24.9% during the Eighth Five Year Plan. However, the economy registered an average annual GDP growth rate of 6.7% per annum as against 5.3% during the Ninth Plan. This is explained by the fact that the investment rate when measured in nominal terms has declined from 24.8% in the Eighth Plan to 24.3% in the Ninth Plan period. Also, the nominal investment rate has been at or below the private savings rate. The Ninth Plan period was characterized by a decline in the levels of capacity utilization thereby explaining a decline in the investment rate in nominal terms.

Thirdly, the growth of the agriculture sector is a key determinant of the overall economic growth rate. Although the share of agriculture in aggregate GDP has declined to 26.9% of GDP reducing the sensitivity of GDP growth rate to fluctuations in agricultural performance, the agricultural incomes play an important role in determining the demand for non-agricultural commodities. Therefore, growth of the agriculture sector is a determinant of future growth rate.

A1.3. Assumptions

A.1.3.1 Production function

The main point of departure from the BRICs study16 is in our choice of a labour augmenting Cobb Douglas production function. The production function exhibits constant returns to scale, and the technological progress is of the type that increases the efficiency of the abundant factor of production, which in the case of India is labour. Labour augmenting technical change can be manifested in the adoption of technologies that lead to the production of more labour-intensive goods or in technologies that increase the efficiency of the labour input (Acemoglu 2002).

We believe that this specification is more relevant than the Goldman Sachs specification, to the direction that Indian growth is most likely to take. Our production function is specified as

$$Y = (AL)^{-1}\alpha K\alpha$$

where A= labour-augmenting technology

L = labour input

K = capital

α Share of capital in income

A.1.3.2 Convergence

One of the factors driving growth in the model is the rate of growth of TFP (total factor productivity). The difference between the per capita income of the US and the per capita income of India determines the potential for technological ‘catch up’. The rate of convergence would depend on the initial income of the developing country. Under these conditions, technological progress could be expected to be faster in developing countries such as India than in the US.

As higher TFPG (total factor productivity growth) rates and diminishing returns to capital lead to higher output growth rates, the potential for catch up decreases and the developing country converges towards the steady-state growth rate of technological progress in the US.

Unconditional convergence would imply that the steady-state balanced growth paths for the developing and developed country coincide (Islam 1998). This, however, need not be the case when conditional convergence is assumed. In this case, any one or more of the parameters defining steady state can differ among countries. This model assumes the convergence of TFP growth rates in steady state. The economies can, however, differ in terms of steady-state growth rates of population, savings rates, educational attainment, depreciation, and TFP levels (Jones 1997). The growth rates that a country can achieve in the steady state would depend on country-specific factors such as technique choice, geography, and institutional structures that affect saving and investment rates, physical and social infrastructure, education levels, and quality of governance. This would imply that given the same initial levels of per capita income, a country with an underdeveloped infrastructure or lower levels of educational attainment would converge at slower rates than a country with more favourable conditions.

We use the same specification for the evolution of TFPG as in the BRICs paper. The growth rate of TFP in the developing country is given by the following relation.

Log (A_t A_{t-1}) = (long-run TFPG for the US) β Log [(per capita GDPDC)/(per capita GDPUS)]
where At = TFP level at time t
A_{t-1} = TFP level at time t-1

β Log [(per capita GDPDC)/ (per capita GDPUS)] = conditional convergence rate for the developing country.

This specification assumes that the TFPG rates along the path to steady state in the developing country are higher than the steady state TFP growth rate in the US. The higher the rate of convergence (β), and the larger the difference in per capita incomes, the higher the rate of TFP growth in the developing country relative to the long-run TFPG rate in the US. Conventional estimates of the rates of convergence in per capita income for developed countries to their own steady states are about 2% (Mankiew, Romer, and Weil 1992). We would expect conditional convergence rates in developing countries to be lower as a consequence of retarding institutional factors. The BRICs paper has assigned a convergence rate of about 1.5% to developing countries. It mentions that calculations for long-term projections of GDP use lower initial convergence rates for Brazil and India. These increase to 1.5% through the period for which the projections are made. We have assumed the conditional β convergence rates for India to be equal to 1.3% throughout our analysis. We expect convergence rates for India to be lower than those used for China and Russia in the BRICs paper, because of higher illiteracy levels, infrastructural bottlenecks, and social constraints that affect the participation of women in the workforce and the large proportion of the population employed in subsistence or unorganized activities in both the agricultural and urban sectors.

We have used long-term TFP growth rates for the US to be consistent with those used by the CBO (Congressional Budget Office) of the Government of the US. The CBO (2002) uses a TFP growth rate of 1.3% for their long-term GDP projections. This was revised upwards from 1% average annual growth (CBO 1997). The CBO also uses more conservative long-run US TFPG (1.1%) rates for alternative projections.

The results from our analysis are very sensitive to the assumptions made regarding the convergence rates and long-run TFPG rates. Changing long-term US TFPG rates from 1.3% to a more pessimistic 1.1% would change our results appreciably.

A.1.3.3 Capital stock

The growth of net capital stock in the model follows the equation given below.

$K_t = K_{t-1}(1 - \partial) + sY_{t-1}$

Where Kt = net capital stock at time t
K_{t-1} = net capital stock at time t-1
s = investment rate
Y_{t-1} = GDP at time t-1

From this specification we find that sY_{t-1} gives us the gross capital formation in time $_{t-1}$. This forms a part of the net capital stock that is available for use in the following year. To calculate the net capital stock for the initial year in our analysis, we have used data on net capital stock and gross capital formation from the National Accounts Statistics published by the CSO (Central Statistical Organization), GoI. To calculate the subsequent capital series we assume that the investment rate in India will remain at 24% throughout the period for which projections are made. We also assume that the depreciation rate will remain at 5% for the entire period. This assumption is again a very stringent one and the rates of capital attrition (a combination of deterioration and technological obsolescence) can be expected to change. In the Indian case we could expect rates of capital attrition to rise in the long term as capital intensity and ICORs (incremental capital–output ratio) decline due to relocation of capital from investment in infrastructure to investment in production. Capital attrition due to technological obsolescence could also be expected to rise with changing market structures favouring the increase in competition and a corresponding increase in the share of R&D (research and development) expenditures in total investment.

The share of capital in income, as computed from data on operating surplus and net national product from the National Accounts Statistics, is approximately 60%. This is on the higher side and we would expect this share to decline in the long run with the adoption of more labour-augmenting technologies, increased employment, and regulation in the unorganized sector. The long-run share of capital in income could be taken as 1/3, which is the share of capital in the income of the US and several other developed countries. For the purpose of our analysis we keep the share of capital in GDP as 3/5.

A. 1.3. 4 Demographics

We have used population figures given by the PFI (Population Foundation of India). We have projected population till 2030 assuming growth rates to decrease from current levels of 2003 to about 0.9% in 2030. We have assumed a constant rate of increase of 1.07% in the Indian work force. Assuming a shift in the age structure of the population in favour of people above the age of 65, and a decline in population growth, a constant rate of increase allows for future increases in the rate of participation of women in the work force. This is an expected consequence of increased expenditures on social infrastructure and increased life expectancies.

A.1.3.5 0ther assumptions

As in the BRICs paper, we assume that the GoI continues to pursue liberal economic and social policy with emphasis on the gradual withdrawal of government intervention in industry and trade, and increasing government expenditures on health and education. We have used the estimates of the US per capita GDP calculated in the BRICs paper to arrive at TFP growth rate figures for India. We have deflated these values to 1993/94 rupee values. We have taken 2003 as the initial year in our analysis, and have used available data on GDP and capital stock valued at 1993/94 prices. Labour force, work force, and population figures are in millions and the values for the initial year are obtained from the PFI. We have computed long-term GDP growth rates for India for the base model with investment rates at 24%, depreciation at 5%, convergence rate at 1.3%, and long term US TFPG at 1.3%.

A.1.3.6. Results

The results from the simulations in our base model indicate that the long-term average annual GDP growth rate for India is 6.7% per annum for the modelling time frame 2001–36.

TERI considers it be the low growth scenario relative to the 8% GDP growth rate adopted in the baseline scenario.

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APPENDIX 2

CLIMATE PLAN DATA SHEET OF INDIA

Appendix B to be inserted

APPENDIX 3

CLIMATE PLAN DATA SHEET OF STATES

Data sheet for the Climate Plans – JHARKHAND

			Baseline			Climate plan		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capacity of Jharkhand State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	11,954,542	1,348,979	13676726			
		Specific Emissions	1.00	1.00	1.00			
	Type of plant		Thermal					
	Capacity in MW		3559.7					
	Fuel Type	Coal	□					
		Oil	□					
		Gas						
		Diesel	□					
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval Processing and Distribution							
	Residential, commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							

	Agriculture, Forest and Fishing						
	Industry, Construction, wholesale, Private, and Public Service Housing						
	Households & commercial						
	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Jharkhand State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans –BIHAR

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capacity of Bihar State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	6332691.31	6,135,106.28	6430033			
		Specific Emissions	0.50	0.48	0.42			
	Type of plant		Thermal					
	Capacity in MW		2,424.90					
	Fuel Type	Coal	□					
		Oil	□					
		Gas						

		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval Processing and Distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Bihar State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							
	Photovoltaic							
	Hydro power		□					
	Wave and Tidal							
	Total							

Data sheet for the Climate Plans – WEST BENGAL

			Baseline			Climate plan		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of West Bengal State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	44566965.28	44,700,799.97	46093149			
		Specific Emissions	0.83	70603.00	0.81			
	Type of plant		Thermal					
	Capacity in MW		8,552.50					
	Fuel Type	Coal	□					
		Oil	□					
		Gas						
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval Processing and Distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							

	Households & commercial						
	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of West Bengal State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – ORISSA

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Orissa State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	25552735.73	28195050.69	28700906			
		Specific Emissions	0.40	0.40	0.40			
	Type of plant		Thermal					
	Capacity in MW		5,901.50					
	Fuel Type	Coal	□					
		Oil	□					
		Gas						
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							

	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Orissa State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							
	Photovoltaic							
	Hydro power		□					
	Wave and Tidal							
	Total							

Data sheet for the Climate Plans – SIKKIM

		Baseline			**Climate plan**		
		2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**

GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Sikkim state							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	0.00	0.00	0.00			
		Specific Emissions	0.00	0.00	0.00			
	Type of plant							
	Capacity in MW		594.00					
	Fuel Type	Coal						
		Oil						
		Gas						
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							

	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Sikkim State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – ASSAM

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Assam State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	1303400.83	1,314,855.61	1362741			
		Specific Emissions	0.32	0.28	0.29			
	Type of plant		Thermal					
	Capacity in MW		1,074.00					
	Fuel Type	Coal	□					
		Oil	□					
		Gas	□					
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						

		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Assam State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							
	Photovoltaic							
	Hydro power		□					
	Wave and Tidal							
	Total							

Data sheet for the Climate Plans – MANIPUR

		Baseline			Climate plan		
		2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh						
	Methane						
	Nitrous oxide						

	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Manipur State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	0.00	1,629.31	523			
		Specific Emissions	0.00	0.32	0.32			
	Type of plant		Thermal					
	Capacity in MW		141.00					
	Fuel Type	Coal						
		Oil						
		Gas						
		Diesel	□					
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							

	Total						
	Non Conventional Power Generation Capacity of Manipur State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – TRIPURA

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Tripura State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	868539.97	876,259.86	902076			
		Specific Emissions	0.63	0.58	0.56			
	Type of plant		Thermal					
	Capacity in MW		210.00					
	Fuel Type	Coal						
		Oil						
		Gas	□					
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							

	Residential, Commercial and other Sources (Construction)						
	Land Use and Biomass burning						
	Waste Disposal and Treatment						
	Total						
Energy Consumption by Sector (PJ)	Transport						
	Agriculture, Forest and Fishing						
	Industry, Construction, wholesale, Private, and Public service Housing						
	Households & commercial						
	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Tripura State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – AURUNACHAL PRADESH

		Baseline			**Climate plan**		
		2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh						
	Methane						
	Nitrous oxide						
	CFC						
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Arunachal Pradesh State						
GHG Emissions	Power stations (CO_2 Absolute Emissions	**0.00**	**0.00**	**0.00**			

by Sector (CO_2 equivalents)	Emissions ton per MWh)	Specific Emissions	**0.00**	**0.00**	**0.00**			
	Type of plant							
	Capacity in MW		415.50					
	Fuel Type	Coal						
		Oil						
		Gas						
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Aurunachal Pradesh State							
Renewable Energy	Waste							

	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – MEGHALAYA

			Baseline			Climate plan		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Meghalaya state							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	235.20	0.00	0.00			
		Specific Emissions	0.00	0.00	0.00			
	Type of plant							
	Capacity in MW		235.20					
	Fuel Type	Coal						
		Oil						
		Gas						
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							

	Waste Disposal and Treatment						
	Total						
Energy Consumption by Sector (PJ)	Transport						
	Agriculture, Forest and Fishing						
	Industry, Construction, wholesale, Private, and Public service Housing						
	Households & commercial						
	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Meghalaya State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – NAGALAND

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Nagaland State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	0.00	0.00	0.00			
		Specific Emissions	0.00	0.00	0.00			
	Type of plant							

	Capacity in MW		99.00					
	Fuel Type	Coal						
		Oil						
		Gas						
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Nagaland State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							

	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – DELHI

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Delhi State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	9816270.50	9,432,580.35	9762541			
		Specific Emissions	1.08	1.05	1.01			
	Type of plant		Thermal					
	Capacity in MW		1,714.90					
	Fuel Type	Coal	□					
		Oil	□					
		Gas	□					
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector	Transport							

(PJ)							
	Agriculture, Forest and Fishing						
	Industry, Construction, wholesale, Private, and Public service Housing						
	Households & commercial						
	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Delhi State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power						
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – HARYANA

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Haryana State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	11606087.78	12,724,187.10	12898002			
		Specific Emissions	3.46	0.88	0.75			
	Type of plant		Thermal					
	Capacity in MW		2,632.40					
	Fuel Type	Coal	□					

		Oil	□					
		Gas	□					
		Diesel						
		Naptha	□					
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Hryana State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							
	Photovoltaic							
	Hydro power		□					
	Wave and Tidal							
	Total							

Data sheet for the Climate Plans – PUNJAB

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Punjab State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	15351079.24	15,680,290.34	16514545			
		Specific Emissions	0.35	0.34	0.34			
	Type of plant		Thermal					
	Capacity in MW		3,680.50					
	Fuel Type	Coal	□					
		Oil	□					
		Gas						
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							

	Industry, Construction, wholesale, Private, and Public service Housing						
	Households & commercial						
	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Punjab State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – RAJASTAN

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Rajasthan State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	19076712.76	19,152,561.26	19934028			
		Specific Emissions	0.31	0.29	0.35			
	Type of plant		Thermal, Nuclear					
	Capacity in MW		4,222.80					
	Fuel Type	Coal	□					
		Oil	□					
		Gas	□					
		Diesel	□					

		Naptha	□					
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Rajasthan State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							
	Photovoltaic							
	Hydro power		□					
	Wave and Tidal							
	Total							

Data sheet for the Climate Plans – UTTAR PRADESH

			Baseline			Climate plan		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Uttar Pradesh State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	63940453.72	72,492,126.75	73896713			
		Specific Emissions	0.73	0.72	0.71			
	Type of plant		Therma, Nuclearl					
	Capacity in MW		13,267.60					
	Fuel Type	Coal	□					
		Oil	□					
		Gas	□					
		Diesel	□					
		Naptha	□					
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, commercial and other Sources (construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							

	Industry, Construction, wholesale, Private, and Public service Housing						
	Households & commercial						
	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Uttar Pradesh State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – JAMMU & KASHMIR

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Jammu & Kshmir State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	8477.57	0.00	0.00			
		Specific Emissions	0.09	0.00	0.00			
	Type of plant		Thermal					
	Capacity in MW		2,041.15					
	Fuel Type	Coal						
		Oil						
		Gas						

		Diesel	□					
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Jammu & Kshmir State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							
	Photovoltaic							
	Hydro power		□					
	Wave and Tidal							
	Total							

Data sheet for the Climate Plans – HIMACHAL PRADESH

			Baseline			Climate plan		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Himachal Pradesh state							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	0.00	0.00	0.00			
		Specific Emissions	0.00	0.00	0.00			
	Type of plant							
	Capacity in MW		6,073.45					
	Fuel Type	Coal						
		Oil						
		Gas						
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							

	Industry, Construction, wholesale, Private, and Public service Housing						
	Households & commercial						
	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Himachal Pradesh State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – GUJARATH

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Gujarat State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	40288251.41	40,987,628.65	43282773			
		Specific Emissions	0.63	0.63	0.62			
	Type of plant		Thermal, Nuclear					
	Capacity in MW		10,680.00					
	Fuel Type	Coal	□					
		Oil	□					
		Gas	□					
		Diesel	□					

		Naptha	□					
		Lignite	□					
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Gujarat State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							
	Photovoltaic							
	Hydro power		□					
	Wave and Tidal							
	Total							

Data sheet for the Climate Plans – MADHYA PRADESH

			Baseline			Climate plan		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Powere Generation Capicity of Madhya Pradesh State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	33861304.66	35,323,344.24	39639983			
		Specific Emissions	0.39	0.33	0.33			
	Type of plant		Thermal					
	Capacity in MW		7,951.00					
	Fuel Type	Coal	□					
		Oil	□					
		Gas						
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							

	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Madhya Pradesh State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – CHATTISGARH

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Chattisghar State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	24007920.67	24,592,801.65	26928697			
		Specific Emissions	0.84	0.82	0.72			
	Type of plant		Thermal					
	Capacity in MW		5,250.00					
	Fuel Type	Coal	□					
		Oil	□					
		Gas						
		Diesel						
		Naptha						
		Lignite						
	Total							

	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Chattisghar State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							
	Photovoltaic							
	Hydro power							
	Wave and Tidal							
	Total							

Data sheet for the Climate Plans – MAHARASHTRA

		Baseline			Climate plan		
		2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**

GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Maharashtra State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	54994915.46	56,144,555.19	60828772			
		Specific Emissions	0.33	0.35	0.35			
	Type of plant		Thermal, Nuclear					
	Capacity in MW		16,112.30					
	Fuel Type	Coal	□					
		Oil	□					
		Gas	□					
		Diesel						
		Naptha	□					
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							

	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Maharashtra State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – GOA

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Goa State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	201230.46	197,584.59	200614			
		Specific Emissions	0.59	0.57	0.63			
	Type of plant		Thermal					
	Capacity in MW		48.00					
	Fuel Type	Coal						
		Oil						
		Gas						
		Diesel						
		Naptha	□					
		Lignite						
	Total							
	Industrial processes							

	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Goa State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							
	Photovoltaic							
	Hydro power							
	Wave and Tidal							
	Total							

Data sheet for the Climate Plans – ANDHRA PRADESH

		Baseline			Climate plan		
		2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**

GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Andhra Pradesh State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	47368203.83	48,874,807.93	50251288			
		Specific Emissions	0.45	0.34	0.32			
	Type of plant		Thermal					
	Capacity in MW		12,305.85					
	Fuel Type	Coal	□					
		Oil	□					
		Gas	□					
		Diesel	□					
		Naptha	□					
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Industry, Construction, wholesale, Private, and Public service Housing							

	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Andhra Pradesh State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – KARNATAKA

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Powere Generation Capicity of Karnataka State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	10275743.82	13,085,764.81	12830920			
		Specific Emissions	0.18	0.18	0.19			
	Type of plant		Thermal, Nuclear					
	Capacity in MW		6,178.22					
	Fuel Type	Coal	□					
		Oil	□					
		Gas	□					
		Diesel	□					
		Naptha	□					
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						

		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Karnataka State							
Renewable Energy	Waste							
	Biomass							
	Geothermal							
	Solar heat							
	RE electricity : Wind							
	Photovoltaic							
	Hydro power		□					
	Wave and Tidal							
	Total							

Data sheet for the Climate Plans – KERALA

		Baseline			**Climate plan**		
		2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh						
	Methane						
	Nitrous oxide						

	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Kerala State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	319998.23	920,902.93	1405078			
		Specific Emissions	0.14	0.14	0.14			
	Type of plant		Thermal					
	Capacity in MW		2,547.40					
	Fuel Type	Coal						
		Oil	□					
		Gas	□					
		Diesel	□					
		Naptha	□					
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, commercial and other Sources (construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							

	Non Conventional Power Generation Capacity of Kerala State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – TAMILNADU

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capicity of Tamilnadu State							
GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	39878698.67	42,235,415.86	45237491			
		Specific Emissions	0.42	0.38	0.39			
	Type of plant		Thermal, Nuclear					
	Capacity in MW		9,234.05					
	Fuel Type	Coal	□					
		Oil	□					
		Gas	□					
		Diesel	□					
		Naptha	□					
		Lignite	□					
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							

	Residential, Commercial and other Sources Cconstruction)						
	Land Use and Biomass burning						
	Waste Disposal and Treatment						
	Total						
Energy Consumption by Sector (PJ)	Transport						
	Agriculture, Forest and Fishing						
	Industry, Construction, wholesale, Private, and Public service Housing						
	Households & commercial						
	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Tamilnadu State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – PONDICHERY

		Baseline			**Climate plan**		
		2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO_2 equivalents)	CO_2 Emissions ton per MWh						
	Methane						
	Nitrous oxide						
	CFC						
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Power Generation Capaicity of Pondichery State						

GHG Emissions by Sector (CO_2 equivalents)	Power stations (CO_2 Emissions ton per MWh)	Absolute Emissions	122665.92	127,882.09	128471			
		Specific Emissions	0.50	0.50	0.50			
	Type of plant		Thermal					
	Capacity in MW		32.50					
	Fuel Type	Coal						
		Oil						
		Gas	□					
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO_2						
		CH_4						
	Fossil fuel retrieval processing and distribution							
	Residential, Commercial and other Sources (Construction)							
	Land Use and Biomass burning							
	Waste Disposal and Treatment							
	Total							
Energy Consumption by Sector (PJ)	Transport							
	Agriculture, Forest and Fishing							
	Industry, Construction, wholesale, Private, and Public service Housing							
	Households & commercial							
	Diesel , electricity, fuels							
	DG sets/generators							
	Energy Sector (Production and Distribution)							
	Oil							
	Gas							
	Coal							
	Nuclear							
	Total							
	Non Conventional Power Generation Capacity of Pondichery State							

Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

Data sheet for the Climate Plans – Uttarakhand

			Baseline			**Climate plan**		
			2005-06	**2006-07**	**2007-08**	**2015**	**2030**	**2050**
GHG Emissions (CO$_2$ equivalents)	CO$_2$ Emissions ton per MWh							
	Methane							
	Nitrous oxide							
	CFC							
	Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Conventional Powere Generation Capicity of Pondichery State							
GHG Emissions by Sector (CO$_2$ equivalents)	Power stations (CO$_2$ Emissions ton per MWh)	Absolute Emissions	0.00	0.00	0.00			
		Specific Emissions	0.00	0.00	0.00			
	Type of plant		Thermal					
	Capacity in MW		3,361.85					
	Fuel Type	Coal						
		Oil						
		Gas	□					
		Diesel						
		Naptha						
		Lignite						
	Total							
	Industrial processes							
	Transportation fuels							
	Fuel Type	petrol						
		Diesel						
		Gas						
	Agriculture							
	Emissions	CO$_2$						
		CH$_4$						
	Fossil fuel retrieval processing and distribution							
	Residential, commercial and other Sources (construction)							
	Land Use and Biomass burning							

	Waste Disposal and Treatment						
	Total						
Energy Consumption by Sector (PJ)	Transport						
	Agriculture, Forest and Fishing						
	Industry, Construction, wholesale, Private, and Public service Housing						
	Households & commercial						
	Diesel , electricity, fuels						
	DG sets/generators						
	Energy Sector (Production and Distribution)						
	Oil						
	Gas						
	Coal						
	Nuclear						
	Total						
	Non Conventional Power Generation Capacity of Pondichery State						
Renewable Energy	Waste						
	Biomass						
	Geothermal						
	Solar heat						
	RE electricity : Wind						
	Photovoltaic						
	Hydro power	□					
	Wave and Tidal						
	Total						

APPENDIX 4

POWER DEMAND AND GENERATION DATA

Demand for **Petroleum** products (2004-05) =124 Mt (2009-10) = 147 Mt, 2014-15) =174 Mt,(2029-30) =281 Mt

Demand of **Coal (**2006-07) = 481Mt, (2011-12) = 612 Mt (2016-17) = 764 Mt, (2030) = 1417 Mt

Demand for **Natural Gas** (2004-05) = 98 MMscmd, (2009-10) = 134 MMscmd (2014- -15) = 183 MMscmd, (2029-30) = 667MMscmd

Electricity generation from **Hydro power** (2006-07) =87 BkWh, (2011=12) =139 BkWh (2016-17) = 204 BkWh =139 BkWh, (2031-32) = 401 BkWh

Electricity generation from **Nuclear power** (2006-07) = 39 BkWh, (2011=12) = 64BkWh (2016-17) = 118 BkWh, (2031-32) = 375 BkWh

Electricity generation from **Renewable** (2006-07) = 8 BkWh, (2011=12) =11BkWh (2016-17) =14 BkWh, (2031-32) = 24 BkWh

Primary Commercial Energy requirements

Hydro (2011-12) = 12 Mtoe, (2016-17) = 18 Mtoe, (2031-32) = 35 Mtoe,

Nuclear (2011-12) = 17 Mtoe, (2016-17) = 31 Mtoe, (2031-32) = 98 Mtoe,

Coal	(2011-12)	(if GDP 8%)	= 257 Mtoe	(if GDP 9%)	= 283 Mtoe
	(2016-17)	,,	= 338 Mtoe	,,	= 375 Mtoe
	(2031-32)	,,	= 835 Mtoe	,,	= 937 Mtoe
Oil	(2011-12)	(if GDP 8%)	= 166Mtoe	(if GDP 9%)	= 186Mtoe
	(2016-17)	,,	= 214 Mtoe	,,	= 241 Mtoe
	(2031-32)	,,	= 486 Mtoe	,,	= 548 Mtoe
Gas	(2011-12)	(if GDP 8%)	= 44Mtoe	(if GDP 9%)	= 48Mtoe
	(2016-17)	,,	= 64Mtoe	,,	= 74Mtoe
	(2031-32)	,,	= 197 Mtoe	,,	= 240 Mtoe

TECHNOLOGIES

POWER SECTOR

Commercial

1. Thin Film Solar Sheets Technology: Solar cells made from poly crystalline and more aesthetic and cheaper than the bulkier conventional solar cells.

2. Best Practices in Compressed Air Systems: It is possible to save 25% to 30% energy in compressed air systems by following few best practices by power stations.

3. Improvement of Boiler Efficiency: Cleaning of super heater was carried out by making a c circuit taking the ceiling, convection and platen super heaters. Significant heat transfer and decrease in metal temperatures was observed after chemical cleaning.

4. Using Electro Chlorinators: Electro chlorinator keeps intakes free of bio fouling and maintenance the efficiency of heat transfer to the desired level and reduces the system life cycle costs.

5. Methane Drive: Removing methane from under ground coal mines**.** Coal bed methane is natural gas found in coal beds that can be used for domestic commercial and industrial purposes and even for generating electricity.

6. Introduction of Powered Ventilators: Powered ventilators are pollution work efficiently with low power consumption.

7. Selective Catalytic Reduction: Urea is used to convert nitrogen oxides in to harmless nitrogen.

8. Co. Gasification: Various type of coal and biomass are put together and converted in to a gaseous product stream that can be used to produce electricity, hydrogen, chemicals.

9. Chemical Looping Combustion: Carbon containing fuels can be oxidized with a metal oxide that provides the oxygen for consuming the fuel. That product is $CO_{2,}$ water and reduced metal. The reduced metal can be re- oxidized with air in a separate reactor

10. Capture the acid gases and CO_2 from flue gas: Capture the acid gases and CO_2 from flue gas at coal burning power plants buy using ammonia based solution. Primarily to remove SO_2 & NO_X. Fertilizer is produced in the process and the spent ammonia solution is generated and recycled back to the scrubbing unit.

11. Fuel Cell Technology: A fuel cell is an electro chemical device that converts chemical energy of hydrogen in to heat and electricity with out combustion. Fuel cell system mainly operate on pure hydrogen and air to produce electricity with water and heat as the by product.

12. Carbon Dioxide Capture and Storage:

i) Post combustion

Amine Based Process: The flue gas is cooled and treated to reduce its level of particulates SO_X and NO_X. Then boosted .The clean flue gas continue to the stack by a fan to overcome pressure drops through an absorbs in it a clean amine solution, typically monoethanolamine is pushed in a counter to the flow the gas and the interaction absorbs the CO_2 .The clean flue gas continue with the stack. Mean while, amine solution now rich in CO_2 pumped in to a stripper to separate the amine from gas. Chilled ammonia process: The process requires the flue gas to be chilled to 35 F before entering the clean up system. The cooled flue gas flows upward, against the current of slurry containing a mix of dissolved and suspended ammonium bicarbonate. The CO_2 rich spent ammonia then is regenerated under pressure to reduce the energy requirements of CO_2 liquefaction and compression. Nitrogen excess of oxygen and low concentration of CO_2 flows to the stack.

ii) Pre combustion

iii) Oxy fuel combustion: Burning the coal in the presence of oxygen, rather than air produces a highly pure CO_2 exhaust that can be captured and sequestered at relatively low cost. Often the oxygen is mixed with the exhaust to regulate combustion and to raise the level of in the flue gas.

iv) Chemical looping

13. Fast breeder reactors: Fast reactor designs use liquid metal as the primary coolant, to transfer heat from the core to steam used to power the electricity generating turbines. Some early FBRs used mercury, and other experimental reactors have used Na K. Both of these choices have the advantage that they are liquids at room temperature, which is convenient for experimental rigs but less important for pilot or full scale power stations Sodium is the normal coolant for large power stations, but lead has been used successfully for smaller generating rigs.

R&D

1. Reversing CO_2 Emissions: By using solar energy to reverse combustion and convert CO_2 to CO and then use the CO to manufacture gasoline and other such fuels by building a navel reactor that can chemically re generalize $CO_{2.}$ The device uses two stage combustion thermo chemical reactions to break down CO_2 to produce CO. C O readily be employed to produce different fuels including hydrogen, methanol, gasoline by using conventional technologies.

2. Electro Chemical Separation: An anion exchange membrane was sandwiched between the gas diffusion electrodes consisting of a nickel based electro catalyst on carbon papers. When a potential was applied across the low temperatures

electrochemical cell a mixtures of CO_2 O_2 was flowed over the wetted electrolyte on the cathode side, a stream of CO_2 O_2 of about 4;1 was produced on the anode side, bi carbonate ions are CO_2 carriers in the membrane .A mix of $CO_{2,}$ O_2 is produced.

3.Electrolysis and Pre Treatment Methods: Electrolysis of NACL solution and the serpentine as the source of mg^{+2} absorb CO_2 in the simulating flue gas is introduced which is used the electrolyze NACL solution to produce HCL solution was used to absorb CO_2 in simulation were mixed to form $MGCO_3$ deposition could be produced at low temperature and pressure. In order to further increase the solubility of mg^{+2} from serpentine, the heat pre treatment of serpentine, under nitrogen was investigated.

4. Medical Technique adapted to Study Mobility of CO_2 in Coal: Using the computed tomography to asses the potential long term storage of CO_2 in deep, unmineable coal seems. The scanner is used to measure in situ fluid displacement and sorption of fluids with in mineral cores.

5. Recovery of Coal bed Methane by using Nitrogen Technology: large scale of injection of CO_2 in to coal deep coal beds through the nitrogen.

6. Cement Plugs will resist Degradation by CO_2: The cement is used to install and/ or plug existing wells in critical in preventing leakage of to the surface under geological sequestration scenarios.

TRANSPORT

Commercial

Hybrid Propulsion System: Recovering the braking energy and its use for acceleration purpose. (Finland)

R&D

1. Solar Taxi: It is an energy neutral car & an electrical vehicle, with a 5 meter solar trailer covered with 6 square meters of high energy solar cells. The car is powered by the zebra batteries which are stored the electricity. The solar cells on the trailer produce enough electricity to run the car for up to 100 km a day.

2. Methane Drive: Using of methane to run the cars.

3. Hydrogen Pellets for Vehicles: Ammonia borane compressed in to small pellets to serve as a hydrogen storage material.

4. Fuel from Food Waste: Two kinds of bacteria to produce hydrogen in a bio reactor with the product from one providing food for another.

6. Hydrogen for Fuel cells from Formic Acid: In the presence of an amine and a suitable catalyst formic acid is selectively converted in to CO_2 and hydrogen at room temperature. Char coal filter is used to purify the hydrogen gas for use in a fuel cell.

Commercial

1. Waste to Fuel Technology: To convert plastic, organic, electronic waste in to petroleum.(using in Netherlands, West Asia, Malaysia, Australia Italy Germany).

2. Introduction of new Braking and Duct System in Trains: Regenerative braking system involves a machine that supplies electric energy back to the over head power lines, used by other trains in the same service line. Mumbai sub urban railways use this technique and conserving approx 35 % energy saving.

AGRICULTURE

Commercial

1. Oil from Algae: Algae can lock up CO_2 emissions called bio fixation. Prototype algae farms use the tiny plants to suck up CO_2 emissions from power plants.

R&D

1. Running Cars on Hydrogen made from Starch: Using set of 13 commercially available enzymes which are isolated from yeasts, bacteria, spinach and rabbit muscle enzymes, to convert starch available from numerous sources including corn and potatoes in to hydrogen gas at low temperatures. The starch and water used to oxidize the starch .The enzymes facilitates chemical reactions in which the water and starch can be completely converted in to hydrogen and CO_2.

2. Rhizofiltaration: It is an eco friendly technique for waste management. Rhizofiltaration is a type of photo remediation, which refers to the approach of using hydroponically cultivated plant roots to remediate contaminated water through absorption, concentration, precipitation of pollutants. This contaminated water is either collected at contaminated waste site are brought to the plants or plants are planned up taken the water and the contaminants dissolved in it.

3. Paddy Fields as Carbon Sinks: paddy sequesters organic carbon from the atmosphere their by **r**educing global warming. Paddy fixes carbon in the soil because submerged conditions prevent the carbon from oxidizing and aquatic plants added 0.7 tones of carbon per hectare of carbon in the soil annually through the photosynthesis.

4. Biogas Production from Rice Straw: Treat the lignocelluloses materials with sodium hydroxide. It is easily digested by anaerobic bacteria to produce biogas.

5. Hydrogen Production from Carbonaceous Solid Wastes by Steam Reforming: It converts renewable biomass materials in to clean fuel gases or synthesis gas includes mainly Hydrogen and CO. Bio syngas rich in CO and H_2 obtained by gasification of biomass.

6. Bio Methanol Production from Organic Waste Materials: Methanol can be produced from hydrogen –carbon oxide mixtures by means of the catalytic reaction of CO_2 and CO with Hydrogen. Bio synthesis gas rich in CO and H_2 obtained by gasification of biomass.

7. Conversion of Corn Stover to Chemical and Fuels: Converting Corn Stover in to valuable products such as chemicals and fuels by thermal conversion including liquefaction and cytolysis methods.

8. Bio Diesel Production from Vegetable Oils & Animal Fats: Modifying vegetable oils and fats to use them as diesel fuel, such as

i) Pyrolysis - Thermal cracking

ii) Blending – Dilution with hydro carbons

iii) Emulsification

iv)Transesterification- It is affected by molar ratio of glycerides to alcohols

CONSTRUCTION

Commercial

1. Electricity from Plastic Waste: By burring of the liquid hydrocarbons from plastic waste.

R&D

2. Roads from Plastic Waste: Waste plastic is grounded and made in to powder and 3 to 4% of plastic is mixed with bitumen .plastic increases the melting point of bitumen and road retain.

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