The Final Report of the Expert Group on Low Carbon Strategies for Inclusive Growth






सत्यमेव जयते

Planning Commission
Government of India

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April, 2014

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MONTEK SINGH AHLUWALIA

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उपाध्यक्ष
योजना आयोग
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DEPUTY CHAIRMAN
PLANNING COMMISSION
INDIA

Foreword

The Twelfth Five Year Plan set the target of faster, sustainable and more inclusive growth as the cornerstone of India's growth policy, for the period 2011-12 to 2016-17. The Plan also emphasised that energy was going to be a critical constraint, and it was vital to move towards a rational energy policy that would keep in mind constraints on account of the total availability of domestic energy resources, the limits on import dependence for energy security, and in the longer term, the implications of the level and mix of energy sources for carbon emissions.

The **Report of the Expert Group on Low Carbon Strategies** is an important contribution quantifying some of the challenges we face over a longer period, especially from the perspective of the need to move towards a lower carbon future. The findings of this Report add vital dimension to the perspectives that emerge from the various conventional economy wide models used for plan projections, which typically have not focussed on the low carbon objective. The Report examines these issues based on a multi-sector economy wide optimising model. It casts interesting light on the sector specific challenges we face in trying to move towards a lower carbon future.

The Report indicates the broad range of options available. The Baseline Inclusive Growth (BIG) strategy generates an average growth rate of 7 percent between 2007 and 2030, whereas the Low Carbon Inclusive Growth (LCIG) strategy generates only marginally lower growth of 6.9 percent, but brings about a significant reduction in emissions per capita in terminal year (2030) from 3.6 tonnes in the BIG case to 2.6 tonnes in LCIG. However, the shift requires substantial additional investment amounting to 1.5 percent of GDP, and it is assumed that funding needed to finance this will be obtained as an addition to what is available in the baseline case, either through international or additional domestic sources. Clearly, if resources of this magnitude are not available, the outcomes in terms of growth, inclusion and sustainability would be lower.

This Report complements the Energy Pathways Calculator launched by the Planning Commission recently, which provides a web tool to explore the implications of making different assumptions about demand and supply, including the source mix. The calculator can be accessed through the Planning Commission website.

I compliment Dr. Kirit Parikh and his team for preparing this Report, which would be a valuable input into the formulation of policy going forward. Hopefully, it would also stimulate a wider debate and discussion on these issues.

(Montek Singh Ahluwalia)
April 30, 2014

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Expert Group on Low Carbon Strategies for Inclusive Growth

Composition of the Expert Group

1.	Kirit Parikh	Chairman
2.	Nitin Desai	Member
3.	Ajay Mathur	Member
4.	Jamshyd N. Godrej	Member
5.	Chandrajit Banerjee	Member
6.	Ritu Mathur	Member
7.	Anshu Bharadwaj	Member
8.	Anand Patwardhan	Member
9.	Arunavo Mukerjee	Member
10.	Jagdish Kishwan	Member
11.	Tulsi Tanti	Member
12.	Pavan Goenka	Member
13.	Jyotirmay Mathur	Member
14.	Rita Roy Choudhury	Member
15.	Indrani Chandrasekhran	Member
16.	Varad Pande	Member
17.	U. Sankar	Member
18.	S.C. Sharma	Member
19.	S.S. Krishnan	Member
20.	Arunish Chawla	Member-Secretary

In addition, representatives of Ministry of Power, New and Renewable Energy, Environment and Forest, Road Transport and Highways, Railways, Urban Development, Coal, Petroleum, Agriculture, Industrial Policy and Promotion, Central Electricity Authority, NTPC etc. took part in the deliberations of the Expert Group.

Terms of Reference of the Expert Group

1. Review existing studies on low carbon growth/low carbon pathways for India prepared by various organizations
2. Conduct further analysis, as required, to assess low carbon options for the Indian Economy
3. Present a report outlining the roadmap for India for low carbon growth. This would include the following:-
   i. An evaluation of some key alternative low carbon options with an analysis of their cost-benefit, and relative merits and demerits
   ii. An Action Plan comprising of critical low carbon initiatives to be undertaken, including sector-specific initiatives, along with a suggested timeline and targets starting 2011, that can feed into the Twelfth Plan process.
   iii. List of enabling legislations, rules or policies required to operationalize the low carbon roadmap.
4. The Expert Group shall submit its Report to the Planning Commission.

सत्यमेव जयते
Dr. Kirit Parikh
Chairman
EXPERT GROUP ON LOW CARBON STRATEGIES
FOR INCLUSIVE GROWTH

GOVERNMENT OF INDIA
PLANNING COMMISSION
YOJANA BHAWAN
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Preface

The Expert Group on "Low Carbon Strategies for Inclusive Growth" was set up by the Planning Commission to suggest low carbon pathways consistent with inclusive growth. The Expert Group submitted its Interim Report in May 2011. The group also made contributions to the Twelfth Five Year Plan and is now presenting the Final Report.

As is well known, India is one of the lowest emitters of greenhouse gases (GHGs) in the world on per capita basis. At 1.4 tCO_2/person in 2010, India's emissions were less than one third of world average of 4.5 tCO_2/person, less than one fourth that of China and one twelfth that of the US. Yet, India is highly vulnerable to climate change, and has an interest in a fair and equitable global compact to minimise the risk of climate change. Climate change is already an existing threat, manifesting itself in the form of increased frequencies and intensities of extreme events. There is a need for urgent action at the global level, which is why India has promised to keep its per capita emissions below the per capita emissions of industrialised countries. India has also prepared a national action plan for climate change and said that it will reduce the emission intensity of its GDP by 20 to 25 percent, over 2005 levels, by 2020. These measures are taken in the hope that they will encourage countries to arrive at a global agreement.

The Interim Report of the Expert Group, which provided a menu of options, had shown that it is possible for India to reduce its emission intensity by 20-25 percent over 2005 levels by the year 2020. This Final Report provides a more detailed and longer term assessment of these options, and the macro-economic and welfare implications of the low carbon strategy.

In the low carbon strategy described here, we have given high priority to inclusive growth. It is possible for India to attain high level of human wellbeing. The pursuit of low carbon development is consistent with growth and inclusion. In the low carbon strategy, energy efficiencies in households, buildings, industry and transport play important roles. At the same time low carbon supply technologies, such as solar and wind in the power sector, and greater use of public transport and non-motorized transport are critical. Increased sequestration through enlarged green cover through Green India Mission also helps.

Nevertheless, unless a dramatic reduction in the cost of renewable energy takes place, the expansion of renewable capacities requires additional investment in the power sector. Thus, less investment will be available for other sectors resulting in lower GDP. Of course, there are other benefits of low carbon strategy such as reduced local environmental pollution and reduced dependence on imported energy. However, valuation of these benefits, which has not been done here, may suggest that even with lower GDP, the low carbon strategy is worth pursuing.

The monetary value of the loss in GDP, however, is sizeable. External resources required to put Indian economy back on the same growth path are far in excess of the size of climate fund that is currently being talked about.

In preparing this report many have contributed in varying degrees. Some have worked hard and made major contributions. It is my pleasure to particularly thank them. Among these are, in no particular order, Arunish Chawla, member-secretary of the group for his passion, interest, involvement, commitment and support throughout the long period that it has taken to prepare this final report; Probal Ghosh of IRADe for bearing the brunt of the modelling; Ajay Mathur of the Bureau of Energy Efficiency for his support in different chapters on energy efficiency; Anshu Bhardwaj, S. S. Krishnan, Nihit Goyal, Mohamad Sahil of CSTEP for contributions to chapters on industry, power and development implication; Ritu Mathur and Sarbojit Pal of TERI for contributing to the chapter on transport, Anand Patwardhan and Indrani Chandrashekharan for their contributions to introduction and development linkages; Varad Pande for his contribution to policy recommendations; Jagdish Kishwan for his contribution to chapter on Green India Mission; Jyotirmay Mathur for his contribution to the buildings chapter; Rita Roy Choudhury of FICCI for her contribution to policy recommendations, and Jayeeta Bhadra of IRADe for her contributions to the household energy efficiency chapter. I would also like to thank the team of young professionals in the Planning Commission namely Ami Misra, Poorvi Goel and Urvana Menon for their hard work in putting together this Final Report.

Apart from them, other members of the Expert Group have given many useful suggestions and have contributed to this report. I thank them all.

Kirit Parikh
Chairman

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Conversion Tables

Calorific Values, Units and Conversion Factors

Calorific Value of Various Fuels

Sl. No.	Name of Fuel	Unit	Calorific Value (kilo-calories)
1.	Biogas	M3	4713
2.	Kerosene	kg	10638
3.	Firewood	kg	4500
4.	Cow-dung Cakes	kg	2100
5.	Coal	kg	4000
6.	Lignite	kg	2865
7.	Charcoal	kg	6930
8.	Soft coke	kg	6292
9.	Oil	kg	10000
10.	LPG	kg	11300
11.	Furnace Oil	kg	9041
12.	Coal gas	m3	4004
13.	Natural gas	m3	9000
14.	Electricity	kWh	860

Conversion Factors

Kilo Calorie	3.96832 BTU, 4186.8 Joules
Kilowatt Hour	3412.14 BTU, 3.6x106 Joules
Btu	0.252 Kilo Cal, 1.055 Kilo Joules
US Gallon	0.833 Imperial Gallon, 0.134 Cu. Feet 0.00378 Cu.M
Imperial Gallon	1.2009 US Gallon, 0.1605 Cu. Feet 0.0045 Cu.M
Cubic Metres	264.172 US Gallons, 219.969 Imperial Gallons, 35.3147 Cu. Feet
Cubic Feet	7.4805 US Gallons, 6.2288 Imperial Gallons, 0.0283 Cu. M
1 BkWh Hydro, Solar or Wind Electricity	0.086 Mtoe*
1 BkWh Nuclear Electricity	0.261 Mtoe
1Mt of Coal	0.41 Mtoe
1 Mt of Lignite	0.2865 Mtoe
1 Billion Cubic Meter of Gas	0.9 Mtoe
1 Mt of LNG	1.23 Mtoe
1 Mt of Fuel wood	0.45 Mtoe
1 Mt of Dung Cake	0.21 Mtoe
***Mtoe conversion factors are taken as per International Energy Agency (IEA) Practice**	

Crude Oil	Tonnes (Metric)	Kilolitres	Barrels	US Gallons
Tonnes (Metric)	1	1.165	7.33	307.86
Kilolitres	0.8581	1	6.2898	264.17
Barrels	0.1364	0.159	1	42
US Gallons	0.0032	0.0038	0.0238	1

Natural Gas	B Cu. M-NG	B Cu. Feet-NG	MTOE	MT-LNG	Trillion BTU	Million Barrels of Oil
B Cu. M	1	35.3	0.9	0.73	36	6.29
B Cu. Feet	0.028	1	0.026	0.021	1.03	0.18
Mtoe	1.111	39.2	1	0.805	40.4	7.33
MT-LNG	1.38	48.7	1.23	1	52.0	8.68
Trillion Btu	0.028	0.98	0.025	0.02	1	0.17
Million Barrels of Oil	0.16	5.61	0.14	0.12	5.8	1

Units

Units	Name	Remarks
BCM	Billion Cubic Meter	= 109 m3
BkWh	Billion Kilowatt Hours	
Bt	Billion Tonne	= 109 Tonne
GWe	Giga Watt Electrical	
GW-Yr	Giga Watt Year	= 8.76 x 109 kWh
kcal	Kilo Calorie	= 4186.8 J or 396832 Btu
kg	Kilogram	-
kgoe	Kilogram of Oil Equivalent	-
kW	Kilo Watt	= 103 Watt
kWh	Kilo Watt Hour	= 3.6x103 J, also expressed as Unit
M. ha	Million hectares	
M. ltrs	Million litres	
MMBtu	Million British Thermal Unit	Traditional British unit
MMscmd	Million Standard Cubic Meters per Day	Traditional unit used in gas industry
Mt	Million Tonnes	= 106 Tonne
Mtoe	Million Tonnes of Oil Equivalent	-
MVA	Million Volt Amperes	
MW	Mega Watt	= 106 Watt or 103 kW
MWe	Mega Watt Electrical	
MWt	Mega Watt Thermal	
T	Tonne	Same as Metric Ton = 1000 kg
tkm	Tonne Kilometer	tonne of material moved by km
TWH	Terawatt Hour	

Emission Factors

Coal and Lignite	1.614 tonne of CO_2 per tonne of Indian Coal & Lignite mix
Crude Oil	0.175 tonne of CO_2 per tonne of crude oil refined
Petroleum Products	3.102 tonne of CO_2 per tonne
Natural Gas	0.002 tonne of CO_2 per cubic metre
Cement	0.451 tonne of CO_2 per tonne

Acronyms

AEEI	Autonomous Energy Efficiency Improvement
AD	Accelerated Depreciation
AERB	Atomic Energy Regulation Board
AR	Assessment Report
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BEE	Bureau of Energy Efficiency
BIG	Baseline Inclusive Growth
BLY	Bachat Lamp Yojana
CAGR	Compound Annual Growth Rate
CAIT	Climate Analysis Indicators Tool
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CFL	Compact Fluorescent Lamp
CH4	Methane
CMIP	Coupled Model Intercomparison Project
CN	Conservation
CO2	Carbon Dioxide
CS	Carbon Sequestration
CSC	Convention on Supplementary Compensation
CSP	Concentrated Solar Power
CSR	Corporate Social Responsibility
CSTEP	Center for Study of Science, Technology and Policy
CWET	Center for Wind Energy Technologies
DAE	Department of Atomic Energy
DC	Designated Consumer
DCR	Domestic Content Requirement
DISCOM	Distribution Company
DSM	Demand Side Management
EAF	Electric Arc Furnace
EC Act	Energy Conversation Act
ECBC	Energy Conservation Building Code
EE	Energy Efficiency
EEFP	Energy Efficiency Financing Platform
EPRI	Electric Power Research Institute
ESCOs	Expert Energy Service Companies
ESS	Energy Storage Systems
FAR	Floor Area Ratio
FDA	Forest Development Agency
FDs	Forests Departments
FEEED	Framework for Energy Efficient Economic Development
FSA	Fuel Supply Agreement
FY	Fiscal Year
GBI	Generation Based Incentive
GCal/tcs	giga calories per tonne of crude steel
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHGs	Green House Gases
GIM	Green India Mission
GIZ	Gesellschaft für Internationale Zusammenarbeit
GRIHA	Green Rating for Integrated Habitat Assessment
HVAC	Heating Ventilation and Air Conditioning
IEA	International Energy Agency
IEP	Integrated Energy Policy
IGBC	Indian Green Building Council
IL	Incandescent Lamp
INCCA	Indian Network on Climate Change Assessment
IPCC	The Intergovernmental Panel on Climate Change
IPP	Independent Power Producers
IRADe	Integrated Research for Action and Development
IT	Information Technology
JFMC	Joint Forest Management Committee
JNNSM	Jawaharlal Nehru National Solar Mission
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
kCal/ kg	kilo calorie per kilogram
kVA	kilo Volt Ampere
kW	kilowatt
kWh	kilowatt-hour
kWh/sq.m/year	Kilowatt hour per square metre per year
LBNL	Lawrence Berkeley National Laboratories

LCIG	Low Carbon Inclusive Growth
LCoE	Levelised Cost of Energy
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land Use Change and Forestry
LWR	Light Water Reactor
M&E Framework	Monitoring and Evaluation Framework
MDF	Medium Dense Forests
MEDA	Maharashtra Energy Development Agency
MNIT	Malaviya National Institute of Technology
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MoRTH	Ministry of Road Transport and Highways
MPCE	Monthly Per Capita Consumer Expenditure
MSME	Micro Small and Medium Enterprise
MSW	Municipal Solid Waste
MT	Million Tonnes
MtCO2	Million Tonnes of Carbon Dioxide
MTEE	Market Transformation for Energy Efficiency
MTOE	Million Tonnes of Oil Equivalent
MW	megaWatt
N2O	Nitrous Oxide
NAMA	Nationally Appropriate Mitigation Actions
NAPCC	National Action Plan for Climate Change
NATCOM	National Communication (to the United Nations Framework Convention on Climate Change)
NCAER	National Council of Applied Economic Research
NCDMA	National Clean Development Mechanism Authority
NEW	North East West
NIMZ	National Investment and Manufacturing Zones
Nox	Nitrogen Oxides
NSS	National Sample Survey
NTFP	Non Timber Forest Produce
NTPC	National Thermal Power Corporation
NWM	National Wind Mission
OF	Open Forests
PAs	Protected Areas
PAT	Perform Achieve and Trade
PGCIL	Power Grid Corporation of India Limited
PHS	Pumped Hydroelectric Systems
PHWR	Pressurized Heavy Water Reactors
PPP	Public Private Partnerships
PPP	Purchasing Power Parity
PSUs	Public Sector Undertakings
PV	Photo-Voltaic
QA/QC	Quality Assurance/Quality Control
RCP	Representative Concentration Pathways
REDD	Reducing Emissions from Deforestation and Forest Degradation
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
RHI	Renewable Heat Incentive
SCEF	State Clean Energy Fund
SEC	Specific Energy Consumption
SERC	State Energy Regulatory Commission
SEZs	Special Economic Zones
SMEs	Small and Medium Enterprises
SMF	Sustainable Management of Forests
SOx	Sulphur Oxides
SRES	Special Report on Emissions Scenarios
T/m3/Day	tonnes per metric cube per day
T/tcs	tonnes per tonne of crude steel
tCO2/tcs	tonnes of carbon dioxide per tonne of crude steel
TEPCo	Tokyo Electric Power Co
TERI	The Energy and Resources Institute
TPD	tonnes per day
TPES	Total Primary Energy Supply
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
USD-INR	United States Dollar - Indian National Rupee
VDF	Very Dense Forests
VGF	Viability Gap Funding
VSS	Van Samrakshana Samiti
WGI	Worldwide Governance Indicators
WRI	World Resource Institute

Executive Summary

There is near consensus among the scientific community that ongoing global warming is an anthropogenic phenomenon, a result of carbon intensive activities since the industrial revolution. However, different countries are at different stages of development, and have had different emission trajectories in the past. On a per capita basis, India is one of the lowest emitters of greenhouse gases in the world, yet it is threatened by the impact of global warming and climate change.

As per NATCOM 2007, India emitted 1,728 million tonnes CO_2 equivalent of greenhouse gases, making it the sixth largest emitter of greenhouse gases in the world. India is, however, conscious of its global responsibility, and in December 2009, it announced that it would reduce the emissions intensity of its GDP by 20 to 25 percent, over the 2005 levels, by the year 2020. This voluntary commitment, which India has made to the international community, shows India's resolve to ensure that its growth process is sustainable and based on low carbon principles. With the approval of the Twelfth Five Plan by the National Development Council, sustainability has become an integral part of India's growth policy at both central and state levels.

The Expert Group on Low Carbon Strategies for Inclusive Growth has evolved a macro-model to fully elucidate the inter-sectoral implications of different mitigation measures and ensure that the low carbon strategies being recommended are mutually consistent with each other. The Low Carbon Growth Model is a multi-sectoral, dynamic optimization model that maximizes present discounted value of private consumption subject to commodity supply, natural resource and technology constraints. The Expert Group takes the year 2007, for which India's official greenhouse gas inventory is available, as the base year, and makes projections going forward up to the year 2030.

The Model output is summarized through two end-point scenarios: the BIG (Baseline, Inclusive Growth) and the LCIG (Low Carbon, Inclusive Growth). While inclusive actions remain unchanged between the two scenarios, low carbon strategies span the vector space between them. Pursuit of Low Carbon Strategies brings down the average GDP growth rate by 0.15 percentage points, while per capita CO_2 emissions (in 2030) fall from 3.6 tonnes per person in the BIG scenario to 2.6 tonnes per person in the LCIG scenario. However, in both the scenarios, the total carbon emissions continue to rise up to the year 2030. The cumulative costs of low carbon strategies have been estimated to be around 834 billion US dollars at 2011 prices, over the two decades between 2011 and 2030. If these costs were borne entirely by domestic resources, the cumulative loss in output (GDP) between 2011 & 2030 would be 1,344 billion US dollars at 2011 prices.

While total power demand remains unchanged between the two scenarios, emission intensity of GDP declines by 22 percent, over 2007 levels (by 2030) in the BIG scenario, as compared to 42 percent, over 2007 levels (by 2030) in the LCIG scenario. Further, due to a massive change in the energy mix by 2030, demand for coal comes down from 1,568 Mt in the BIG to 1,278 Mt in the LCIG scenario, demand for crude oil comes down from 406 Mt in the BIG to 330 Mt in the LCIG scenario, while demand for gas marginally rises from 187 bcm in the BIG to 208 bcm in the LCIG scenario. At the same time, the installed wind and solar power capacities need to be increased to 118 GW and 110 GW respectively, by the year

2030, in the LCIG scenario. The sectoral chapters focus on a more detailed analysis of the low carbon strategies that are in line with the LCIG scenario. The residential and commercial sector has grown rapidly over the past fifteen years, as an upshot of increasing population and income. Lighting and appliances in households (such as refrigerators, air conditions, water heaters, fans, etc.) account for 10 percent; while residential and commercial sectors together account for 29 percent of the total electricity consumption. As accelerating urbanization takes urban population to 600 million plus by 2030, demand for electricity will rise. In order to improve energy efficiency in the use of power, the Bureau of Energy Efficiency (BEE) periodically mandates regulatory standards, and also formulates promotional schemes, which encourage the use of efficient lighting, heating, ventilation, air-conditioning (HVAC), and electric motor based appliances in the residential and commercial establishments across the country.

Construction is the second largest economic activity in India that contributes around 8 percent to the nation's GDP. It has been estimated that 70 percent of the building stock in the year 2030 would be built during the period 2011 to 2030. The Energy Conservation Building Code specifies the energy performance requirement of commercial buildings in India. The analysis here estimates carbon abatement potential, by appropriating this code into the proposed construction of buildings, to help reduce the need for lighting, heating, ventilation and air conditioning. The likely opportunities for reduction in emissions intensity are based on the projected ECBC complaint built-up space, existing as well as new, by the year 2030. The Expert Group emphasizes the importance of creating a policy environment that incentivizes builders and owners alike, to opt for energy efficient options in their buildings. Some incentives to promote uptake of green buildings and alternative options to finance such projects have also been recommended.

The industry sector presents an opportunity for considerable energy savings, in the iron and steel, and cement sectors, which are the most energy intensive manufacturing sectors in the country. In Cement, use of high efficiency crushers and cooling fans, control of operations of kilns, installation of air-lifts with bucket elevators etc., have reduced displacement of particulate matter in the atmosphere and contribute to saving both energy and time. Additionally, in Iron and Steel, several energy efficient options like coke dry quenching, recovery of blast furnace gas and preheating of scraps have been introduced, that are also economically feasible. The main policy driver, the National Manufacturing Policy coupled with National Mission on Enhanced Energy Efficiency (NMEEE), has introduced the Perform, Achieve and Trade (PAT) scheme, which is estimated to lead to a cumulative energy savings of 6.7 Mtoe in the first round of the PAT cycle by 2015. An Energy Conservation Fund for promoting energy efficiency measures in the industry is also being explored as an alternative to PAT, as the former will addresses the latter’s shortcomings of coverage and simplicity.

The transport sector accounts for more than half of India’s petroleum consumption, and a quarter of the overall energy needs. It is estimated that this demand will increase further with increasing socio-economic mobility of the population. A bottom-up approach is used to examine fuel use and emissions from the transport sector. Projections have been divided into two categories, namely, freight and passenger transport. Subsequently, an array of options is presented for road, rail, air and other modal categories. The primary focus is on increasing the efficiency of railways to increase its modal share of both passenger and freight transport, for example, by increasing the frequency of semi-high-speed trains for inter-city transport and by creating six dedicated freight corridors along the major routes. Other means to improve energy efficiency in the transport sector include enhanced uptake of the public transport, promoting alternatives fuels such as CNG, electric/hybrid mobility and improving the fuel efficiency of both light and heavy vehicles.

The power sector in India has to provide for the dynamic needs of a fast growing economy. Despite this growing demand, it is estimated that in the LCIG scenario, India could keep its electricity requirement down to 3,200 Billion kWh by 2030 (less than an earlier figure of 3,600 Billion kWh projected in the Twelfth Five Year Plan Document). Coal will continue to be the dominant source of power, and even in the LCIG scenario, will have a 65 percent stake in power generation. However, super-critical coal plants, which presently account for only 6-7 percent of the installed coal based generation capacity, should account for more than half of such capacity by the year 2030. The focus in this Report is on policy measures, including grid integration of renewable power, to reduce the usage of fossil fuels in power generation. Nuclear and Hydro power needs to be pursued with greater vigour, even though there are feasibility constraints. The aim should be that at least one-third of power generation by 2030 is fossil free.

The discussion on advancing the integration of renewable sources of power is primarily focused on wind and solar power, which are inherently variable, and therefore, non-dispatchable. Integration of large scale wind and solar power requires additional technologies, which can ensure smooth grid operation. The policy framework that combines the use of smart grids with improved energy storage, while enhancing the flexibility of base load power systems, is also an urgent need of the hour.

Forests are a significant part of the carbon cycle. A carbon sink absorbs CO_2 from the atmosphere and stores it as carbon. In the case of a growing forest, carbon storage takes place in the form of wood, other vegetation and soil carbon. Investment in this sector not only increases the carbon sink, but also contributes to the national GDP. The mitigation efforts discussed for increasing the sequestration potential of forests are multi-pronged, involving sustainable management, conservation and improvement in the density of existing forests, facilitation of wood products use management and promoting efficiency in the use of fuel-wood at rural homes. Government of India needs to allocate more resources to the Green India Mission to enhance the stock of growing forests, and to improve the provisioning of ecosystem goods and services in the country.

As far as implementation is concerned, a two pronged strategy is recommended; first, that chases the explicit low carbon targets, and second, that combines policy instruments like energy pricing, carbon tax, cap-and-trade, subsidies and regulation in the right mix. Since low carbon strategies are multi-sectoral and inter-disciplinary in nature, a body like the Planning Commission, whose mandate is to formulate growth policy and coordinate it across the Central Ministries and the States, is best placed to periodically monitor the achievement of these targets, and to place it before the Union Cabinet for information and direction. The Expert Group strongly recommends that this should be done on a yearly basis.

As the Expert Group becomes *functus officio*, it leaves behind, a new model of growth policy, which incorporates faster, inclusive and sustainable growth in an integrated framework. Domestic policymakers and negotiators alike, will need to revisit and rerun this model, to better understand, in an endogenous framework, the growth and development implications of any proposed low carbon strategy, as also to monitor the achievement of low carbon targets from time to time.

1 Introduction

1.1 The Background

The Planning Commission set up an Expert Group, ahead of the Twelfth Five Year Plan, to advise and help evolve low carbon strategies for inclusive growth. In May 2011, the Expert Group submitted its Interim Report. The Interim Report outlined a menu of options that could help reduce India's emissions' intensity by 25 percent over the 2005 levels, by 2020. The Expert Group also contributed to the sustainable development chapter of the Twelfth Five Year Plan. The Final Report builds on, and takes further forward, the growth policy outlined in the Twelfth Five Year Plan, namely of faster, more inclusive and sustainable growth.

There is a growing concern about climate change in the world. Despite India being among the lowest emitters of greenhouse gases (GHGs), in per capita terms, it is highly vulnerable to the impact of climate change. And this impact is not just a concern of the distant future! An increased frequency and intensity of extreme natural conditions such as storms, cyclones, longer dry spells, erratic rainfall, etc. is already perceptible today (See Box 1.1). Even though it may not be possible to unequivocally attribute extreme natural events to climate change, it is now widely accepted by the scientific community that climate change will increase the frequency and intensity of these extreme events in the future. An effective global compact to minimize climate change is, therefore, of utmost importance to all countries, including India. The inculcation of a low carbon strategy, in our already inclusive growth policy, will lend weight to India's voice at an international level.

This Report is organised as follows: Chapter 2 is an analysis of options and outcomes in a macro-economic model that combines bottom-up and top-down approaches gauging different policy options in a mutually consistent manner. Chapters 3, 4, 5 and 6 explore individual policy options, and the scope of reducing energy use and emissions in households, buildings, industry and transport sectors respectively. Chapter 7 examines the absorption feasibility of the power supply options proposed in the macro-model. It also explores the problems of expanding capacities of renewable power based on solar and wind energy. Chapter 8 outlines the Green India Mission to assess the extent of carbon sequestration. Chapter 9 examines the consequences, co-benefits and risks of the proposed low carbon strategy. Finally, Chapter 10 provides a summary of all the chapters and policy conclusions.

Box 1.1: Observed Changes in Climate

Biophysical alterations, coupled with instances of socio-economic repercussions as consequences of climate change are being observed with increasing frequency.

Human and natural systems are being affected by climate change. The phenomenon of warming has been observed throughout Asia, with Northern regions having the fastest escalation in temperatures on the planet. Precipitation trends vary geographically, with a more frequent but weaker Indian monsoon (WGI AR5 Chapter 14.7.10). The degradation of permafrost occurring across its current distribution in Siberia, Central Asia and on the Tibetan Plateau is among the most widespread impacts of climate change in Asia. This can be correlated to observations from other parts of the world, explained by warming to a high degree. Substantial new evidence has been collected since AR4 on glaciers in Asia. Across most of Asia, glaciers have been shrinking except for some areas in the Karakorum and Pamir.

In spite of changing socio-economic factors taking precedence over the direct impact of climate change for managed ecosystems and human systems, the events being experienced with accounting for changes in technology, other non-climate factors and agricultural crop yields appear to have changed in many regions as a result of climate change. Auffhammer et al., (2006) compared predicted rice yields in India using climate model simulations of temperature for the late 20th century with yields estimated from observed temperatures between the years 1930-1960, using the latter period as a surrogate for climate without recent changes in greenhouse gases. They found that rice yields in a world without greenhouse gas emissions would have been significantly higher, thus attributing the negative impact to emissions. The detected impact of elevated Ozone, with reductions estimated at roughly 10 percent for wheat and soy, and 3 – 5 percent for maize and rice (Van Dingenen et al., 2009), was most significant for India and China; but, this was also found to be true for soybean production in the United States in recent decades (Fishman et al., 2010).

There is a small but growing literature on the attribution of specific hydrometeorological events to anthropogenic climate change, thus creating the possibility of linking observed socio-economic outcomes and consequences to climate change. Recent modelling studies have attempted to link observed events (such as flooding events in the UK/ Pakistan and heat waves in Europe/ Russia) to anthropogenic climate change. While such detection and attribution studies are still at an early stage, they raise the probability of linking socio-economic outcomes (loss and damage) to climate change. As Tren berth (2012) points out, even if it is not possible to attribute a particular weather event exclusively to global warming; all weather events are affected by climate change because the environment in which they occur is warmer and moister than it used to be, due to anthropogenic forcing in the post-industrial revolution era.

1.2 Current State of Knowledge on Climate Change

1.2.1 Global Picture: Current Trends of Emissions and Projected Climate Change

Although the international community has adopted a target of limiting anthropogenic global warming to below 2 degree Celsius by the year 2100, current projections and trends of greenhouse gas emissions indicate that achievement of this goal appears unlikely. In fact, many recent assessments suggest that we are already on the track for a 4 degree Celsius world.

- The IEA's World Energy Outlook 2012 indicates that global mean warming above the pre-industrial level would approach 3.8 degree Celsius by 2100. In this assessment; there is a 40 percent chance of warming exceeding 4 degrees Celsius by 2100, and a 10 percent chance of exceeding 5 degree Celsius.
- Estimates of emissions from the most recent generation of energy-economic models suggest that, in the absence of further substantial policy action (business as usual), median temperature projections could lead to a warming of 4.7 degree Celsius above the pre-industrial level by 2100, with a 40 percent chance of exceeding 5 degrees Celsius.
- The updated UNEP Emissions Gap Assessment, released in Doha in December 2012, found that present emission trends and pledges are consistent with emission pathways that reach warming in the range of 3 degree Celsius to 5 degree Celsius by 2100, with the global emissions' estimate for 2020, closest to levels consistent with a 3.5/4 degree Celsius pathway.

1.2.2 What are the Conditions Required for a 2 degree Celsius Target?

It should be noted that, from a geophysical perspective, a 2 degree Celsius target is still feasible. However, achieving this target requires that cumulative global greenhouse gas emissions need to be kept within a limit (Meinshausen et al. 2009), and global emissions need to start declining by 2020 for most of the cases to eventually reach a near zero mark (Rogelj et al. 2011). This would require deploying tens of terawatts of carbon free energy in the next few decades, which can only happen with a fundamental and disruptive overhaul of the global energy system.

Current scientific understanding therefore makes it clear that the window of opportunity for achieving a 2degree Celsius target is narrow and shrinking rapidly. Action taken in this decade will be of critical importance, in determining the trajectory of future emissions, and the consequent global warming. Delay will lead to greater stringency and costs of mitigation in the long run.

1.2.3 What are the Implications of Current Emissions and Radiative Forcing Trends?

Despite the global community striving to achieve the 2 degree Celsius target, the current trends indicate that we will experience a world with significantly greater levels of warming. It is, therefore, critical to assess the impact of climate change outcomes. As an input for the IPCC's fifth assessment report, the climate science community has carried out a major model inter-comparison project called CMIP5 (K. E. Taylor, Stouffer, & Meehl, 2011) to develop climate change projections for four different radiative forcing pathways that were designed to reflect the range of future global emissions. The four representative concentration pathways (or RCPs) correspond to radiative forcing levels of 2.6, 4.5, 6 and 8.5 W/m2 by the end of the century. Higher the concentration of greenhouse gases (GHGs) in the atmosphere, higher is the radiative forcing. The RCP 2.6 pathway is considered to be generally consistent with the 2 degree Celsius target in the sense that this level of forcing typically leads to global mean temperature change remaining below 2 degree Celsius. The RCP 8.5 pathway is the high forcing pathway, and is generally associated with the current "business-as-usual" emissions trajectory. From a risk management and climate change adaptation perspective, the RCP 8.5 pathway is important, because it reflects the kind of climate change outcomes that may be experienced in the absence of mitigation actions. Therefore, in the subsequent material, we review the projections associated with RCP 2.6 and RCP 8.5 pathways,which represent the lower and upper bounds of the range of possible climate change outcomes.

Temperature

Under the RCP 2.6 pathway, global land surface temperatures for boreal summer peak is estimated to be about 2 degree Celsius above the baseline of 1951-1980, by the year 2050, and will remain at this level until the end of the century. The high emission RCP 8.5 pathway leads to a temperature trajectory similar to that of the RCP 2.6 pathway until 2020, but starts to deviate strongly upwards after 2030. Warming continues to increase until the end of the century with global mean land surface temperature for boreal summer reaching 6.5 degree Celsius above the baseline of 1951-1980 by the year 2100. Under RCP 8.5, the temperature in tropical regions increases by a very high degree (beyond the 90th percentile, Sillmann & Kharin, 2013 a) for more than 300 consecutive days creating a year-long duration of warm spells.

Extremes that represent an exceedance above a particular percentile threshold derived from natural variability show the highest increase in tropical regions, where inter-annual temperature variability is relatively small. Both ecosystems and human infrastructure typically adapt to the local climatic conditions and its historic variations; hence, even a relatively small change in the temperature of the tropics can have a relatively large impact. The annual frequency of warm nights beyond the 90th percentile increases to between 50 percent and 95 percent, depending on the region, by the end of the century under the RCP 8.5 pathway (Sillmann & Kharin, 2013b). Under RCP 2.6, the frequencies of warm nights remain limited to between 20 percent and 60 percent, with the highest increases in tropical Southeast Asia and the Amazon region (Sillmann & 18 Kharin, 2013b).

Precipitation

On a global scale, total wet day precipitation and maximum five day precipitation, are robustly projected to increase by 10 and 20 percent respectively under RCP 8.5 (Sillmann & Kharin, 2013b). Regionally, the number of consecutive dry days is expected to increase in sub-tropical regions, and decrease in tropical and near-Arctic regions (Sillmann & Kharin, 2013b).

Sea Level Rise

Sea level rise is attributed to various factors, including ocean heat uptake and thermal expansion, melting mountain glaciers, and the large ice sheets of Antarctic and Greenland. The specific contributions of the Antarctic and Greenland ice sheets to global sea level rise have generated a significant debate.

Process based approaches dominate sea rise projections. Under the RCP 8.5 pathway, global mean sea level riseis predicted to be around 0.8 m in 2081-2100 relative to 1986-2005 (Church et al., 2013). The yearly increase under the RCP 8.5 pathway increases sharply from about 5mm/yr in 2020 to over 15 mm/yr by 2100 (Church et al., 2013). Under the RCP 2.6 pathway, the global mean sea level rise is predicted to be around 0.5 m, with the yearly rate of increase changing marginally from around 5mm/yr in 2020 to 6mm/yr by 2100 (Church et al., 2013).

Another issue with sea level rise predictions is that sea level rise varies across regions. Regionally, sea level rise for South Asia is predicted to occur at 5-10 percent above the global mean. Under the 4 degree scenario, the expected rise in sea level is about 30 cm in the 2040s, increasing by over 100 cm by the 2090s (World Bank, 2013, pp. 105-108). Coastal areas in Asia are particularly susceptible, as the rate of recent rise has accelerated compared to the long-term average (Cruz et al., 2007). Projected Asian coastal sea level rise also increases the risk of flooding in coastal parts of South and Southeast Asia (Cruz et al., 2007).

Moreover, increase in global mean sea level is expected to raise coastal sea levels, damaging the oceanic and coastal ecosystems, and increasing vulnerability to salt water intrusion of river deltas, coastal freshwater swamps and marshes (Cruz et al., 2007). Sea level rise is also expected to adversely affect aquaculture production and capture fisheries in river deltas (Barange and Perry, 2009). Significant negative impact on fisheries has already been experienced in Vietnam's Mekong Delta (Halls et al., 2009). In Arctic Asia, increasing sea levels have already contributed to changes in permafrost and storm wave energy leading to coastal retreat (Are et al., 2008; Razumov, 2010; Handmer et al., 2012). Sea level rise is expected to be a major issue for Asian coastal areas, particularly when combined with changes in frequency and intensity of cyclones (Vaughan et al., 2013).

1.2.4 What are the Key Climate Change Consequences for India?

Current Climate Trends

Studies based on observational data for a period of around 130 years find no clear trend in the all-India mean monsoon rainfall in relation to global warming (Guhathakurta & Rajeevan, 2008; R. Kripalani, Kulkarni, Sabade, & Khandekar, 2003). Even though the country as a whole does not show any significant trend in the all-India rainfall, smaller regions within the country show significant increasing and decreasing trends (Guhathakurta & Rajeevan, 2008; K. R. Kumar, Pant, Parthasarathy, & Sontakke, 1992).

Climate Projections

Under the RCP 2.6 pathway, temperature increase is expected to peak at about 1.5 degree Celsius above the baseline of 1951-1980. Under the RCP 8.5 pathway, warming increases until the end of the century and monthly summer temperatures by the end of the 21st century to reach about 5 degree Celsius above the 1951-1980 baseline in the multi-model mean. The warming is expected to be uniform geographically; however, in-land regions are expected to warm somewhat more in absolute terms. Relative to the local year-to-year variability, the pattern reverses in coastal regions, with more warming observed in the South West. Under the RCP 8.5 pathway, the West coast and Southern India shift to new climatic regimes, with the monthly temperature distribution moving by 5/6 standard deviations towards the warmer values. Model projections, in general, show an increase in the Indian monsoon rainfall under global warming scenarios, which is attributed to an increase in the moisture flux into the Indian land region, because of enhanced atmospheric moisture content as well as increased evaporation over the tropical Indian ocean (May, 2011). The precipitation projected from a subset of CMIP-3[1] models, which are considered more realistic, show a range of trends, including negative trends in the monsoon rainfall by 2100 (Turner. A. G; Annamalai, 2012b), under the SRES A1B[2] scenario (3.5 degree Celsius above pre-industrial levels). A study based on twenty of the CMIP-5 models shows a consistent increase in the all-India monsoon rainfall under the various RCP scenarios with reduced uncertainty compared to CMIP-3 models (Menon, Levermann, Schewe, Lehmann, & Frieler, 2013). Some of the more realistic models show an increase in the mean monsoon rainfall by about 5-20 percent over the pre-industrial period, by the end of the 21stcentury under the RCP 8.5 pathway (Jourdain et al., 2013).

Changes in extreme rainfall events are as important as changes in seasonal mean rainfall. Extreme rainfall events show wide spatial variability with more extreme events occurring over the West coast, Central and North East India (Pattanaik & Rajeevan, 2009). Goswami et al (2006) have demonstrated an increase in heavy rainfall events and a decrease in low rainfall days over Central India. CMIP-3 models also project an increase in extreme rainfall events under anthropogenic warming (Allan & Soden, 2008). In South Asia, an increase in the length of the longest period of consecutive dry days is combined with increases in heavy precipitation days (days with precipitation >10mm), and maximum consecutive five day long precipitation shows an intensification of wet and dry seasons by the end of the 21st century. Given the dependence of agriculture on the exact timing and amount of precipitation during the growing season, any change in intra-seasonal variability is likely to have an adverse impact. An increase in frequency and intensity of extreme rainfall events is also likely to result in an increase in the number of floods and landslides, further damaging crops and infrastructure.

1.2.5 What are the Implications for a National Climate Change Policy?

Given the magnitude of projected changes, and the high vulnerability of the key socio-economic sectors, it is imperative that we focus on enhancing adaptation and resilience. This will require efforts to build a more detailed and accurate picture of the range of possible climate change outcomes. Nevertheless, it is essential to adopt a low carbon growth strategy that seeks mitigation co-benefits from an accelerated and inclusive development perspective. This will ensure that a gradual enhancement of adaptive capacity is achieved through development goals, parallel with gradual decarbonization of the economy. Finally, it will be in our national interest to accelerate the multilateral process towards an equitable climate regime. Delay may lead to an increase in grandfathering of emissions from the developed world, further reducing the available carbon space for the developing world.

1.3 The Global Emissions Scene

The threat of climate change is increasing, and simultaneously, the total GHG emissions keep growing. Current global greenhouse gas emissions, based on 2010 data from bottom-up emission inventory studies, are estimated at 50.1 $GtCO_2e$ with a 95 percent uncertainty range of 45.6 to 54.6. Modeling groups use a median value of 49 $GtCO_2e$ for 2010. This is already 14 percent higher than the median estimate (44 $GtCO_2e$) of the emission level in 2020 that is consistent with the 2 degree Celsius target. It is also about 20 percent higher than the emissions in 2000. Global emissions are again picking up after their decline during the economic downturn of 2008 -09 (The Emissions Gap Report 2012, A UNEP Synthesis Report).

The GHG emissions of a country depend on several factors, including but not limited to, level of income,

[1] CMIP-3: Phase 3 of the Coupled Model Intercomparison Project.

[2] SRES: The IPCC Special Report on Emission Scenarios, which defined a number of emission pathways resulting from different assumptions for key socio-economic variables such as population and GDP growth. The SRES scenarios are the precursors for the Radiative Concentration Pathways (RCP's) used in the most recent climate simulations.

lifestyle, population and its density, economic activity, trade patterns, urbanisation, size of the country, transport infrastructure, natural resources, etc. Not only the total emissions, but also per capita emissions vary widely across countries. The same applies to emissions intensities of economic activities as measured in tonnes of carbon dioxide emitted per dollar of gross domestic product (See Table 1.1 below).

Table 1.1 Emissions in the year 2010 for Selected Countries

	Poulation (million)	GDP billion 2005 US$	GDP (ppp) billion 2005 US$	CO2 emissions (MT CO2)	Total Primary Energy Supply TPES (Mtoe)	Energy TPES/ GDP (PPP) (toe/000 2005 US$)	Per Capita Energy Supply (Mtoe/ capita)	Per capita CO2 emissions (MTCO2 /capita)
World	6958.00	52486.00	70313.00	31342.30	13113.00	0.19	1.88	4.5
China	1351.20	4425.80	10286.30	7999.60	2743.00	0.27	2.03	5.92
Brazil	196.70	1126.70	2021.30	408.00	270.03	0.24	1.37	2.07
India	1241.50	1317.50	3976.50	1745.10	749.45	0.19	0.60	1.41
Japan	127.80	4622.00	3932.20	1186.00	461.47	0.12	3.61	9.28
South Africa	50.60	298.10	489.60	367.60	141.37	0.29	2.79	7.27
Thailand	69.50	210.30	530.80	243.20	119.15	0.22	1.71	3.5
UK	62.70	2386.60	2063.30	443.00	188.07	0.09	3.00	7.06
USA	312.00	13225.90	13225.90	5287.20	2191.19	0.17	7.02	16.94
France	65.10	2249.10	1958.70	328.30	252.83	0.13	3.88	5.04
Germany	81.80	3048.70	2828.00	747.60	311.77	0.11	3.81	9.14
Russia	141.90	947.20	2103.50	1653.20	730.97	0.35	5.15	11.65

Source: *International Energy Agency (IEA) 2013. Mtoe- Million tonnes of oil equivalent.1toe equals 2.5 tonnes of Indian coal or 900 cubic metres of natural gas/ coal bed methane(CBM)*

What about cumulative emissions? It can be seen from Table 1.2 below that India's contribution to global emissions since 1850 was only 2.7 percent, while that of USA was 27 per cent. Annex I (developed) countries account for nearly 70 percent and Non-Annex I (developing) countries around 28.5 percent of cumulative global emissions.

Table 1.2 Energy Related Cumulative CO_2 Emissions

Country	1990-2010		1850-2010	
	MTCO2	Percent	MTCO2	Percent
World	761727.9	100	1322588	100
India	33886.3	4.4	36299.1	2.7
China	118226.4	15.5	135886.7	10.2
Brazil	19082.9	2.5	13858.4	1
USA	138381.1	18.1	361034.1	27.2
Europe (15)	85056.9	11.1	267870.5	20.2
Annex-1	370,493.6	48.6	926706.3	70
Non-Annex-1	368,165.8	48.3	377923.6	28.5

Source: WRI, CAIT data base accessed on 18/03/2014

List of Annex I countries is given in the Box 1.2. When looking at cumulative emissions since 1990, the share of Non-Annex I countries is nearly 48 percent, as emissions of Non-Annex 1 countries have grown faster than emissions of Annex I countries over this period.

Box 1.2: Annex I Parties

Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, United States of America

Global energy related CO^2 emissions have increased from 22.0 $GtCO_2$ in the year 1990 to 29.9 $GtCO_2$ in the year 2007, while that of the US has increased from 4.8 $GtCO_2$ to 6.1 $GtCO_2$ over the same period, the increase being almost as much as India's total emissions of 1.5 $GtCO_2$ the year 2007. While the total emissions of most countries have grown, the intensities have been declining gradually. Germany was the only major advanced economy that showed an absolute decrease in its emissions, while the US Emissions have grown despite the UNFCCC and Kyoto protocols[3]. The most dramatic increase was shown by China which has tripled its emissions since 1990 and now emits more than the US.

1.4 India's Actions on Climate Change

Even though India needs to increase its levels of energy consumption to meet its human development needs, India has takena decisive action to reduce the risk and impact of climate change. In December 2008, Government of India approved an Integrated Energy Policy (IEP). The IEP estimates that India's primary energy supply will need to increase by 4 to 5 times, and its electricity generation capacity by 6 to 7 times of its 2003-04 levels, to deliver a sustained growth rate of 8 to 9 percent through to the year 2031-32. While this will imply a primary energy supply growth of around 5.8 percent per year, commercial energy supply will need to grow at a faster rate of 6.8 percent per annum, as non-commercial energy sources will be replaced over time.

If the growth is to be inclusive, demand for energy must necessarily increase. At the minimum, inclusive growth means all households have access to clean and convenient means of modern energy. This means all households are electrified, and have access to clean cooking fuels such as natural gas or LPG. In other words, a secular shift from traditional biomass to modern commercial energy has to be consciously built into our strategy. Towards these ends, the IEP scenarios project 100 percent electrification of all households by the year 2020. They also estimate the cooking fuel requirement for 1.5 billion persons at about 55 Mtoe by the year 2020.

India is determined to see that its per capita emissions' level will never exceed the average per capita carbon emissions' level of developed countries. This declaration, made by India's Prime Minister on June 8,2007, at Heiligendamm, (Germany) continues to guide India's stand onenergy consumption and places a self-imposed restraint.

In December 2009, India announced that it would aim to reduce the emissions' intensity of its GDP by 20 to 25 percent, over the 2005 levels, by the year 2020. This is a voluntary commitment India has made to the international community, which shows India's resolve to ensure that its growth process is sustainable and based on low carbon principles. Pursuit of this goal will require sector specific actions to reduce emissions' intensities over the period of India's Twelfth and Thirteen Five Year Plans.

[3] US has refused to ratify the Kyoto Protocol.

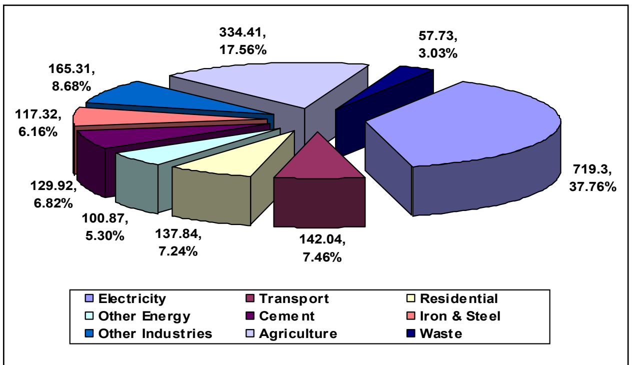
The Expert Group Report is conscious of the above postulations. A brief summary of the Interim Report is given at the end of this chapter. This will be followed by chapters that work out the details of major policy options.

1.5 India's Emission Structure

In order to explore strategic options to reduce emission intensity of the economy, analysis of the quantities and trends of GHG emissions from different sectors is necessary. The emission intensity of an economy can be lowered by reducing the need for production and consumption, as well as by making consumption and production processes more energy efficient. For example, by reducing the need for air conditioning through better insulation, or by setting the temperature at a higher level, or increasing the efficiency of the air conditioner itself, will all help reduce energy requirement and emissions.

Estimation of anthropogenic GHG emissions and making of emission inventories began on a limited scale in India, in the year 1991. These were enlarged and revised, and the first definitive report for the base year 1990, was published in 1998 (ALGAS, 1998). Since then, several papers and reports have been published, which have upgraded the methodology for estimation, including estimation of India-specific emission factors, accounting for new sources of emissions, as well as new gases or pollutants (Garg et al., 2000; Mitra et al., 2002). Taking stock of these developments, a comprehensive emission inventory of CO_2, CH_4 and N_2O was prepared for the year 1994 from various energy related activities, including industrial processes, agriculture, land use, land use change, forestry and waste management practices, and this was reported in India's initial National Communication to the UNFCCC in 2004 (NATCOM, 2004). Recently, the Ministry of Environment and Forests, under its Indian Network for Climate Change Assessment (INCCA) programme has made an assessment of GHG emissions by sources and removal by sinks for the year 2007. This allows us to examine the trends in emissions, energy and emissions' intensity over the last decade of post-liberalisation economic growth.

Figure 1.1 GHG Emissions' Distribution across Sectors in 2007



Note: For each category, the CO_2eq emissions in million tons are indicated just below the category name, along with the percentage contribution of emissions from that particular category to the total GHG emissions in 2007[6]

India aims at reducing its emissions' intensity over 2005 levels, by 20 to 25 percent, by the year 2020. The next section studies the GHG emissions' structure for India for the year 2007 and understands the trends of growth or fall in emissions from various sectors to ascertain what sectors can be targeted for reduction in emission intensities.

1.5.1 GHG Emissions in 2007

In the year 2007,[4] India's CO_2 equivalent emission[5] of 1904.73 million tons was primarily due to fast growing sectors like cement production (growing at 6 percent), electricity generation (growing at 5.6 percent) and transportation (growing at 4.5 percent). The distribution of emissions across different sectors is shown in Figure 1.3.

[4] The 2007 data is based on various publications, mentioned in the reference to this chapter

[5] Here CO_2 equivalent is the sum total of CO_2, and CH_4 and N_2O converted in CO_2eq using Global warming potentials of 21 and 310 respectively)

[6] Other energy sector components: include solid fuel manufacturing, petroleum refining, manufacturing industries, residential & commercial activities, agriculture & fisheries, coal mining and handling of oil and natural gas. Other manufacturing industries: include glass and ceramics, soda ash, ammonia, nitric acid, carbides, titanium dioxide, methanol, ethylene oxide, acrylonitrile, carbon black, caprolactam, ferro-alloys, aluminum, lead, zinc, copper, pulp and paper, food processing, textile, leather, mining and quarrying, non specific industries and use of lubricants and paraffin wax.

Energy sector: The energy sector emitted 1100.06 million tons of CO_2 eq due to fossil fuel combustion in electricity generation, transport, commercial/institutional establishments, agriculture/fisheries, and energy intensive industries such as petroleum refining and manufacturing of solid fuels, including the use if biomass in the residential sector. Fugitive emissions from mining and extraction of coal, oil and natural gas are also accounted for in the energy sector. Of this, 65.4 percent of the emissions were from generation of electricity, 3.1 percent from petroleum refining and solid fuel manufacturing, and 2.9 percent were from fugitive emissions due to handling of coal, oil and natural gas. About 15 percent of the total CO_2 equivalent emissions (or 128.08 million tons of CO_2eq) were from fossil fuel and biomass combustion in both rural and urban residential households. About half of the residential CO_2eq emissions were in the form of non-CO_2 emissions, primarily from combustion of fuel wood, wood waste, cow dung, crop residue etc. in rural households. Replacement of biomass with alternate sources of energy in rural households will not only have positive health benefits, but also lead to lower GHG emissions.

Transport: The transport sector comprising of road transport, aviation, navigation and railways accounted for 142.04 million tons of CO_2 eq emissions, i.e., 7.5 percent of the total GHG emissions in the country in the year 2007. Of this, road transport alone accounted for 87 percent of the GHG emissions (i.e., 123.57 million tons of CO_2 eq). Civil aviation constituted 7 percent or 9.94 million tons of CO_2 eq emissions from the transport sector. Fossil fuel used by the Railways released 7.12 million tons of CO_2 eq of GHGs into the atmosphere. The emissions due to electricity consumption in the railways are already accounted for, in emissions from electricity generation in the energy sector.

Industries: The industries sector accounted for 21.7 percent of the total GHG emissions or 412.55 million tons of CO_2 eq in the year 2005. The sector comprises cement and iron & steel as well as other industries dealing with manufacture and processing of metals, minerals and chemicals. Among all industries: cement, iron and steel are the largest; thereby feeding the boom in infrastructure growth in India. In the year 2007, cement manufacturing and iron & steel production resulted in 6.8 percent emissions (129.92 million tons of CO_2 eq) and 6.2 percent emissions (117.32 million tons) respectively. Industries comprising other metals, minerals, chemicals, etc. released 165.31 million tons of CO_2 eq i.e., 8.7 percent of the total GHG emitted in the year 2007. The GHG emissions from the industry sector are a sum total of emissions from fossil fuel/ biomass combustion as well as other process related emissions.

Agriculture: The sector comprises biogenic emissions of CH4 and N_2O due to enteric fermentation in livestock, anaerobic emissions from organic manure and cultivation of rice, on site burning of agricultural crop residue, etc. Together, all these activities released 334.41 million tons of CO_2 eq in the year 2007, i.e., 17.6 percent of the total emissions. In the year 2007, livestock and rice cultivation together emitted 84.3 percent of the total CO_2 eq. emissions from the agriculture sector.

Waste: The increase in population has led to an increase in solid waste and waste water output. Systematic collection of solid waste, recycling and incineration for energy recovery have a huge potential for reducing emissions from this sector. In India, however, systematic collection and dumping of waste is only carried out in urban areas. Incineration of waste for energy has also started on a pilot basis. The domestic waste water is managed in most of the cities, and industrial waste water is treat edmostly by the industries themselves. These together are a large source of CH_4 emission. In the year 2007, the waste sector released 57.73 million tons of CO_2 eq., of which 12.69 percent was from the municipal solid waste, 39.8 percent from the domestic waste water and 38.2 percent from the industrial waste water.

Table 1.3 gives emissions of various greenhouse gases by different sectors in the year 2007. The data reveals the amount of different gases comprising the GHGs and their presence in the overall carbon inventory of the economy. In the year 2007, India's net CO_2 emissions were 1221.76 million tons (1497.03 million tons gross less 275.36 million tons sequestered), CH_4 emission 20.56 million tons and N_2O emission was 0.24 million tons i.e., 71 percent, 24 percent and 5 percent respectively, of the total 1727.7 million tons of CO_2 equivalent greenhouse gas emissions from all sources.

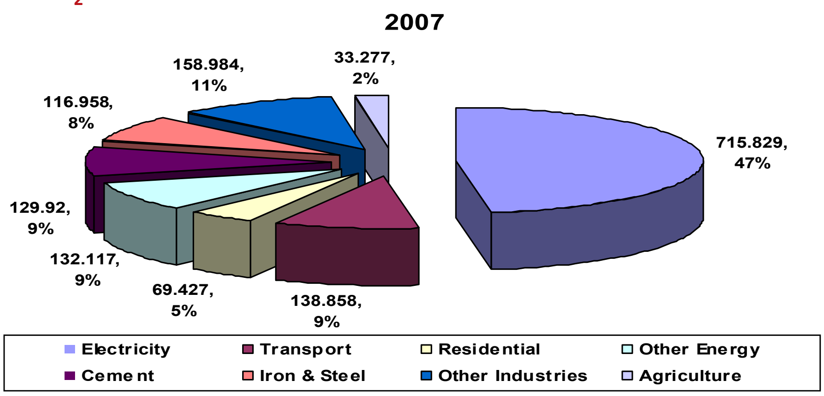
Analysis of CO_2 emission across sectors reveals that 47.81 percent of this was from the electricity generation, while 27.11 percent was from manufacturing in the industrial sector (iron & steel, and cement production constituted 16.49 percent of CO_2 emissions). CO_2 emission from transport sector was 138.9 million tons, i.e., 9.27 percent of country's total CO_2 emission in the year 2007. The residential sector accounted for 49 percent of the CO_2 emissions from other energy related activities, indicating a potential for reduction of emissions through the use of more energy efficient domestic appliances (See Figure 1.2 for details).

Table 1.3 Emissions of Different Gases from Each Sector in 2007

	CO_2 (million tons)	CH_4 (million tons)	N_2O (million tons)	CO_2eq (million tons)
Electricity	715.83	0.008	0. 011	719.31
Transport	138.86	0.023	0.009	142.04
Residential	69.43	2.722	0.036	137.84
Other energy activities	33.79	0.002	0.0001	33.84
Cement	129.92	-	-	129.92
Iron and Steel	116.96	0.001	0.001	117.32
Other ManufacturingIndustries	158.98	0.014	0.019	165.31
Agriculture	-	13.78	0.146	334.41
Waste	-	2.52	0.015	57.73
TOTAL	**1497.03***	**20.56**	**0.24**	**1727.71****

** gross emissions including from LULUCF; ** excludes sequestration of 275.36 MT*

Figure 1.2 CO_2 Emissions Distribution across Sectors in 2007 (in million tons)



1.5.2 GHG Inventory - Data and Measurement

Accurate and timely availability of national GHG emissions data is critical for good policy making and for tracking the progress towards the goal of reducing the emissions' intensity of our GDP. Inventories of GHG gases such as CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 emitted from various sectors of the economy need to be prepared on a regular basis. Measuring the trends of GHGs emitted each year is critical as it enables policymakers to understand the actual reduction in intensity achieved through the policy measures introduced. Currently, there are long gaps in official reporting of National GHG inventories. The year of reporting of the GHG inventories in the National Communication (NATCOM) is determined by the Conference of Parties to the UNFCCC. Currently, GHG inventories are officially available for the year 1994, as reported in India's first National Communication to the UNFCCC (NATCOM-I). The Second National Communication (NATCOM-II) required GHG inventories to be reported for the year 2000 by 2011. In view of the time lag, the Ministry of Environment and Forests carried out a rapid assessment and arrived at GHG inventories through sources and removal by sinks for the year 2007. However, an inventory management system needs to be put in place and a systematic approach is required to develop a time series for the gap years as well as for the years ahead. Annual GHG inventories will provide an opportunity to measure the impact of the steps taken to reduce carbon intensities, as reporting with large lags does not provide timely information for policy making. There is, therefore, a need for creating a mechanism that can estimate the GHG emissions on a regular basis, particularly with respect to the goal India has set for itself, of reducing the emissions' intensity of its economy. This is a daunting task, as uncertainty exists in terms of gap in the data on activity, its quality, non-availability of emission factors, etc. These gaps can be bridged, over a period of time, by collating activity data from various Ministries, their Departments, the industry sector, performing QA/QC checks on routine basis, commissioning surveys to ascertain data gaps, developing emission factors for key emission sources, analysing the level of uncertainties, and in conclusion, including a regular review of the estimates by a third party for reliable inventory estimate of greenhouse gases at all levels.

A systematic approach for measuring and reporting GHG inventory as an annual cycle is therefore required to ensure the automaticity of generating GHG information covering all emission and sequestering sources. The system will estimate GHG emissions for each year with recognised methodologies such as those provided by the IPCC, and institute measures to prepare country specific emission factors for the key sources. 'Bottom up' and 'top down' approaches for measuring and mapping the GHG inventories need to be put in place.

- The top-down approach entails preparing GHG inventories at the national/ state/city level, emitted from all activities according to the sector.
- The bottom-up approach tracks GHG inventories of companies/ factories that would take into account the impact of the energy efficiency or fuel switching measures implemented at the utilities/ installations levels (can be referred to as source points). This approach will have two major benefits: First, it will allow validation of the results of the estimation done through the top down level, thereby improving accuracy and confidence of the estimates. Second, it will form the basis of emissions trading programmes, voluntary disclosure programmes, carbon or energy taxes, regulations and standards on energy efficiency etc.

The key initiatives that need to be undertaken for India to have a comprehensive database of GHG emissions for all sectors of the economy include the following:

1. Setting up of a National Greenhouse Gas Inventory Management Authority (NGIMA) to track trends of greenhouse gas emissions from all sectors of the economy at national, state, district and point source level;
2. Setting up of a National GHG Inventory Management System (NGIMS) for archiving, updating and producing information on activity

leading to GHG emissions or removals, by sector at the national/ state/ district/ point source level;

3. Designing mechanisms for voluntary disclosure of GHGs, on annual basis, from installations managed by PSUs/ Corporations and by Medium Scale Enterprises, to track the impact of energy efficiency or GHG mitigating measures undertaken by them.

Box 1.4: The Year 2007 Assessment

- Estimates were made using revised IPCC 1996 guidelines (1997), IPCC Good Practice Guidance (2000), the LULUCF Good Practice Guidance (2003).
- Carbon pools in addition to forests have been considered in the LULUCF sector (crop land, grass land, settlements).
- Emission factors were also a mix of default and CS, leading to improved accuracy as more number of CS' are being used in this assessment (35percent of the source categories used CS factors).
- The 2007 assessment reports both fossil fuels related and process based emissions from the Industry.
- In 2007, 12 percent of the emissions are estimated using Tier III approach, implying greater accuracy.

1.6 Interim Report - A Brief Recap

The Interim Report of the Expert Group looked at a number of local carbon options and assessed the possibility of reducing emissions intensity. The Interim Report had two scenarios called 'determined effort' and 'aggressive effort,' each with 8 percent growth and 9 percent growth trajectories. In this report, however, only the determined effort scenario with eight percent growth rate is elaborated. The sector wise summary is given below:

Power: Emissions can be reduced by lowering demand for energy through demand side management (DSM) to improve energy efficiency, and altering the mix of electricity generation in favour of plants that emit lower emissions. The Interim Report had assessed that energy efficiency measures can reduce CO_2 emissions by 96 Mt by the year 2020, while the supply side measures can reduce emissions by another 85 Mt over the same period.

The Interim Report also projected that to achieve 8 percent growth, the country needs an installed capacity of 320,000 to 332,000 MW in 2020. When the supply side possibilities are matched with the demand side scenarios, CO_2 emissions in the year 2020 are expected to be in the range 1263 to 1428 million tonnes of CO_2 equivalents for the 8 percent growth scenario.

Buildings: Implementation of Energy Conservation Building Code and Green Buildings Rating System for both new and existing commercial buildings in the country can save electricity consumption over and above what can be saved by energy efficient appliances.

Much of the action on this front, however, is likely to be seen after the year 2020. It is still important to make a beginning and ensure a suitable code is evolved and integrated with statutory regulations at all levels of the Government. If action is initiated on this front, CO_2 equivalents emitted from the building and power sectors are expected to come down to a range of 1368 to 1141 million tonnes for an 8 percent growth scenario by the year 2020.

Transport: Early completion of the dedicated freight train corridor, investment in urban public transport and improvement in fuel use efficiency of vehicles are critical for emissions reduction in this sector. After these measures are taken, emissions can be reduced to the range of 435 to 413 Mt of CO_2 equivalents in the 8 percent growth scenario.

Industry: Process and fossil fuel emissions from industry (not including emission from generation and use of power) totalled 478 Mt CO_2 equivalents in the year 2007. Iron & steel, cement, and oil & gas industries constitute around 60 percent of the industrial emissions in the country. The iron & steel industry emitted 117 million tons of CO_2 equivalents in the year 2007 for a production of 53 million tons. The cement sector emitted 130 million tons of CO_2 equivalents for a production of 165 Mt in the year 2007.

Emissions from oil & gas industry were 55 million tons in the year 2007. This includes fugitive emissions (like gas flaring) as well as emissions from petroleum refining. Emissions from this sector are expected to rise to a range between 115 and 125 million tons of CO_2 equivalents in the 8 percent GDP growth scenario.

For other sectors, the emission-GDP elasticity over the period 1994-2007 has been used for projecting forward up to the year 2020. Other industries are expected to emit 240 to 300 million tons of CO_2 equivalent in the 8 percent GDP growth scenario.

Other Energy Emissions: This refers to the use of biomass and fossil fuels (LPG, kerosene and coal) to meet the cooking and lighting requirements of households, institutions and commercial establishments, and also their use for energy in the agriculture and fisheries sector.

While burning of wood does not lead to net addition of CO_2 to the atmosphere, it does add GHGs in the form of nitrogen. When wood is replaced with LPG, total GHG emissions in CO_2 equivalent terms are reduced. If our efforts at inclusive growth lead to a wider use of improved cooking stoves and increase in the coverage of LPG, emissions from this sector could be brought down by 20 percent to a level of 261 to 235 million tons CO_2 equivalents by the year 2020.

Waste: The emissions through waste increased at a compounded annual growth rate of 7.3 percent between the years 1994 and 2007. Projecting the same emission-GDP elasticity forward up to the year 2020, emissions from the waste sector are expected to rise to a level of 146 to 163 million tons of CO_2 equivalents in the year 2020 under the 8 percent GDP growth scenario.

Agriculture Processes: The agricultural processes emitted 334 million tons of CO_2 equivalents in the year 2007. Given the need for inclusive growth, and an understanding of the Expert Group that a significant reduction in agriculture emissions may not be practically possible up to the year 2020, no recommendation was made for reducing the agriculture process emissions.

Forestry: The Expert Group recommends implementation of a comprehensive Green India Mission, wherein emphasis is placed not just on increasing the forest and tree cover, but also on increasing the forest stock, volume and density of existing forests. This will increase carbon sequestration to 43 million tons of CO_2 equivalents annually, thereby increasing the GHG removals by India's forest cover to 6 percent of annual GHG emissions, by the year 2020.

Miscellaneous Emissions: As explained above, in spite of our best efforts, the discrepancy in the power emissions data from the two sources, namely CEA and NATCOM, could not be reconciled. This gap was 121 Mt of CO_2 eq in the year 2007 (nearly 20 percent over and above the CEA data). The CEA estimates are based on coal burnt at the power houses and NATCOM numbers are based on coal dispatched from coal mines. Some of the difference may be due to pilferage on the way and some due to overstatement of coal loaded. When burnt, the pilfered coal will also lead to emissions. Making a reasonable assumption that improved governance will bring this gap down to 10 percent by the year 2020, we projected miscellaneous emissions for each growth and mitigation scenario as outlined in Table 1.3 below. Scenario Summary: India has already achieved commendable emission intensity reduction since the early 1990s, when global action started in the right earnest. The official data has made a comparison between the years 1994 and the 2007 emissions' inventory as compiled using a bottom-up methodology explained in the last section. In terms of CO_2 equivalents, the total non-agriculture GHG emissions increased from 870 Mt in the year 1994 to

1,570 Mt in the year 2007 implying an emission-GDP intensity reduction of 25 percent over this period.

Table 1.4 compares the anticipated emissions intensity reduction as compared to the 2005 (interpolated) and 2007 levels by the year 2020. It should, however, be noted that while some of these reductions look large, the cost effectiveness of these measures needs to be reassessed. While some measures may not prove to be cost effective, others could face institutional barriers limiting our ability implement them. The feasible technology options and policy actions are further are spelt out in the Final Report.

Table 1.4 Summary of Projected GHG emissions for India in 2020

	Higher and Lower Ends of the Range	2007	2020 with 8% GDP growth
1	GDP (1999-00 prices) Rs Billion	30,619	83,273
2	GHG Emissions (in million tonnes of CO2 eq)#	1,570	3,537
	a. Power	598	1,428
	Plus Building Code		1,368
	b. Transport	142	435
	c. Industry	478	1,167
	i) Iron and Steel	117	406
	ii) Cement	130	336
	iii) Oil and Gas	55	125
	iv) Other Industries	176	300
	d. Other Household Energy	173	261
	e. Waste Management	58	163
	f. Miscellaneous	121	143
3	Emission at 2005 Levels	1,570	4,270
4	Emission Intensity (grams CO2eq/ Rs GDP)	51.28	42.47
5	Emissions per capita (tonnes/person)	1.43	2.67

#This excludes Agriculture Process Emissions in accordance with the international commitment India has made. #With LULUCF and Agriculture Processes added, it is difficult to predict what the net emissions would be, but the indications are that net emissions may not be very far from the gross emissions indicated above.

Table 1.5 Projected Emission Intensity Reduction over 2005 and 2007 levels

		2005	2007	2020	%age Reduction in Emission Intensity	
					Over 2005	Over 2007
1	Emissions at 2005 Levels (MT CO2-eq) #	1,433	1,570	4,571		
2	Emission Intensity (grams CO2eq/Rs GDP)	56.21	51.28	42.47	24.4	17.2

 # excludes LULUCF and Agriculture Process Emissions

1.7 Summary

GHG emissions from India have increased between the years 1994 and 2007, the two years for which official data is available. Electricity and transport sectors have witnessed very high growth in emissions in terms of CO_2 equivalent at CAGRs of 5.6 and 4.5 percent respectively. The GHG emissions from waste, which comprises municipal solid waste, domestic and industrial waste water, witnessed the highest CAGR of 7.3 percent over this period. It is pertinent to mention that over the last two decades, GDP from services (on an average) grew faster than the overall GDP. As growth accelerates and manufacturing takes its due place in the overall economy, emissions are expected to increase further in the coming years.

The Expert Group was unanimous in its opinion on low carbon strategies going forward up to the year 2030. However, given the fast evolution and an almost disruptive nature of the green technology; projections beyond 2030 were found to be difficult and subject to greater uncertainty. The Final Report, therefore, takes the year 2007, for which official data is available, as the base year, and makes sector wise projections up to the year 2030. The Expert Group has evolved a growth model which endogenises the three main objectives of India's growth policy namely: faster, more inclusive and sustainable growth. The Low Carbon Growth Model is presented in Chapter 2.

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2 Macro Model: Low Carbon, Inclusive Growth

2.1 Why a Macro Model?

Measures, which reduce emissions intensity, impact the economy in a variety of ways. Such mitigation efforts, however, do not come cheap. They require additional investment, which in turn reduces investment available for other needs. An assessment of economic costs and benefits is, therefore, important. Energy efficient processes can increase the profitability of many value added activities, while also facilitating structural changes in the economy (MoEF, 2009). This not only makes an economy more productive, but also sustains economic growth by relaxing the energy constraints in the long run. It is important to understand the macro-economic and inter-sectoral implications of different mitigation alternatives to ensure that the low carbon strategies being recommended are mutually consistent with each other.

2.2 The Model and its Appropriateness

A combination of bottom-up and top-down approaches is used to create the Low Carbon Growth Model. This macro-model is a multi-sectoral, dynamic optimization model that is bottom-up in the sense that it includes many available technology options, and top-down in the sense that it covers the whole macro-economy (Parikh J and Ghosh P, 2009).

The model endogenises income distribution with ten expenditure classes, both in urban and rural areas. The demand function is empirically estimated as a Linear Expenditure System (LES) which fits the NSS data well (Swamy, G., Binswanger, H.P., 1983 and Parikh K. et al, 2014). An LES also ensures that expenditure of a given consumer on different goods and services adds up to her total expenditure (Stone, R., 1954). The distribution of consumption expenditure into 20 expenditure classes helps in assessing the inclusiveness of a low carbon strategy. On the supply side, there are 25 production sectors, and the output of some sectors can be produced by more than one activity, for example, electricity can be produced by 13 different activities. Finally, the model is solved simultaneously for a number of time periods, with the objective of maximizing present discounted value of private consumption. The model uses actual data for the Indian economy and endogenously solves for major macroeconomic variables like output, consumption, investment, energy demand, energy supply mix, carbon emissions, etc. The model projects outcomes for all the years till 2030. The model is solved using the GAMS programme (Brooke, A., Kendrick, D. and A. Meerhaus, 1998). A detailed technical description of the model is given in the Appendix.

2.3 The Scenarios

The model scenarios are run year by year from 2007-08 onwards to a few time periods beyond 2030-31 to minimize the impact of the terminal period. The model output is summarized through two extreme scenarios outlined below.

1. Baseline, Inclusive Growth (BIG): This scenario incorporates inclusive growth policies as outlined in the Twelfth Five Year Plan, and serves as the reference scenario.
2. Low Carbon, Inclusive Growth (LCIG): This incorporates low carbon strategies while maintaining the inclusive growth interventions as introduced in the BIG scenario.

It is important to mention that while inclusive actions remain unchanged between the two scenarios, low carbon strategies span the vector space between them. The Model can therefore be used to generate an infinite number of low carbon scenarios between the two extremes. However, for analytical simplicity in the sectoral chapters, we focus on more detailed analysis of the low carbon strategies that are in line with the LCIG scenario.

The motivation and specific details of the two endpoint scenarios are outlined below.

2.3.1 The BIG: Baseline, Inclusive Growth

India's Twelfth Five Year Plan (2012-2017) aims at "Faster, More Inclusive and Sustainable Growth". Inclusion was also an objective of the earlier Five Year Plans. The Twelfth Plan lists a number of monitorable targets that seek to achieve inclusion in the long run. These are enumerated in Box 2.1 below.

Box 2.1: Inclusion Indicators in the Twelfth Five Year Plan

Poverty and Employment

5. Head-count ratio of consumption poverty to be reduced by 10 percentage points over the proceeding estimates by the end of Twelfth Five Plan.

Education

7. Mean Years of Schooling to increase to seven years by the end of Twelfth Five Year Plan.
8. Enhance access to higher education by creating two million additional seats for each age cohort aligned to the skill needs of the economy.
9. Eliminate gender and social gap in school enrolment (that is, between girls and boys, and between SCs, STs, Muslims and the rest of the population) by the end of Twelfth Five Year Plan.

Health

10. Reduce IMR to 25 and MMR to 1 per 1,000 live births, and improve Child Sex Ratio (0–6 years) to 950 by the end of the Twelfth Five Year Plan.
12. Reduce under-nutrition among children aged 0–3 years to half of the NFHS-3 levels by the end of Twelfth Five Year Plan.

Infrastructure, Including Rural Infrastructure

15. Provide electricity to all villages and reduce AT&C losses to 20 percent by the end of Twelfth Five Year Plan.
16. Connect all villages with all-weather roads by the end of Twelfth Five Year Plan.
19. Increase rural tile-density to 70 percent by the end of Twelfth Five Year Plan.
20. Ensure 50 percent of rural population has access to 40 lpcd piped drinking water supply, and 50 percent gram panchayats achieve Nirmal Gram Status by the end of Twelfth Five Year Plan.

Service Delivery

24. Provide access to banking services to 90 percent Indian households by the end of Twelfth Five Year Plan.
25. Major subsidies and welfare related beneficiary payments to be shifted to direct cash transfer by the end of the Twelfth Plan, using the Aadhar platform with linked bank accounts.

Source: Twelfth Five Year Plan Document, Volume 1

Based on these, the Expert Group set up targets for well-being indicators for 2030 to define inclusive growth. Thus, poverty is sought to be reduced to less than one per cent. Every household is to be provided a pucca house, minimum electricity consumption of one kWh per day, clean cooking fuel in the form of at least 6 cylinders of LPG per year, access to clean water and sanitation facilities to all as well as health and educational services at a reasonable level of public expenditure. These targets are sought to be achieved by a variety of means. Income transfers that simulate the ongoing entitlement and employment guarantee programmes are introduced as cash transfers, beginning with an amount Rs. 1,000 per person per year at 2007-08 prices, increasing to Rs. 2,000 by the end of the Twelfth Five Year Plan and to Rs. 3,000 thereafter. The coverage of rural and urban population is gradually increased over the Twelfth Plan period to reach the levels mentioned in the recently enacted National Food Security Act, i.e. bottom 70 percent of the rural, and bottom 50 percent of the urban population.

To provide a pucca house to every household by the year 2030, government demand for construction between 2011 to 2025 is correspondingly increased. The houses are then transferred free of cost to the poor households. Universal access to drinking water and sanitary latrines is similarly ensured as increased government expenditure till the end of the Thirteenth Five Year Plan. Government expenditure on Education and Health is increased by 2 percentage points of GDP from 2015 and maintained at that level thereafter. To ensure that every household has access to at least 1 kWh of electricity and 6 cylinders of cooking gas per year, the deficit from households' normal consumption, on both these counts, is made up by the Government.

Through these interventions, the Model achieves the inclusion objectives of India's growth policy as outlined in the Twelfth Five Year Plan. Since this is a national level model, regional and group specific measures are not introduced; the latter, however, do not require additional resources, but only modifications in governance interventions.

The additional expenditure required for the various inclusion measures are subtracted from total available savings, and investment is correspondingly reduced. The available savings are constrained by a marginal savings rate of 35 percent.

Apart from inclusive growth, other assumptions in the BIG scenario are as follows:

- **"Autonomous" Energy Efficiency Improvement (AEEI):** AEEI at a rate of 0.5 percent per year has been stipulated for energy inputs into the production activities for coal, petroleum products, natural gas and electricity. These reflect efficiency improvements observed in the past, without specific low carbon initiatives, and are autonomous to that extent. It is assumed that improvement up to 0.5 percent per year have a payback period of less than one year and so no additional investment is required during the year.
- **Total Factor Productivity Growth (TFPG):** It is stipulated at 1 percent for agricultural sectors and 1.5 percent for non-agricultural sectors. These are the historically observed values. Since capital is the only factor in the model, TFPG reduces the capital output ratios.
- No carbon emission constraints or specific measures to reduce the emission intensity of the economy are introduced in the BIG scenario.

2.3.2 The LCIG: Low Carbon, Inclusive Growth

This scenario, while maintaining inclusive growth, introduces a number of additional measures:

- The rate of autonomous energy efficiency improvement (AEEI) in production activities is increased to 1.5 percent per year from 2015 onwards. However, in the case of power sector, lower rates of AEEI have been taken to reflect the technological limits, that is, for coal, natural gas and petroleum products required as inputs for generation. AEEI in the power sector is assumed to be 1 percent. AEEI for electricity used in the power sector itself is taken as 0.5 percent, which reflects reduction in T&D losses from 20 percent to 10 percent, and also reduction in auxiliary consumption. One may note that in the Model, the power sector is vertically integrated, and includes generation, transmission and distribution facilities. Efficiency improvements beyond 0.5 percent per year will require upfront investment, for which the payback period is assumed to be six years at a discount rate of 4 percent.
- Many power generation technologies that do not emit CO_2 are introduced. These include solar photovoltaics (PV), solar concentrated solar power (CSP) and wind, all with and without storage, and biomass based power generation plants.

- Hydro and nuclear power development is accelerated.
- The share of generation by conventional coal plants in the total coal based power generation is restricted to increase by only 1.6 percent per year from 2015 onwards. Additional generation from coal plants takes place from the new super critical plants with 20 percent higher fuel efficiency and 25 percent higher capital costs.
- Total factor productivity growth rates (TFPG) for all sectors are the same in both BIG and LCIG scenarios. However, to provide for the falling costs of renewables like wind and solar energy, higher TFPG rates are assumed for renewable power generation technologies up to 2025. After 2025, the TFPG rates for renewables are also the same as that for other non-agricultural sectors.
- A minimum penetration rate for renewable power[1] is prescribed so that the share of renewables in total generation increases from around 7 percent at the end of the Eleventh Plan (2012) to 18 percent by 2030. The total share of non-fossil fuel based power increases from around 20 percent in 2012 to 33 percent by 2030. *To put it simply, one-third of the total power generation by 2030 becomes fossil free.*
- For the transport sector, some of the options assessed are the following:
  i. The share of railways in freight movement is stipulated to increase by 2.5 percent per year, from around one-third in the year 2011 to almost half by the year 2030.
  ii. Fleet efficiency norms on motorized vehicles double fuel efficiency by the year 2030.
  iii. Greater use of public and non-motorized transport by households is introduced by changing demand system parameters to reduce marginal budget shares for petroleum products by 0.2 percent per year beginning 2015.
  iv. The use of electricity and natural gas will substitute petroleum products as alternative fuels in transport sector. This is stipulated by reducing petroleum products inputs in the transport sector by 1.5 percent per year, and replacing them by increasing inputs of natural gas and electricity in the ratio 60:40 percent respectively beginning 2015.
- To reflect the use of energy-efficient appliances, the marginal demand for electricity by households is assumed to fall by 2.0 percent per year from 2015, thereby reducing overall, by 30 percent, by the year 2030.
- An alternative service activity is introduced to reflect higher energy efficiency of commercial buildings, but with higher initial cost. The share of this activity is specified to increase from 1 percent to at least 3.4 percent by the year 2030 to reflect projections for the compliance of Energy Conservation Building Code (ECBC). To reflect energy savings from ECBC compliant public buildings, government consumption of energy is reduced appropriately.
- Higher AEEI rate of 1.5 percent is assumed for the industrial sector based on various industry studies and the on-going 'perform, achieve and trade (PAT)' scheme, as estimated in Chapter 5.
- Finally, to reflect the National Mission for Green India that aims to increase green cover in India by 5 million hectares, and improve the quality of forest on another 5 million hectares by 2020; CO_2 sequestration rates have been increased from around 185 million tonnes of CO_2 per year in 2011 to 270 MT of CO_2 per year by 2030 as estimated in Chapter 8.

2.4 Results

The Macro Economic Outcomes: Starting from the same level in 2007, the Model predictions for 2030 and the resulting compounded annual growth rates of Gross Domestic Product and private (household) consumption for both the scenarios are shown in Table 2.1. It is seen that the growth rate of GDP is lower in the LCIG by 0.16 percent, and the GDP itself in 2030 is lower by 3.33 per cent.

[1] Excludes hydro-power as per the existing Government of India practice.

Table 2.1 Macro-Economic Outcomes

Gross Domestic Product (Rs Billion 2007prices)			Private Consumption (Rs per person 2007prices)	
Year	**BIG**	**LCIG**	**BIG**	**LCIG**
2007	48,330	48,330	21,787	21,787
2015	85,521	84,934	30,674	30,349
2020	121,083	119,731	41,641	41,201
2025	168,582	165,107	57,018	56,416
2030	230,550	222,729	78,804	77,972
CAGR	**7.03**	**6.87**	**5.75**	**5.70**

As inclusiveness is a non-negotiable objective of India's growth policy, both BIG and LCIG scenarios include policies that raise the wellbeing of people. The wellbeing indicators are summarized in Table 2.2.

Table 2.2 Wellbeing Indicators

		BIG	LCIG
Indicator	**2007**	**2030**	**2030**
Poverty	250	8	8
IMR	60.7	14.8	14.8
MYS	4.4	8.7	8.7
LEB male	61.6	71.1	71.1
LEB Female	63.4	73.5	73.5

(Poverty – Millions of persons below poverty line; IMR – Infant Mortality Rate per 1000 live births; MYS – Mean Years of Schooling, LEB – Life Expectancy at Birth in years.)

Figures 2.1 and 2.2 show how the number of persons below poverty line changes over time in rural and urban areas. We project fall in poverty from 2015; and by 2030, poverty is virtually eliminated in both rural and urban areas. Since the government finances the income transfer without any additional taxes, the available resources for investment go down. However, there is no difference between the two scenarios as far as transfers and inclusiveness actions are concerned.

Figure 2.1: People below Poverty Line in Rural Areas

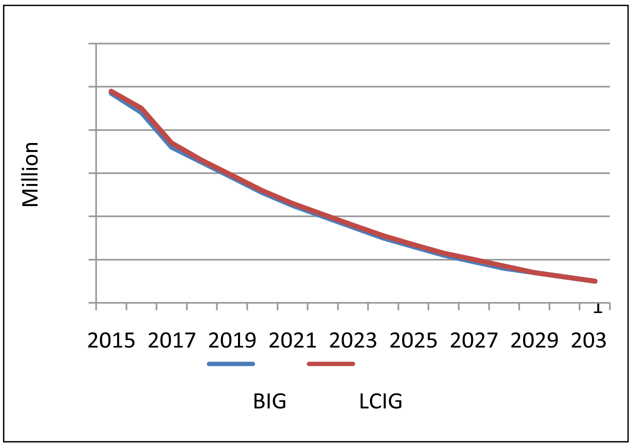
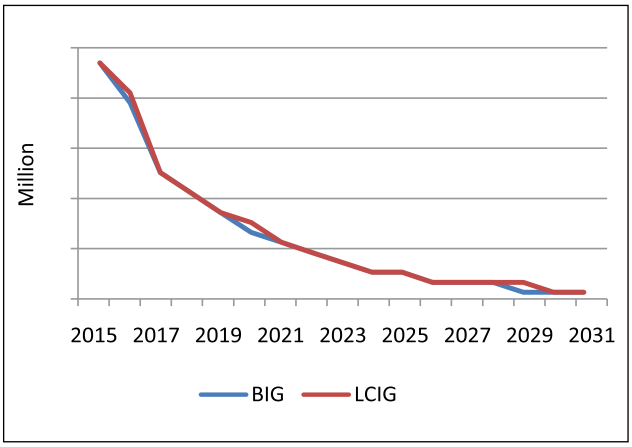


Figure 2.2: People below Poverty Line in Urban Areas



Why is GDP Lower in LCIG?

The cumulative investments in the economy from 2007-08 onwards are shown in Figure 2.3. It can be seen that while cumulative investments in the two scenarios are more or less equal, the LCIG scenario requires 50 percent higher investment in the energy sector (Figure 2.4). Thus, even though the total investment remains the same, GDP and Private Consumption is marginally lower in the LCIG scenario, as higher investment goes into the more expensive renewable energy and other low carbon interventions. This is particularly so because more expensive technologies of power generation are used in the LCIG scenario. Out of a total generation of 3,371 billion units (BU) in 2030 in the BIG scenario, sub-critical coal provides 3,028 BU, whereas in the LCIG scenario, both sub-critical and super-critical coal plants provide only 2,200 BU. On the other hand, non-carbon sources provide 234 BU in BIG and 1134 BU in the LCIG scenario.

Figure 2.3: Cumulated Investments in BIG & LCIG at Constant Prices

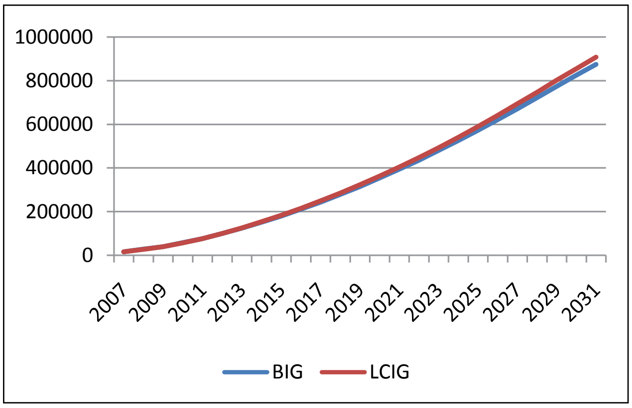
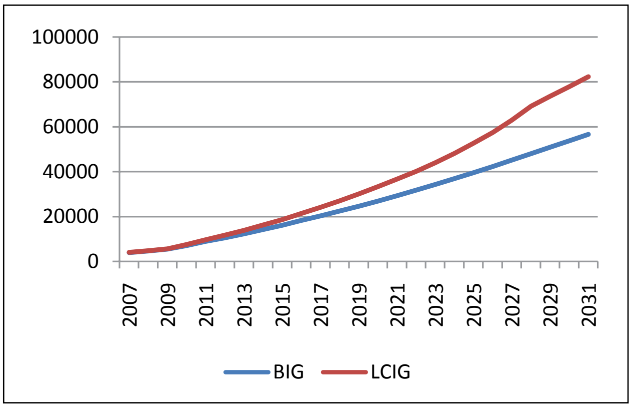


Figure 2.4: Cumulated Energy Investments in BIG and LCIG at Constant Prices



Total and Per Capita Emissions

The Total CO_2 emissions reduce significantly in the LCIG as compared to the BIG scenario. Figure 2.7 shows how they change over time and across scenarios. The total CO_2 emissions are expected to reach a level of 5,271 million tonnes by 2030 in the BIG, but could be lowered to 3,830 million tonnes by pursuit of low carbon strategies in the LCIG scenario. The per capita emissions are expected to be 3.6 Mt of CO_2 by 2030 in the BIG, but could be reduced to 2.6 Mt of CO_2 in the LCIG scenario (Figure 2.6).

Figure 2.5: Total CO_2 Emissions

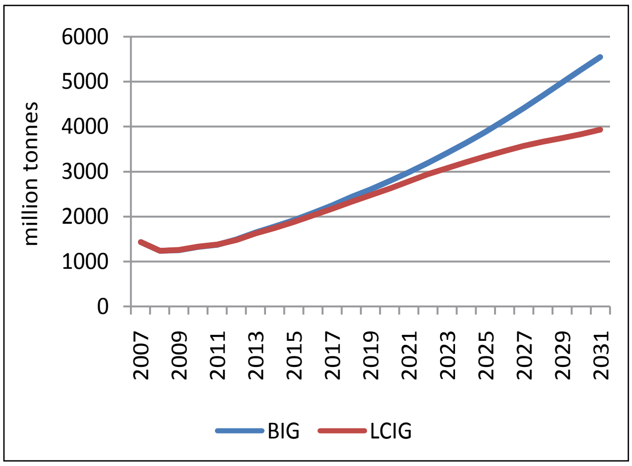
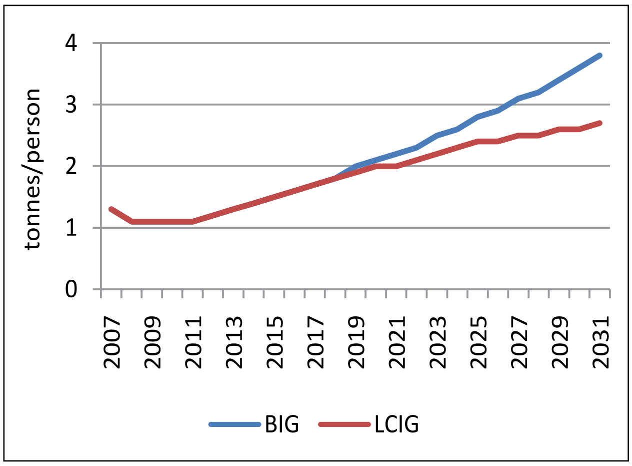


Figure 2.6: Per Capita CO_2 Emissions



It is interesting to note that even though emission intensity falls, the total power demand remains unchanged between the two scenarios (figure 2.7 and 2.8 below). This is because the demand side measures, which reduce power demand in the LCIG scenario, are compensated by the increased demand for electricity due to modal shifts in the transport sector.

Figure 2.7: Power Demand in BIG & LCIG Scenarios

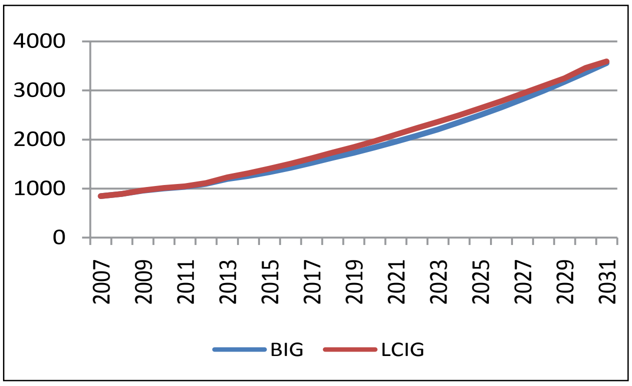
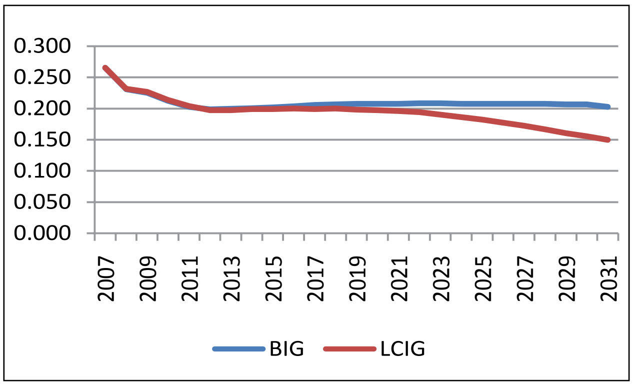


Figure 2.8: Reduction in Emissions Intensity



In the BIG scenario, the emissions intensity falls from 0.43 kg of CO_2/ \$ GDP 2007-PPP, in 2007, to 0.33 kg of CO_2 / \$ GDP 2007-PPP by 2030. This is a reduction of 22 percent over the 2007 levels. In the LCIG scenario, low carbon measures further reduce it to 0.25 kg of CO_2 / \$ GDP 2007-PPP by 2030. This is a cumulative reduction of 42 percent over the 2007 levels in the LCIG scenario, nearly twice as much as that in the BIG scenario.

Total Energy Mix

There is an equivalent shift in the total energy mix between the two scenarios.

Figure 2.9: Energy Mix in BIG Scenario

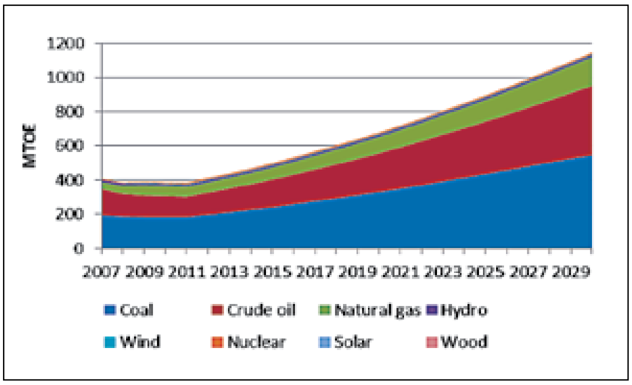
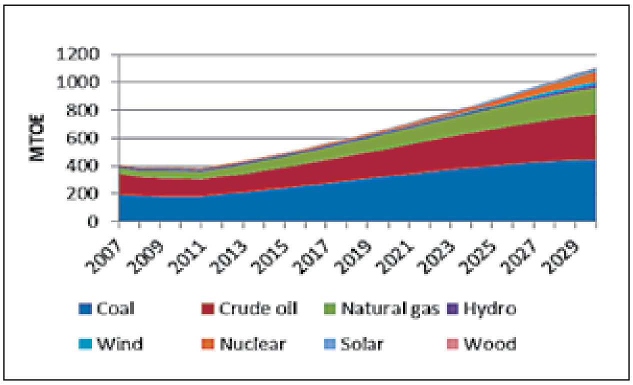
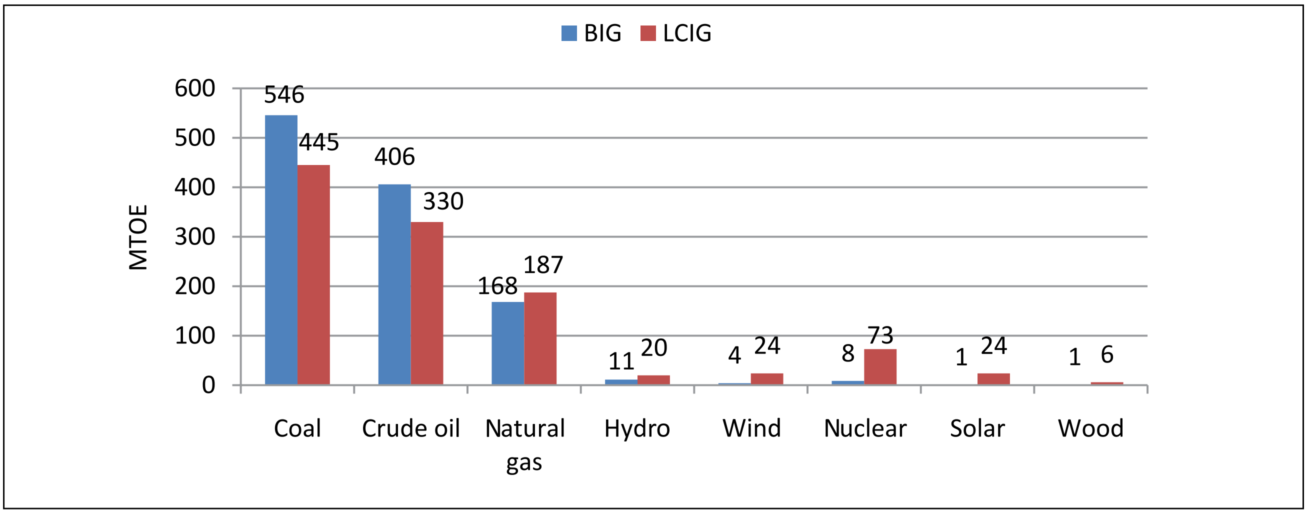


Figure 2.10: Energy Mix in LCIG Scenario



It can be seen from Figure 2.9 and 2.10 above that the total energy requirment rises from 407 Mtoe in 2007 to 1,146 Mtoe in the BIG scenario and 1,108 Mtoe in the LCIG scenario. While the difference in total energy requirment is moderate, the energy mix changes significantly. Demand for coal in 2030 reduces from 1,568 Mt in the BIG to 1,278 Mt in the LCIG scenario, and demand for crude oil reduces from 406 Mt to 330 Mt between the two scenarios, while demand for natural gas rises from 187 bcm in the BIG to 208 bcm in the LCIG scenario. This is shown in the Figure 2.13. The demands for Coal and Crude Oil fall by 20 percent, demand for natural gas rises by 11 percent, while the supply of non-fossil energy increases six fold.

Figure 2.11: Source-wise Contribution to Total Primary Energy in 2030 (in Mtoe)



Since the load factor of solar and wind plants are much lower than thermal plants, the installed capacities of solar and wind are much larger than what the levels of generation might indicate. These are shown in figure 2.14. While solar and wind provide in the LCIG scenario, 427 BU out of 3466 BU in 2030 amounting to 14 percent, their capacities are 225 Gigawatt (GW) out of 698 GW, which amounts to 32.5 percent. Installed capacities in GW and power generation in BU are compared between the two scenarios in figure 2.12 and figure 2.13 below.

Figure 2.12 : Installed Power Capacity (in GW) by Source in 2030

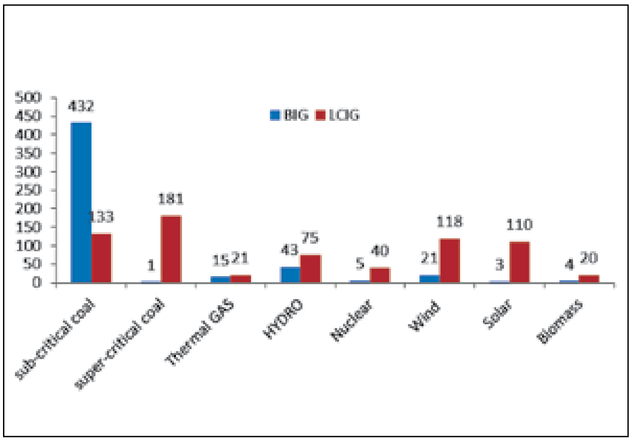
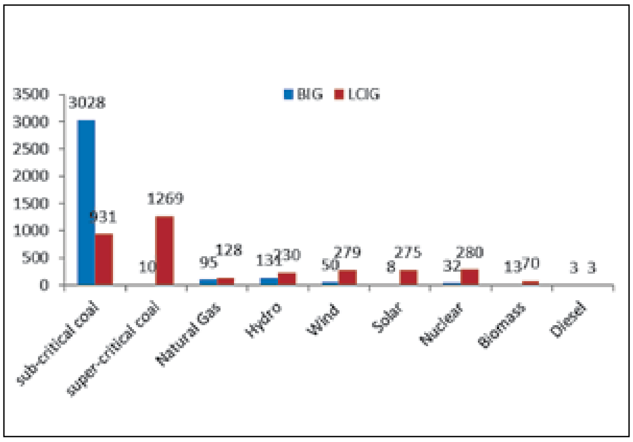


Figure 2.13 : Power Generation (in BU) by Source in 2030

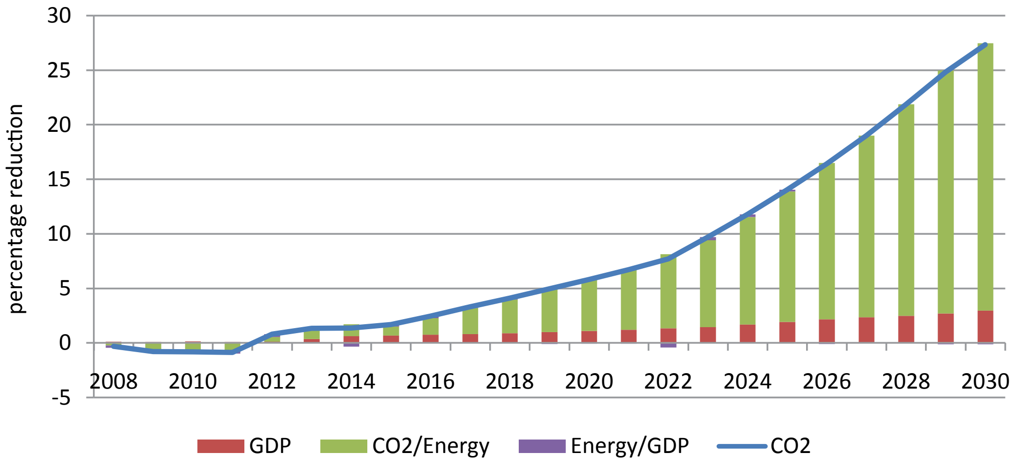


Factors Contributing to Emissions Reduction

The emissions intensity reduction is realized through three measures-reduction in GDP, reduction in energy intensity of GDP through demand side measures, and reduction in emissions intensity through introduction of low carbon sources of energy. The energy intensity of GDP falls from 0.121 kgoe/$ GDP 2007-PPP, in 2007, to 0.071 kgoe/ $ GDP 2007-PPP, in 2030 in both the scenarios. The reason why the LCIG energy intensity not lower, is that in LCIG, the GDP itself is lower, and there are modal shifts in different sectors.

The contribution to reduction in CO_2 emissions through the three broad alternatives, reduction in GDP, energy intensity of GDP and emissions intensity of energy, is given in figure 2.14 below.

Figure 2.12: Decomposition of Emissions Reduction between the BIG and LCIG Scenarios



This decomposition has been attempted in a manner similar to a typical growth accounting exercise in economic literature. It can be seen that even though total emissions in the LCIG scenario are 27 percent lower than in the BIG scenario in 2030, only 3 percent of it comes from reduced GDP, none from energy intensity of GDP and the remaining entire 24 percent comes from change in the supply mix (CO_2/energy).

The impact of specific low carbon measures has to be separated from the impact of lower GDP. Table 2.3 below gives flows of energy sources in 2030 for important sectors and the contribution of different low carbon measures to the overall emission reduction between the two scenarios:

Table 2.3: Contribution of Low Carbon Measures in Important Sectors in 2030

(a) Electricity (BKwh)						
	Requirement	Transport	Household	Government	Industry	Other services
BIG	3370	56	452	286	1294	684
LCIG	3465	58	361	250	1212	587
% reduction in LCIG over IG						
Efficient appliance	0.04		0.26			
Electric Transport	-0.01	-0.32	-0.06	0		
vehicular efficiency						
Road to rail	-0.13					
ECBC Compliant buildings	0.03			0.13		0.11
PAT+ Autonomous efficiency	0.02	0.17			0.04	
Growth	0.03	0.12	0		0.03	0.03
Total	-0.03	-0.03	0.20	0.13	0.06	0.14

(b) Petroleum Products (MT)						
	Requirement	Transport	Household	Government	Industry	Other services
BIG	426	134	152	19	77	164
LCIG	332	70	142	15	67	100

% reduction in LCIG over IG						
Efficiency	0.16					0.36
fuel substitution by gas and electricity		0.24	0.03	0.13		
vehicular efficiency		0.17	0.03	0.11		
Road to rail						
ECBC Compliant						
PAT					0.04	
Growth	0.06	0.06	0		0.09	0.04
Total	**0.22**	**0.47**	**0.07**	**0.24**	**0.13**	**0.41**

(c) Coal (MT)						
	Requirement	**Transport**	**Household**	**Government**	**Industry***	**Other services**
BIG	2024		14	10	1984	16
LCIG	1648		13	10	1612	14
% reduction in LCIG over IG						
Efficiency	0.12		0.07	0	0.12	0.12
fuel substitution						
vehicular efficiency						
Road to rail						
ECBC Compliant						
PAT						
Growth	0.06		0.00	0.00	0.06	0.00
Total	**0.19**		**0.07**	**0.00**	**0.19**	**0.12**

(d) Natural Gas (bcm)						
	Requirement	**Transport**	**Household**	**Government**	**Industry***	**Other services**
BIG	220	0.0	0.2	6.6	151.7	61.7
LCIG	250	34.8	18.9	8.3	131.2	91.2
% reduction in LCIG over IG						
Efficiency	0.04				0.04	0.04
Gas Transportation	-0.30	-38.90	-90.03	-1.41		
vehicular efficiency	0.04	-1.06	0.00	1.16		
Road to rail						
ECBC Compliant						
PAT						
Growth#	0.09	3.08	0.03	0.00	0.10	-0.51
Total	**-0.13**	**-34.76**	**-90**	**-0.25**	**0.14**	**-0.48**

 # For Transport the number reported is absolute number

An analysis of the table 2.3 shows the following:

- The total electricity consumption increases by 95 bkWh in LCIG compared to BIG in 2030. Power demand decreases by 92 bkwh is due to lower GDP. The total consumption of petroleum products falls by 94 Mt of which 26 Mt is due to lower GDP, that of coal by 376 Mt of which 126 Mt is due to lower GDP, and that of natural gas increases by 29 bcm.
- Household consumption of electricity in LCIG falls by 91 bkWh in 2030, which is a reduction of 20 percent. Of this 26 percent is due to energy efficient appliances, and less than 1 percent due to reduction in GDP and an increase of 6 percent due to electric vehicles.
- Government consumption of electricity falls by 36 bkWh, which is 13 percent of consumption in BIG. This is due to 12.58 percent reduction due to ECBC compliant buildings and 0.5 percent increase due to electric vehicles.
- ECBC compliant commercial buildings provide a reduction of 97 bkWh in 2030 which is 14 percent of consumption in BIG.
- Energy efficiency in industry including power generation, due to the PAT scheme reduces electricity demand by 48 bkWh, coal demand by 248 Mt, petroleum products' demand by 3 Mt and natural gas by 6 bcm.
- Transport vehicles efficiency improvement leads to a reduction of 30 Mt of consumption of petroleum products; whereas fuel substitution of petroleum products by natural gas and electricity, and reduced demand by households for motorized transport together reduce consumption of petroleum products by 40 Mt; and increase consumption of electricity by 48 bkWh and of natural gas by 67 bcm.

This highlights the importance of looking at various low carbon measures in an integrated framework. The interactions of various policy measures and feedback are significant. The low carbon measures are examined in further detail in the respective sectoral chapters.

How much will the Low Carbon Strategies Cost?

As a percentage of GDP, LCIG scenario requires an additional energy investment worth 1.5 percent of GDP, over and above the BIG scenario. This amounts to a total of 834 Billion US Dollars at 2011 prices. This diverts resources from other needs, and may not be possible to sustain if the growth is not fast enough. The total GDP loss caused by the additional energy investment in the LCIG scenario has been quantified at 1,344 Billion US Dollars at 2011 prices, which amounts to an output loss of 3 percent over the BIG scenario. International help, in both finance and technology, would therefore be critical to support India's pursuit of Low Carbon Strategies. Some of the financing strategies are outlined in Chapter 9.

2.5 Conclusion

The model output has been summarized through the two endpoint scenarios: the BIG and the LCIG. Inclusiveness remains unchanged between the two scenarios, while the low carbon strategies span the vector space between them. These endpoint scenarios are summarized below:

1. **Baseline, Inclusive Growth (BIG):** An average 7 percent GDP growth is sustained up to 2030. Rural poverty is expected to fall below 10 percent, while urban poverty will be completely eliminated. The aggregate CO2 emissions are expected to rise from 1,429 Mt in 2007 to 5,271 Mt in 2030 and per capita emissions are expected to rise from 1.3 tonnes of CO2 per year to 3.6 tonnes of CO2 per year by 2030. The total energy demand is expected to rise from 400 Mtoe in 2007 to 1146 Mtoe in 2030, while the power demand is expected to increase from 837 Billion Units in 2007 to 3371 Billion Units in 2030. The total demand for fossil fuels is expected to be 1568 Mt of coal, 406 Mt of crude oil and 187 bcm of natural gas in 2030, which is a significant increase as compared to 556 Mt of coal, 156 Mt of crude oil and 43 bcm of natural gas in 2007. Emissions intensity in terms of kg CO2 $ per GDP (2005 PPP) comes down from 0.43 in 2007 to 0.33 in 2030, a reduction of 22 percent over 2007 levels.

2. **Low Carbon, Inclusive Growth (LCIG):** Although the average long term GDP growth is only marginally lower at 6.9 percent, low carbon strategies require an additional investment worth 834 billion US dollars at 2011 prices. Cumulative investment in the energy sector between 2007 and 2030 is almost 50 percent higher in the LCIG scenario as compared to the BIG scenario. A finance of this magnitude would be difficult to mobilize, particularly if the high growth is not sustained in the long run, and adequate assistance in the form of international finance and technology is not forthcoming. Outcomes, which measure inclusion and wellbeing, remain the same as in the BIG scenario. The total CO2 emissions now increase much more moderately to 3,830 Mt and per capita emissions to 2.6 tonnes by the year 2030. The decline in emissions intensity of GDP nearly doubles to 42 percent, over 2007 levels, by 2030. An emission accounting exercise shows that out of this total reduction, 3 percent comes from GDP, 10 percent from energy efficiency and 29 percent from shift to energy sources which emit less carbon. The total energy demand, in 2030, will be lower at 1,108 Mtoe, while the power demand would still rise to 3,466 Billon Units due to improved access and modal shifts. About one-third of power supply should be fossil free and aggregate demand of fossil fuels would be much lower at 1,278 Mt of coal, 330 Mt of crude oil and 208 bcm of natural gas.

To summarize, sustaining high growth is a double imperative. Not only is it necessary to find resources for inclusion, but also to mobilise resources for low carbon investment. Low carbon investments, on the other hand, sustain long run growth by relaxing the natural resource constraints. It is no longer possible to pursue growth policies that treat these imperatives as separate compartments. Fortunately, with the approval of the Twelfth Five Year Plan Document by the National Development Council, faster, sustainable and more inclusive growth has become an integral part of India's growth policy at both the Central and State levels.

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Annexure: Model Description

The following is the description of the Macro Model used in this Report.

Consumption

$C_{iht} = c_{iho} + \beta_{ih} (E_{ht} - \Sigma_i c_{iho})$ .... (1)

where,

C_{iht} = per capita consumption of the ith commodity by the hth household group in tth time period,

c_{ih0} = minimum per capita consumption of the ith commodity by the hth household,

β_{ih} = share of the ith commodity in the total per capita expenditure of the hth household and

E_{ht} = total per capita expenditure of the hth household.

As income rises, per capita consumption increases, moving people from lower expenditure classes to higher expenditure classes. Such changes would impact the demand structure of the economy. The model has an endogenous income distribution, separately for rural and urban areas, to incorporate the change in the number of people in different classes over the time period (2005-2050). The linear expenditure system (LES) and endogenous income distribution together provide a dynamically changing commodity-wise demand structure of the economy. The original input–output table consisting of 115 sectors was aggregated to 25 commodities, being produced by 38 production activities. The model considers one commodity being produced by each production activity, except electricity; that is, to produce power, the model employs renewables (wind, solar thermal, solar photovoltaic, wood gasification) and nuclear-based technologies. Assumptions on nuclear are based on plants that are already present or are in the process of construction. Coal, crude, natural gas and electricity are energy inputs into the model. The model ensures equilibrium between demand and supply along the optimal path for each commodity.

Demand and Supply Equilibrium

$C_{it} = G_{it} + I_{it} + IO_{it} + E_{it} \leq Y_{it} + M_{it}$ .... (2)

Private consumption demand + government consumption demand + investment demand + intermediate input demand + export demand = domestic production + imports

Private consumption demand + government consumption demand+ investment demand + intermediate input demand+ export demand = domestic production + imports

Total private consumption ($C_{i,t}$) is obtained from the LES demand function and endogenous income distribution. Government consumption ($G_{i,t}$) is exogenously specified to grow at a rate of 7 percent per annum (we do not explicitly model the fiscal policy and government's inter-temporal budget constraint).

Iit is the investment requirement of the economy and is matched by a mix of domestic savings and inflow of foreign savings, such that the Savings-Investment identity is maintained. Investments are not divided into public and private, just as the savings are not. This simplicity helps us focus on other parts of the model, particularly on activities related to low carbon strategies. Intermediate demand ($IO_{i,t}$) is determined endogenously by the input–output coefficients. Exports ($E_{i,t}$) and imports ($M_{i,t}$) are determined endogenously from the trade-side equations of the balance of payments block.Domestic availability of commodities is assumed to come from domestic output ($Y_{i,t}$) and imports ($M_{i,t}$).

Capacity Constraint

Domestic production is constrained by capacity, i.e., the maximum output that can be produced at the given level of capital stock.

$(X_{j,t} - X_{j,t-1}) \leq (K_{j,t} - K_{j,t-1}) / ICOR_j$ .... (3)

(Incremental output is related to incremental capital.)

$X_{j,t}$ = domestic output of the jth sector at time t,

$K_{j,t}$ = capital of the j^{th} sector at time t and

$ICOR_j$ = incremental capital output ratio of the j^{th} sector, which is exogenously specified in the model.

Capital stock in sector j depends upon the rate of depreciation, and investment, and is modelled using the following relation.

Capital Stock Equation

$K_{j,t} = DEL(J) * K_{j,t-1} + I_{j,t}$ .... (4)

where DEL(J) is the rate of depreciation in sector j (exogenous), and $I_{j,t}$ is the investment in sector j.

Aggregate investment demand depends on aggregate domestic investible resources (domestic savings determined by the marginal savings rate) and foreign investments available. Investment goods, which reflect the structure of capital goods in the sectors, are identified separately, and are allocated to different sectors as fixed proportions ($P_{i,j}$) of the total investment ($I_{i,j}$) in each sector.

Investment Equations

$\Sigma_i Z_{it} < Z_o + S* (VA_t - VA_o) + (FT_t - FT_o)$ .... (5)

$\Sigma (P_{i,j} * I_{j,t}) \leq Z_{i,t}$ .... (6)

$FT_t = (a - b* t) *VA_t$ .... (7)

where,

$Z_{i,t}$ = investment demand of commodity i at time t,

VA_t = value added at time t,

FT_t = foreign investment at time t,

S = exogenously specified maximum marginal savings ratio,

Z_0 = investment in the base year (2004-05) and

$P_{i,j}$ and a and b are pre-specified constants.

Trade is endogenous to the model. Foreign capital inflow *(FT)* is a changing proportion of the value added. Though exports and imports are endogenous to the model, upper and lower limits are exogenously specified on the growth rates of both exports and imports. The model has a balance of payment constraint for exports and imports so that they grow in a realistic manner.

Balance of Payment Equations

$\Sigma_i (M_{i,t} * MTT_i) = \Sigma E_{i,t} + FT_t$ .... (8)

$M_{i,t} \leq (1+MGRU_t) * M_{i,t-1}$ .... (9)

$M_{i,t} \leq (1+MGRU_t) * M_{i,t-1}$ .... (10)

$E_{i,t} < (1+EXGRU_i) * E_{i,t-1}$ .... (11)

where,

MTT_i = trade and transport margins for commodity i,

$MGRU_i$ and $MGRL_i$ = upper and lower bounds for imports growth rates of commodity i and

$EXGRU_i$ = upper bound for exports growth rate of commodity i.

Equations (7) to (11) specify the trade-side of the model, while equations (1) to (11) form a set of constraints, based on the economic criteria, for the model solution to be meaningful. The optimal solution is where the present discounted value of total private consumption is maximised.

3 Energy Efficiency in Households

3.1 Importance

Promoting energy efficiency in households is important because not only does it reduce emissions' intensity but also improves energy security, thus lowering the need for energy. The options considered for improving energy efficiency in households are lighting, appliances and equipment.

3.2 India's Approach: The Energy Conservation Act

In the year 2001, the Parliament passed the Energy Conservation Act (EC Act). This Act was to provide for efficient use of energy, conservation and for matters connected therewith or incidental thereto. In the year 2010, some features of the EC Act were amended providing more stringent compliance norms. The salient features of the EC Act, 2001 are shown in Box 3.1.

Box 3.1. The Energy Conservation Act, 2001

The EC Act, 2001 empowered the central and state governments to:

- Specify energy consumption standards for notified equipment and appliances;
- Direct mandatory display of label on notified equipment and appliances;
- Prohibit manufacture, sale, purchase and import of notified equipment and appliances not conforming to energy consumption standards;
- Notify energy intensive industries, other establishments, and commercial buildings as designated consumers;
- Establish and prescribe energy consumption norms and standards for designated consumers;
- Prescribe energy conservation building codes for efficient use of energy and its conservation in new commercial buildings having a connected load of 500 kW or a contract demand of 600 kVA and above;
- Direct designated consumers to –
  - Designate or appoint certified energy manager in charge of activities for efficient use of energy and its conservation;
  - Get an energy audit conducted by an accredited energy auditor in the specified manner and interval of time;

Furnish information with regard to energy consumed and action taken on the recommendation of the accredited energy

  - Auditor to the designed agency;
  - Comply with energy consumption norms and standards;
  - Prepare and implement schemes for efficient use of energy and its conservation if the prescribed energy consumption norms and standards are not fulfilled;
  - get energy audit of the building conducted by an accredited energy auditor in this specified manner and intervals of time;
- State Governments may –
  - Amend the energy conservation building codes prepared by the Central Government to suit regional and local climatic conditions;
  - Direct every owners or occupier of a new commercial building or building complex being a designated consumer to comply with the provisions of energy conservation building codes;
  - Direct, if considered necessary for efficient use of energy and its conservation, any designated consumer to get energy audit conducted by an accredited energy auditor in such manner and at such intervals of time as may be specified.

Under the provisions of the Act, the Bureau of Energy Efficiency (BEE) was established with effect from 1st March, 2002, by merging the erstwhile Energy Management Centre, as a society under the Ministry of Power. BEE is responsible for spearheading the improvement for energy efficiency of the economy through various regulatory and promotional instruments. See Box 3.2.

Box 3.2 The Mission of Bureau of Energy Efficiency (BEE)

The mission of BEE is to develop policy and strategies with a thrust on self-regulation and market principles, within the overall framework of the EC Act, 2001 with the primary objective of reducing energy intensity of the Indian economy. This was to be achieved with active participation of all stake holders, resulting in accelerated and sustained adoption of energy efficiency in all sectors of the economy. The primary objective of BEE is to reduce energy intensity in the Indian economy through adoption of result oriented approach. Apart from these, the broad objectives of BEE were:

- To assume leadership and provide policy framework and direction to national energy efficiency and conservation efforts and programmes;
- To coordinate policies and programmes on efficient use of energy and its conservation with the involvement of stakeholders;
- To establish systems and procedures to measure, monitor and verify energy efficiency results in individual sectors as well as at national level;
- To leverage multi-lateral, bi-lateral and private sector support in implementation of the Energy Conservation Act and programmes for efficient use of energy and its conservation;

To demonstrate energy efficiency delivery mechanisms, through private-public partnership; to plan, manage and implement energy conservation programmes as envisaged in the EC Act, 2001.

The BEE has a number of programmes to improve energy efficiency. Among these, some relate to lighting efficiency, labelling of appliances and equipment, efficiency of buildings, fuel efficiency of motorized vehicles and energy efficiency in industries. In this chapter, we cover lighting and appliances.

3.2.1 Lighting: Bachat Lamp Yojana

A compact fluorescent lamp (CFL) can provide the same level of light as an incandescent lamp (IL) at a much lower consumption of electricity. Thus, an 11 watt CFL gives the same light as a 60 watt IL. Replacing all the ILs with CFLs will save a lot of electricity. The main hurdle is that the initial cost of a CFL is 7 to 10 times as high as that of an IL.

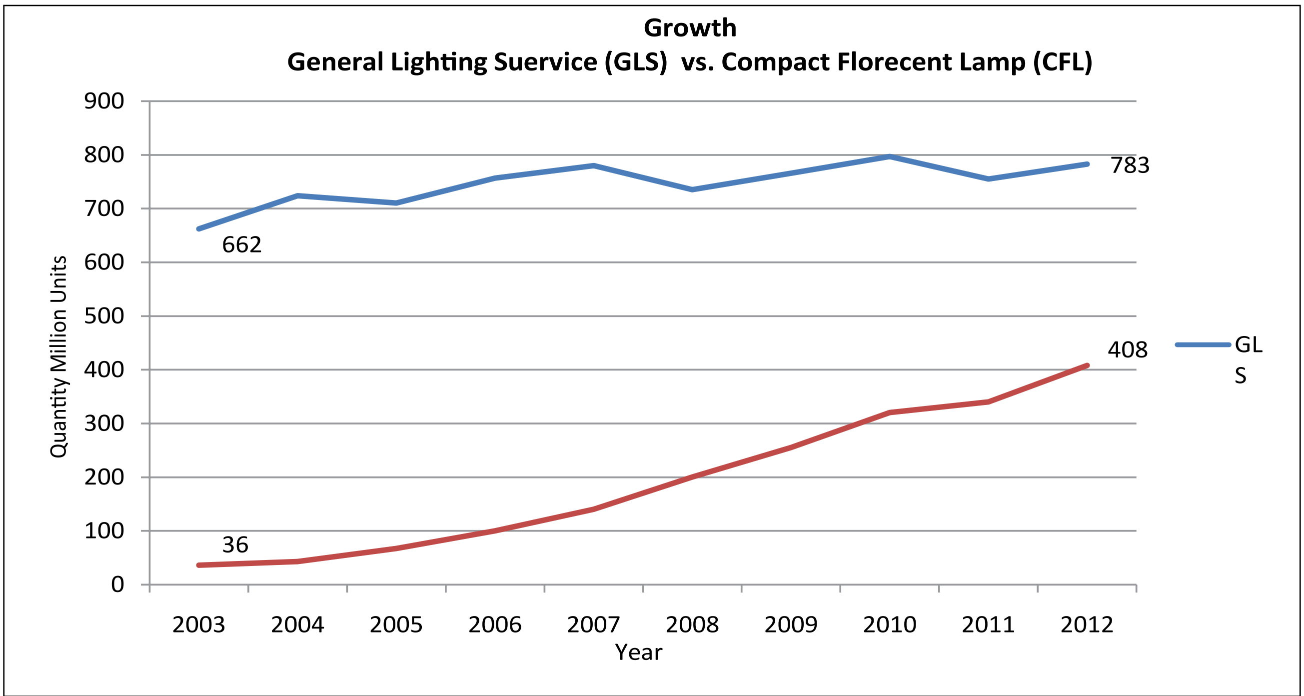
A light emitting diode (LED) lamp consumes even lesser electricity than a CFL, but costs much more than a CFL. Promoting the use of more efficient CFL or LED lights in cases where the consumers are poor, have a high discount rate and for whom the first cost is very important. A commonly used approach is where the distribution utility loans the more efficient CFL and adds a monthly charge to the customer's bill. The customer does not feel any financial burden if the monthly charge is less than the value of electricity saved. Such a system will not work well if poorer consumers, who constitute bulk of the domestic consumers, are charged a flat fee or are supplied electricity at subsidized price. The relatively affluent might have no financial constraint in "switching over" to more efficient lights. On the other hand, for them the cost of electricity for lighting may constitute a small fraction of their expenditure and they may not even bother to change. They may not find the CFL attractive in comparison to other sophisticated lighting options.

We have used a different mechanism. The Bureau of Energy Efficiency (BEE) set up to promote energy efficiency launched its "Bachat Lamp Yojana" (BLY) in February 2009. Under this scheme, a working incandescent bulb is exchanged at a small cost of Rs. 15 (a CFL usually costs Rs. 100 approximately) with a CFL by the distribution company, which has worked out a scheme to get carbon credits for this programme. Chips are introduced in a small number of randomly selected CFLs that measure the number of hours the bulb is turned on. This provides a verifiable estimate of carbon emissions saved.

In the year 2011, nearly 5 million ILs were replaced by CFLs saving 231 MU of electricity and 85 MW of installed capacity. The programme's aim is to replace 400 million ILs to save 6000 MW of installed capacity and 18400 MU of electricity per year. At a carbon price of US $ 20/ ton of CO_2, the saving is worth US $ 400 million per year. Assuming a life of 5 years for a CFL (it is claimed to be much longer), the present discounted value of the saving at 10 percent discount rate will be US $ 1670 million, in terms of the CO_2 value alone. Thus for each CFL, US $ 4.17 is earned and the cost to the DISCOM is only Rs. 85. As long as a good price for carbon credit is assured, the Bachat lamp Yojana should be successful. India must ensure that the Kyoto protocol mechanism of carbon credits is available. Unfortunately, carbon price on the international market has fallen to almost 3 Euros / ton of CO_2. At this price, the BLY scheme is not viable.

Nonetheless, the scheme has created a large supply of CFLs, and these lights currently have a good market penetration in the non-subsidized segment. In many affluent homes, hotels, offices and public places, CFLs are now being used widely. The sale of CFL in the year 2012 was 408 million in number. Figure 3.1 shows the way sale of CFL in comparison with that of GLS (general lighting service) units has grown in India.

Figure 3.1: Growing Sales of CFL in India (Millions)



We do not have data on the use of CFLs in commercial establishments. However, a lower bound estimate of energy saving from the use of CFLs can be made from the household use data. The stock of operating CFLs in the year 2012 based on a lifetime of two years is around 750 million. We do not know the number of hours CFLs would be used in a year. The 46 kWh/ years/CFL reflects the use in poorer households with one or two light points. In richer households and commercial establishments, hours of use per

CFL may be very different with the possibility of a rebound effect. It is difficult to assess the savings. It is also worth noting that an LED lamp consumes only four fifth of the electricity as a CFL uses. The LED bulb in January 2014 costs around Rs. 250 and the price has come down drastically from Rs. 2400 in the year 2009. Scope for additional reduction in the price in future may be there.

It is difficult to make estimate for savings from efficient lighting in households. Electricity saving depends on the number of lighting points, CFL or LED lamps and their hours of use. If we assume that by 2031-32, all lamps will be CFL or LED, the savings in lighting will amount to 70 to 80 percent. A World Bank study estimates a saving of 45 percent electricity in households by 2013-32.

3.2.2 Appliances - Labelling

Energy Efficient Appliances are promoted through an appliance rating scheme. The appliances are rated with one to five stars; five stars referring to most energy efficient model. The label carries the amount of electricity consumed by the appliance and also its energy efficiency. A buyer has the privilege to decide if the savings are worth the additional cost for an appliance with more stars.

Spread of Labelled Appliances:

BEE started appliance labelling programme five years ago. Every year, an independent evaluation is carried out which assesses the penetration of starred products. Using the data from such evaluations, penetrations of different starred products have been worked out. These are shown in the Tables 3.1 to 3.4 and Figures 3.2 to 3.5.

Table 3.1 Total BEE labelled AC sold

Star Rating Category	Cost		Approx. Energy Saving (Compared to Non Star Category) (kwh/product/year)	Year				
	Window	Split		2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
1 Star	18190	23000	259.54	52218	34988	361703	265387	50636
2 Star	19000	26000	415.32	227468	370531	871288	1263155	1034072
3 Star	24990	29000	566.94	10683	162848	692482	993836	1177119
4 Star	27000	31500	688.16	11191	21823	70496	114280	75477
5 Star	30000	33500	787.37	3640	5937	236634	486332	632846
Total				**305200**	**656127**	**2232603**	**3122990**	**2970150**

Source: National Productivity Council Bureau of Energy Efficiency for the year 2009 to 2012

Figure 3.2 Percentage Share of AC Sold in the Year 2007-08 to 2011-12

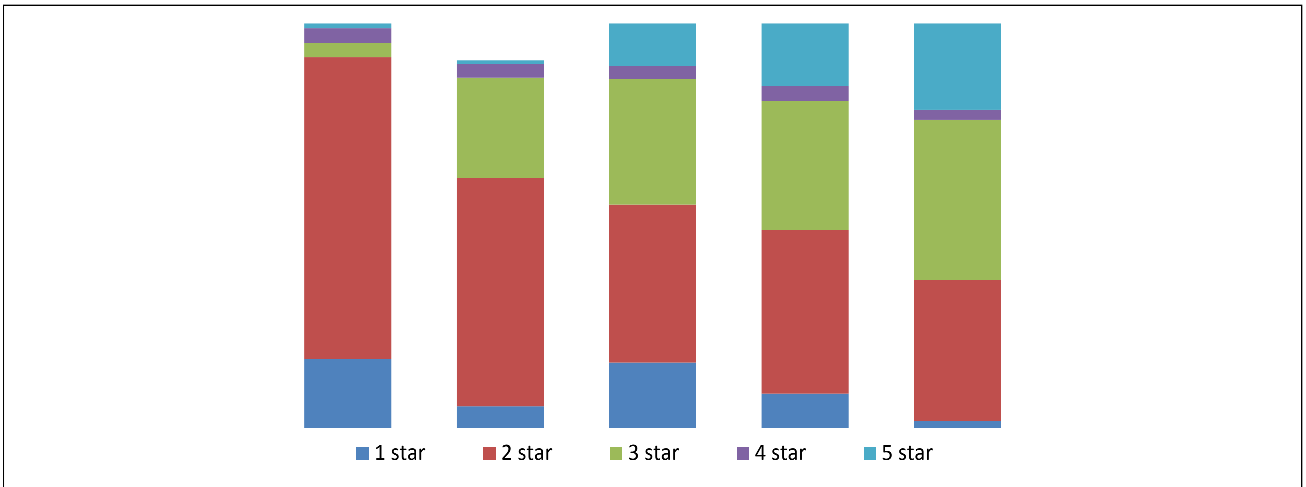


Table 3.2 Total BEE labelled Colour Televisions sold

Star Rating Category	Cost		Approx. Energy Saving (Compared to lowest Star Category) (kwh/product/yr)	Year		
	CRT	LCD		2009-2010	2010-2011	2011-2012
1 Star	7800	16500	0	0	0	0
2 Star	8200	17000	21.5	0	0	0
3 Star	8500	17500	35.81	320765	557413	514203
4 Star	10000	18500	70.51	719919	1449183	2205241
5 Star	13500	23000	117.72	723165	888355	485315
Total				**1763849**	**2894951**	**3204759**

Source: National Productivity Council Bureau of Energy Efficiency for the year 2009 to 2012

Table 3.3 Total BEE labelled Ceiling Fans Sold

Category	Cost	Approx. Energy Saving (Compared to lowest Star Category) (kwh/product/yr)	2009-2010	2010-2011	2011-2012
1 star	0	0	0	0	0
2 star	0	6.7	0	0	0
3 star	1300	12.88	64531	31578	6224
4 star	1900	25.41	29290	17346	10909
5 star	2100	48.33	159245	448581	527502
Total			**253066**	**497505**	**544635**

Source: National Productivity Council Bureau of Energy Efficiency for the year 2009 to 2012

To assess the economic attractiveness of various star rated appliances, we compare the present discounted value of the saving in electricity cost at different discount rates with the additional initial cost. The results are summarised in Table 3.5

Table 3.4 Economics of Star Rated Appliances

Present discounted value of savings at discount rate 10%> Initial cost difference							
		Rs 4/ kwhr			Rs 6/ kwhr		
Appliances	**Base Rating**	**Life of equipment in years**			**Life in years**		
Air conditioners	**1***	**5**	**7**	**10**	**5**	**7**	**10**
Air conditioners	1*	✓	✓	✓	✓	✓	✓
2*			✓	✓	✓	✓	✓
3*			✓	✓	✓	✓	✓
4*			✓	✓	✓	✓	✓
5*			✓	✓	✓	✓	✓
Refrigerators	2*						
3*			✓	✓	✓	✓	✓
4*						✓	✓
5*							✓

Colour Televisions	2*						
3*			✓	✓	✓	✓	✓
4*						✓	✓
5*							
Ceiling Fans	1*						
2*			✓	✓	✓	✓	✓
3*				✓	✓	✓	✓
4*				✓	✓	✓	✓
5*					✓		

Present discounted value of savings at discount rate 20%> Initial cost difference							
		Rs 4/ kwhr			Rs 6/ kwhr		
Appliances	**Base Rating**	**Life of equipment in years**			**Life in years**		
Air conditioners	**1***	**5**	**7**	**10**	**5**	**7**	**10**
2*		✓	✓	✓	✓	✓	✓
3*			✓	✓	✓	✓	✓
4*			✓	✓	✓	✓	✓
5*				✓	✓	✓	✓
Refrigerators	2*						
3*				✓	✓	✓	✓
4*							
Colour Televisions	2*						
3*					✓	✓	✓

The Tables 3.4 and 3.5 show that when electricity is priced at Rs 6/kWh, star rated appliances are economically Notional attractive, even at a discount rate of 20 percent. The tables also suggest that manufacturers should bring down the costs of higher star rated appliances, if they want to reach out to the large market of relatively poorer consumers.

In order to encourage manufacturers, they may be given differential tax relief for more efficient appliances. The level of the relief should not exceed the value of CO2 emissions saved, considered at a notional price of CO2. Tax rebate takes away the incentive to reduce costs or increase efficiency. Thus, relief should be given ex-post in the form of a golden carrot to the manufacturer who is the first to sell a prescribed number of units, for instance, a million in a prescribed time frame.

It is recommended that the appliance-labelling programme should be continued and extended to other presently uncovered appliances. BEE should also periodically revise its rating system to reflect best global technologies.

Projections of Energy Saving

To estimate the energy saving from labelling of household appliances, we have to project the total number of appliances possessed by households for the years 2021, 2031 and the star rating of the appliances. The National Sample Survey data and consumption distribution as projected by the model described in the previous chapter is used to meet this objective.

The National Sample Survey (NSS) is a quinquennial survey of consumer expenditure. The 66th round data (year 2009-10) gives the number of households possessing an appliance per 1000 households for the year 2009-10. Population is divided into 10 decile classes of monthly per capita consumer expenditure (MPCE). NSS considers 12 items of household appliances and durable goods that are possessed by rural and urban households according to their MPCE decile class for all-India level in the year 2009-10. The total estimated households in rural and urban areas in the year 2009-10 were 163 million and 68 million respectively. Thus, each decile class represents 16.3 million and 6.8 million households in rural and urban areas respectively.

The Table 3.6 and Table 3.7 give the number of households out of 1000 households who possessed the four critical appliances for energy consumption for rural and urban areas.

Table 3.5 Rural Households Possessing Appliance per 1000 households

MPCE decile class	MPCE (RS per person per month)	Television	Electric Fan	Air Conditioner, Cooler	Refrigerator
0-537	452.98	94	205	6	1
537-631	584.4	160	289	15	3
631-718	675.35	235	357	12	4
718-804	760.79	294	440	19	7
804-895	848.07	353	511	30	12
895-1001	944.35	398	550	31	25
1001-1133	1062.93	471	629	36	34
1133-1322	1220.59	565	684	52	72
1322-1653	1470.33	612	737	79	122
1653-More	2516.69	702	825	152	292
All	**1053.64**	**417**	**552**	**50**	**71**

Source: NSSO 66th round (2009-10)

Table 3.6 Urban: Households possessing appliance per 1000 households

MPCE decile class	MPCE (Rs. per person per month)	Television	Electric Fan	Air Conditioner, Cooler	Refrigerator
0-733	599.27	429	664	42	24
733-926	830.96	597	822	73	70
926-1101	1011.84	691	831	96	114
1101-1293	1196.08	768	902	143	218
1293-1502	1397.99	830	922	178	328
1502-1773	1633.42	827	938	190	359
1773-2097	1930.96	823	946	208	450
2097-2603	2329.87	818	943	236	537
2603-3665	3050.69	839	966	295	664
3665-More	5863.25	778	970	433	658
All	**1856.01**	**758**	**906**	**214**	**390**

Source: NSSO 66th round (2009-10)

The NSS data combines air conditioners and coolers. Since these two have very different energy consumption, we have used data from a survey by NCAER for the period 2010-11. These are shown in Table 3.8.

Table 3.7 Number of households with Air Conditioner per 1000 households

Rural		Urban	
MPCE(Rs)	Air Conditioner	MPCE(Rs)	Air Conditioner
519	0	715	1
718	1	1104	3
896	1	1516	4
1142	2	2130	13
1994	10	4457	120

Source: *NCAER 2011*

Figures R1 to R4 and U1 to U4 show the number of households possessing the appliance, out of a total 1000 households against the MPCE. The curves have been extended in a heuristic manner to cover higher levels of MPCE that may prevail in 2031.

Figure R-1: Television

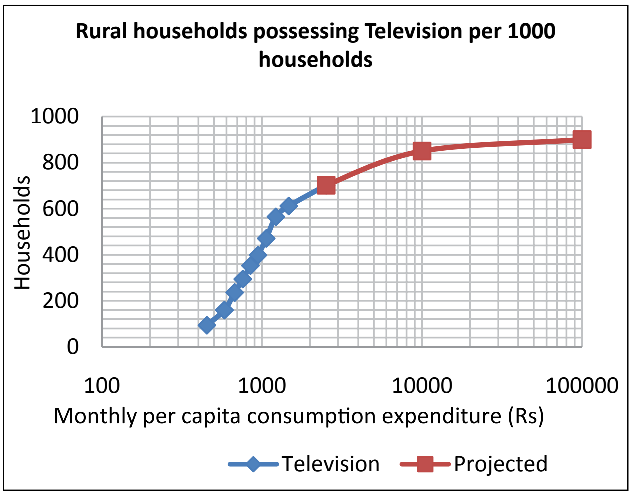


Figure R-2: Refrigerator

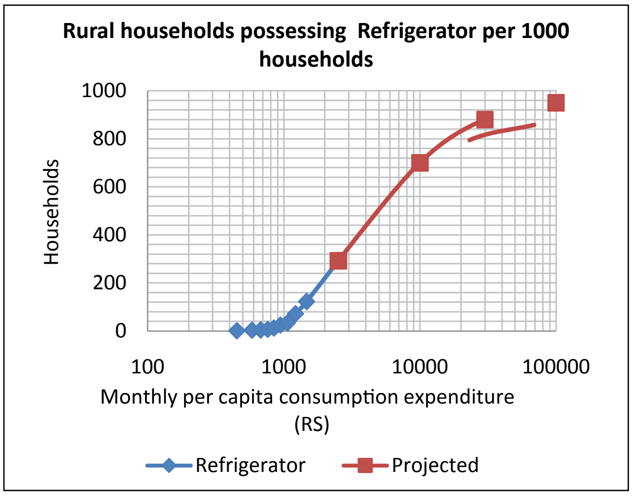


Figure R-3: Electric Fan

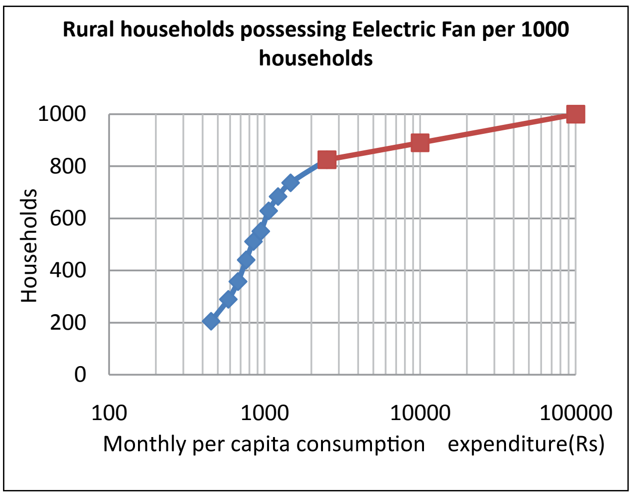


Figure R-4 Air Conditioner

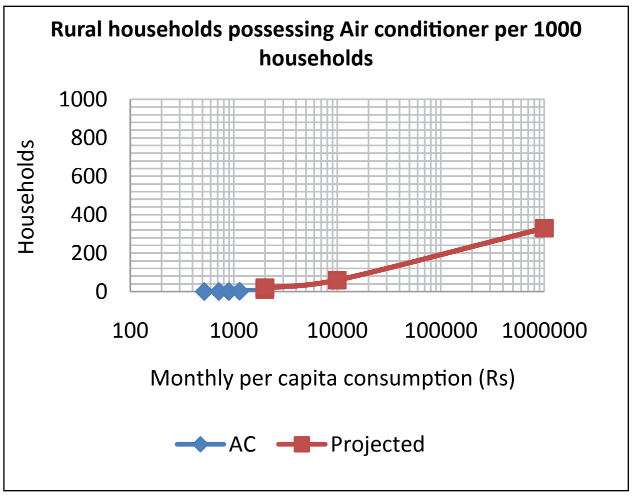


Figure U-1: Television

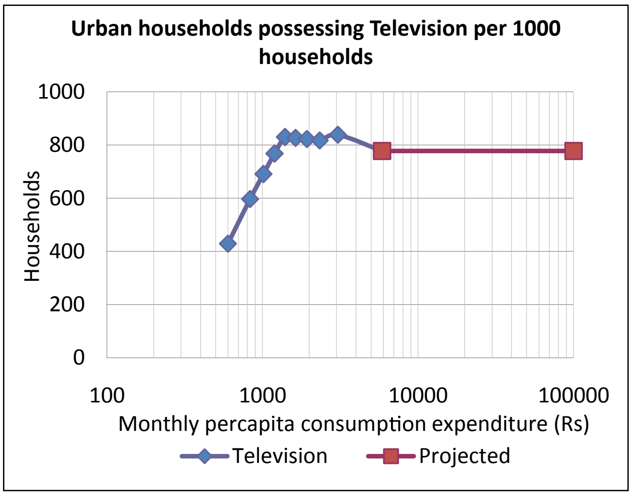
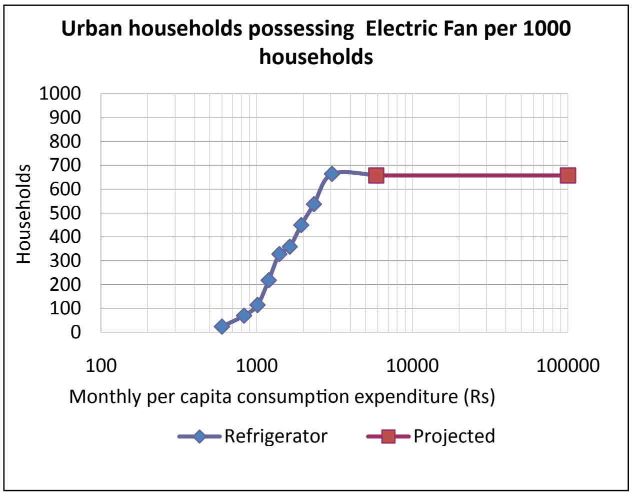


Figure U-2: Refrigerator



FigureU-3: Electric Fan

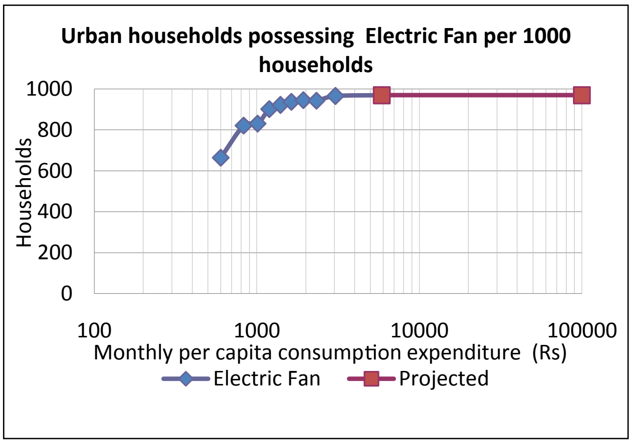
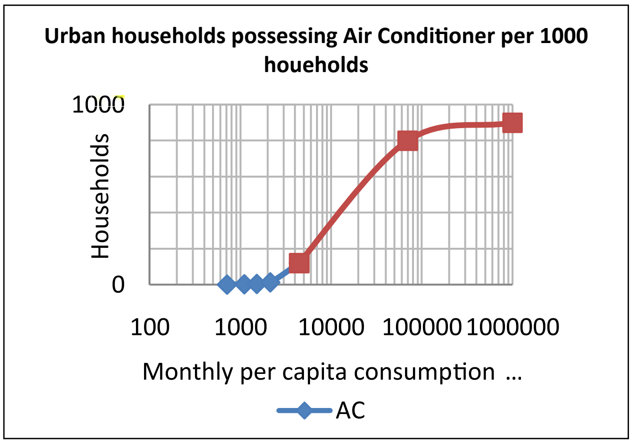


Figure U-4 Air Conditioner



To project the large increase in possession of appliances for the year 2030, the population belonging to different MPCE classes is taken from a simulation of the model described in Chapter 2. These are shown in Table 3.9

Table 3.8 Projected Households in 2021 and 2031 by MPCE

	2021				2031			
Class	**MPCE Rs**	**Millions of households**	**MPCE Rs**	**Millions of households**	**MPCE Rs**	**Millions of households**	**MPCE Rs**	**Millions of households**
1	324	1	378	1	588	0	735	0
2	559	7	812	6	588	1	833	2
3	1073	44	2051	29	1125	10	2158	16
4	1652	34	3779	17	1668	14	3811	14
5	2141	29	5266	12	2154	17	5289	12
6	2936	49	7411	15	2990	44	7478	20
7	4130	27	10454	9	4168	38	10502	14
8	5408	16	13905	7	5448	33	13968	13
9	7032	11	17822	4	7094	31	17865	8
10	11225	9	33947	8	12958	49	40184	27

Based on the MPCE, the corresponding values of households possessing the appliances are read from Figures R1 to R4 and U1 to U4. While households may possess more than one unit of appliance, an assumption is made to obtain a lower bound on energy saving, that only one unit of air-conditioner, refrigerator or TV will be working at a particular time. For electric fans, we assume more that than one unit may be operating. The numbers of units operating for each appliance type in households belonging to each MPCE class are given in Table 3.9.

Table 3.9 Number of Operating Units at a Time

CL	2030	TV	Fridge	Fan	AC	CL	2030	TV	F ridge	Fan	AC
RH1	588	1	1	1	1	UH1	735	1	1	1	1
RH2	588	1	1	1	1	UH2	833	1	1	1	1
RH3	1125	1	1	1	1	UH3	2158	1	1	1	1
RH4	1668	1	1	1	1	UH4	3811	1	1	2	1
Rh5	2154	1	1	1	1	UH5	5289	1	1	2	1
RH6	2990	1	1	2	1	UH6	7478	1	1	2	1
RH7	4168	1	1	2	1	UH7	10502	1	1	3	1
RH8	5448	1	1	2	1	UH8	13968	1	1	3	1
RH9	7094	1	1	2	1	UH9	17865	1	1	3	1
RH10	12958	1	1	3	1	UH10	40184	1	1	3	1

It is assumed that the bottom five classes will have a higher discount rate of 20 percent and a lower electricity rate of Rs. 4 per KWhr. The upper five classes will have a discount rate of 10 percent and electricity tariff of Rs. 6 per kWh. This will suggest the star rated appliances bought. Based on these assumptions, the electricity savings are worked out and shown in Table 3.10.

Table 3.10 Energy Saving by Appliances in 2030

Households	Appliance	Total no operated Millions	Life in years	Star rated	Energy saving (kwh/ product/ year)	Energy saving by star rated appliances (million kwh)	Energy used by non rated appliance (Million kWh)	Energy saved (per cent)
Bottom 5	AC	4	7	2*	415	1660	10400	16
	Refrigerator	26	10	3*	283	7358	18720	39
	Colour Tv	60	7	0	0	0	24000	0
	Ceiling Fans	94	10	0	0	0	21996	0
Top 5	AC	52	10	3*	567	29484	135200	22
	Refrigerator	161	10	5*	411	66171	115920	57
	Colour Tv	247	7	4*	71	17537	98800	18
	Ceiling Fans	585	10	4*	25	14625	136890	11
All						136835	561926	24

Thus, from labelling of these four appliances, the estimated saving of electricity consumption by households in the year 2030 is 136.8 billion units. In terms of percentage, it is 24 percent for the year 2030. We assume the same rate of savings from appliances other than those we have assessed here. Lighting consumes 8 to 10 percent of household electricity consumption in developed countries. If we assume that lighting can save 50 percent of electricity and non-lighting load saves 24 percent of electricity, the total savings would be:

0.9*24 + .1* 75 = 29.1 %

Therefore, 29.1 percent can be the savings in household electricity.

Based on the model used in Chapter 2, we have stipulated a reduction of approximately 30 percent for household electricity consumption, inclusive of both lighting and appliances for the year 2030.

3.3 Implications and Policy

The four appliances considered here, refrigerators, air conditioners, televisions and electric fans are major household electricity consumers. Electricity savings due to energy efficiency are projected from use of energy efficient household appliances based on estimates of ownership of appliances by households of total consumption expenditure classes by the National Sample Survey and NCAER. It considers the spread of different star rated labelled appliances over the past five years, assesses the economic attractiveness of the different star rated appliances, and uses the projections of income distribution from the macro-model of Chapter 2, to project ownership of appliances of different star ratings for the year 2030. A 24 percent savings in electricity consumption has been projected. These savings are based on no specific government policy except labelling of equipment and price of electricity at Rs. 6/ kWh for the richer and Rs 4/kWh for the poorer classes.

The analysis shows the effectiveness of the labelling programme. *We recommend that the labelling programme should cover more appliances and equipment with clear, easily understandable and informative labels. Efforts must be taken to create widespread consumer awareness.*

While private individuals and firms would make an economically rational choice, it is not easy for procurement officers of public sectors firms or government departments to do so. They are required to buy on the lowest first cost basis. *We recommend that government and public sector procurement officers should be empowered to purchase on life cycle cost basis by specifying appliance based price advantage that may be given for different star ratings. If necessary, the Financial Rules may also be suitably amended.*

References

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2. NCAER(2014): National Survey of Household Income and Expenditure (2010-11), NCAER New Delhi. Forthcoming.
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4 Energy Efficiency in Buildings

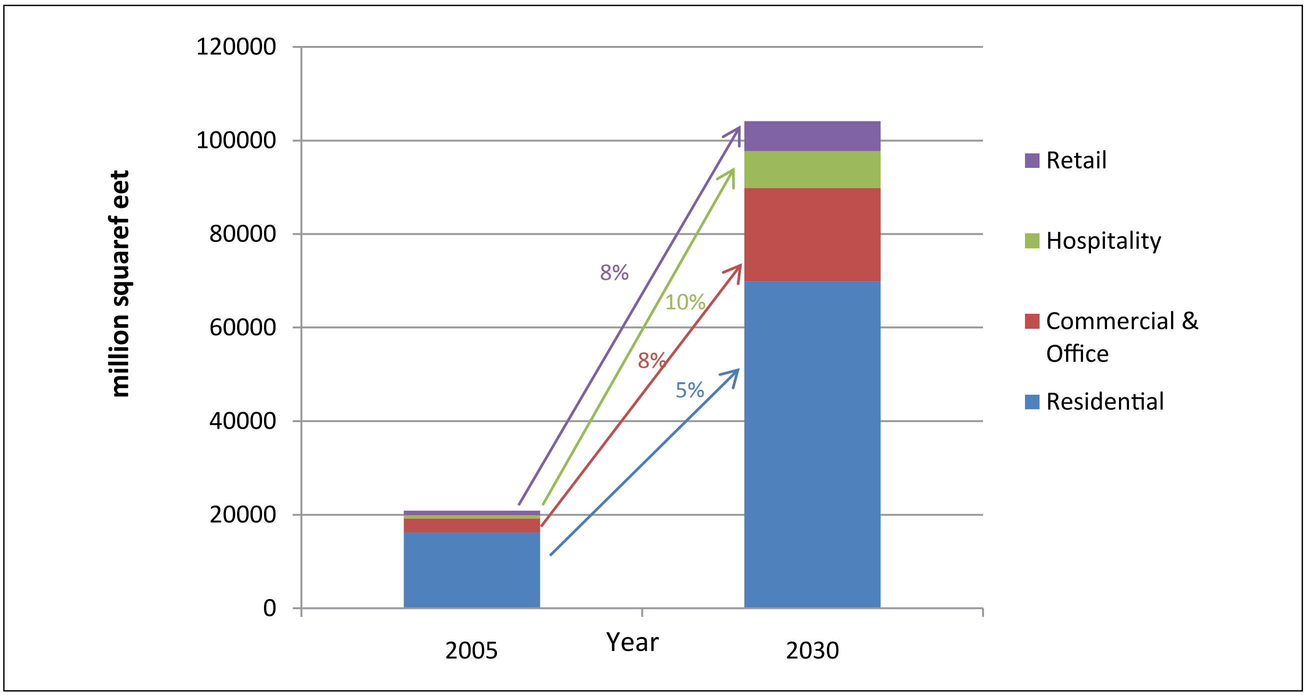
4.1 Energy Use in Buildings

Buildings consume a lot of energy. Energy efficiency in buildings is quite important. A combined application of structural design involving natural sunlight and appropriate orientation, insulation that is based on natural sources of cooling and heating can ensure saving of a substantial amount of energy. Appropriate management including automation systems may also be added to this gamut of applications for increasing savings. Several modern energy efficient commercial buildings use more efficient Heating Ventilation and Air Conditioning (HVAC) systems and also install renewable energy sources. Commercial buildings include offices, hospitals, hotels, retail outlets, educational buildings and public services including government offices. Here we deal with energy consumed in using these buildings. The energy embodied in construction of these buildings and structures is not considered in this section.

The residential and commercial sectors account for 29 percent of the total electricity consumption and is rising at a rate of 8 percent annually (CWF, 2010). A significant part of this percentage goes into heating, cooling and lighting.

Based on the growth rates of building space (CWF, 2010), areas of commercial building are projected for the years 2020 and 2070. These are show in Figure 4.1.

Figure 4.1 Growth of Indian Building Sector (CWF, 2010)

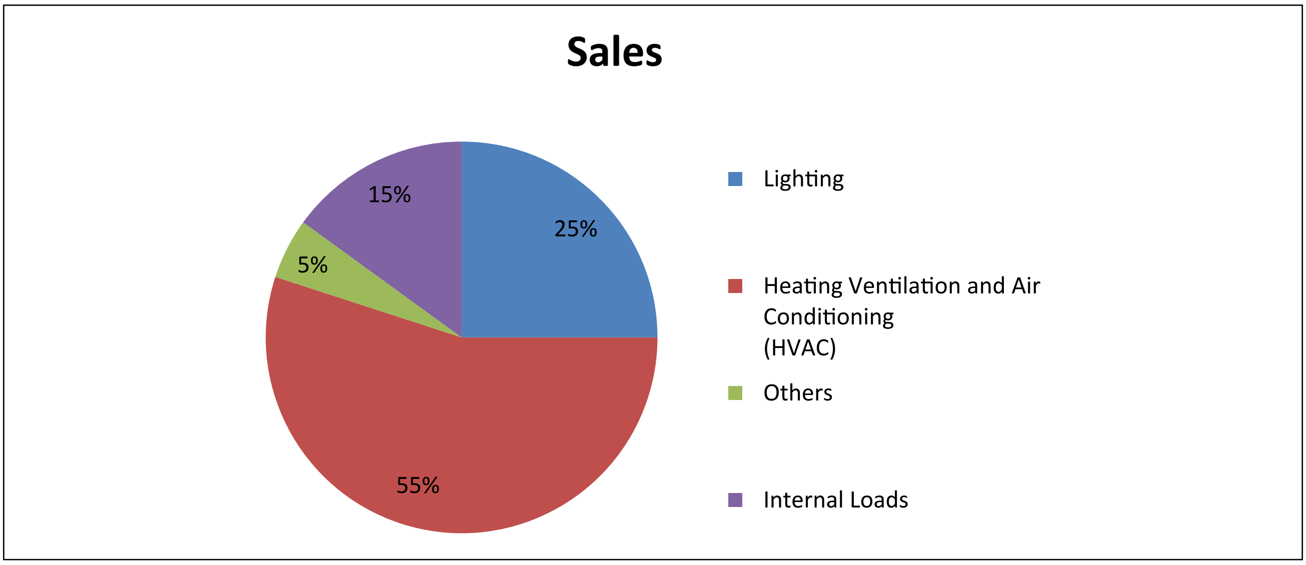


4.2 Commercial Buildings

Bureau of Energy Efficiency (BEE) in India developed an energy conservation building code (ECBC), for large commercial buildings having a connected load of 100 kW or contract demand of 120 kVA or more. It is mandatory in 7 states as of April 2014 and is expected that it would be made mandatory in all states over time. The services sector being the largest in the Indian economy and also the fastest growing makes this a measure of tremendous importance. New office buildings, mostly air conditioned are being built at a rapid pace.

The major energy consuming equipments in the commercial sector are: lighting – 25 percent, heating, ventilation, and air conditioning (HVAC) – 55 percent, and other office related equipment – 5 percent, see Figure 4.2.

Figure 4.2 Energy Consumption Distribution in Commercial Building (Bureau of Energy Efficiency)



Commercial buildings also use window air conditioners. In Chapter 3, we have estimated savings only for households' use of air conditioners, etc. Many of the commercial buildings have central air conditioning and chillers, whose efficiencies can also be improved. This as well as designs that increase day light and reduce need for day time lighting have not been accounted for in the power chapter; nor have been the gains from better insulation, plugging of leaks, and the use of natural ventilation or geo-thermal energy.

The baseline for CO_2 emissions for conventional buildings is estimated at 40,000 tonnes of CO_2 per million Sq.ft or 4, 30,570 tonnes of $C0_2$ per million Sq.m of building. At this rate the expected emissions from the commercial building sector in the absence of efforts to reduce energy consumption, will be 610 Mt of CO_2 in 2020 and 1,370 Mt of CO_2 in 2030.

4.3 Projected Savings

The following assumptions have been made while calculating the carbon abatement potential, by the years 2030. ECBC is applicable to 50 percent of total built-up space (as commercial buildings defined in EC Act shall have connected load of 100kW or contract demand of 120 kVA or more).

1. In order to meet the objectives of Twelfth Plan, it is considered that 75 percent of all new commercial buildings will be ECBC compliant and 20 percent of existing buildings stock would reduce their present energy consumption
2. Existing built-up space stock by 2030 includes existing built-up space stock by the year 2014, and 25 percent of new built-up space, which is assumed to be non-compliant to the ECBC code
3. Emission from Conventional Buildings = 0.04 Million Tonnes/ Million Sq.ft

Scenario considered for the year 2030:

- 80 percent of new built-up space compliant to ECBC save 25 percent of emissions

- 20 percent of the existing built-up space (i.e. existing built-up space by the year 2014 + 25 percent new built-up space non-compliant to ECBC)

Based on this, the projected emissions and abatement from commercial buildings were worked out in Table 4.1

Table 4.1: Projected Emissions from Commercial Buildings

Projected Up To 2020			
Sr. No.	**Particulars**	**Area Considered in (Million Sqft)**	**CO_2 Abated in (Million Tonnes)**
1	75% of ECBC applicable new commercial built-up space (being 50% of new built up space) compliant to ECBC save 25% of emissions	2,290	23
2	10% of the existing commercial built-up space (i.e. existing commercial built-up space by 2014 + 25% new commercial built-up space non-compliant to ECBC) are retrofitted and save 20% of emissions	526	4
3	10 % of existing commercial built-up space (i.e. existing commercial built-up space by 2014 + 25% new commercial built-up space noncompliant to ECBC) respond to market penetration of rating systems and save 20% of emission	526	4
		Total in 2020	**31**
Projections From 2020 to 2030			
Sr. No.	**Particulars**	**Area Considered in (Million Sqft)**	**C02 Abated in (Million Tonnes)**
1	80% of ECBC applicable new commercial built-up space (being 50% of new built up space)compliant to ECBC save 25% of emissions	7,629	76
2	20% of the existing commercial built-up space (i.e. existing commercial built-up space by 2014 + 25% new commercial built-up space non-compliant to ECBC) are retrofitted and save 20% of emissions	1,482	12
3	20 % of existing commercial built-up space (i.e. existing commercial built-up space by 2014 + 25% new commercial built-up space noncompliant to ECBC) respond to market penetration of rating systems and save 20% of emission	1,482	12
		Addition between 2020 and 2030	**100**
		2020	**2030**
	Predicted Commercial Areas in Million Sq.ft	**15,262**	**34,335**
	Emissions Mt of CO2 at 0.04 Mt / million Sq.ft	**610**	**1,371**
	CO2 emissions abated Million tons / year	**31**	**131**
	% Reduction	**5**	**10**

4.4 Experience with Building Codes and Rating

In the Interim Report, we had projected the reductions in emissions that may be realized based on certain assumptions. In order to see the realism of our assumptions, we look at the recent experience and the data available for some of the rated buildings. Three different rating systems by three different agencies use different criteria in India. Green building rating systems have recently become popular in India. The major green building rating systems currently operating in India are:

❖ The Bureau of Energy Efficiency (BEE) gives star rating to buildings as per their energy efficiency.

❖ Indian Green Building Council (IGBC) rates buildings as platinum, gold, silver and certified. The ratings take many sustainability characteristics in to account including minimum energy efficiency level of buildings and therefore, energy efficiency does not necessarily increase beyond certain minimum level, with rating.

❖ The Energy and Resources Institute (TERI) rates building as per its GRIHA system.

4.4.1 ECBC

Energy Conservation Building Code (ECBC), formally launched in May 2005, specifies the energy performance requirements of commercial buildings in India. ECBC has been developed by the Bureau of Energy Efficiency (BEE) and has been mandated by the Energy Conservation Act 2001. The code covers buildings with a connected electrical load of 100 kW or more.

The purpose of this code is to provide minimum requirements for the energy-efficient design and construction of buildings. It is planned that the code shall be mandatory for commercial buildings or building complexes. The Bureau of Energy Efficiency is the primary body responsible for implementing the ECBC; and it works towards policy formulation as well as technical support for the development of the codes and standards and their supporting compliance tools and procedures.

Rajasthan, Odisha, Andhra Pradesh, Punjab and Puducherry have notified ECBC; other states like Karnataka, Uttarakhand, Kerala, Gujarat Uttar Pradesh have amended ECBC; and states like Andhra Pradesh, Kerala, Gujarat and Punjab are in the process of amending and notifying the ECBC.

In order to create a market pull for energy efficient buildings, Bureau of Energy Efficiency (BEE) has developed a Star Rating Programme for existing buildings which is based on actual performance of the buildings, in terms of energy usage in the building over its area expressed in kWh/sq. m/year. The norms for different star ratings are given in Table 4.2.

Table 4.2 Star Ratings and Energy Use Intensity Norms by BEE

Climatic Zone	Composite	Warm and Humid	Hot and Dry	Temperate
A. Day Use Office building				
Less than 50 % air conditioned built up area				
1 Star	80-70	85-75	75-65	
2 Star	70-60	75-65	65-55	
3 Star	60-50	65-55	55-45	
4 Star	50-40	55-45	45-35	
5 Star	Below 40	Below 45	Below 35	
More than 50 % air conditioned built up area				
1 Star	190-165	200-175	180-155	
2 Star	165-140	175-150	155-130	
3 Star	140-115	150-125	130-105	
4 Star	115-90	125-100	105-80	
5 Star	Below 90	Below 100	Below 80	
B. Shopping Mall building				
1 Star	350-300	450-400	300-250	275-250
2 Star	300-250	400-350	250-200	250-225
3 Star	250-200	350-300	200-150	225-200
4 Star	200-150	300-250	150-100	200-175
5 Star	Below 150	Below 250	Below 100	Below 175

In addition to the Star rating scheme, BEE has a retroffiting programme based on Performance Contracting Energy Service Company (ESCO) model for existing government and commercial buildings.

4.4.2 Green Building Rating Systems

One of the major green building rating systems currently operating in India is the Indian Green Building Council (IGBC) rating system. To facilitate the adoption of green building practices relevant to the local climate and regional practices for various building types, IGBC has developed various rating programmes. These rating systems are voluntary, consensus based, market-driven and are designed to address national priorities.

The rating programmes developed by IGBC include IGBC Green Homes, IGBC Green Existing Buildings Operations & Management, IGBC Green Factory Buildings, IGBC Green SEZs, IGBC Green Landscapes, IGBC Green Townships, IGBC's rating for commercial buildings.

Over 2,272 green building projects amounting to 1,715 million sq. ft. are coming up under five climatic zones of country. The various building types covered under IGBC Green Building rating systems include office buildings, IT parks, hotels, airports, hospitals, educational institutions, factory buildings, residential buildings, indoor stadiums, SEZs, townships etc.

Though green building rating takes in to account many attributes of sustainability other than energy use intensity, reduction in energy roughly corresponds to ratings as given in Table 4.3.

Table 4.3 Energy Use Reduction in Green Buildings

Green Building Rating Level	Number of Buildings rated	Built-up area (in sq.m)	Energy reduction
Platinum	109	2,121,060	**40-50%**
Gold	212	7,607,925	**30-40%**
Silver	54	10,12,076	**20-30%**
Certified	25	267,124	**15-20%**

4.4.3 GRIHA of TERI

Energy savings in some GRIHA rated buildings is shown in Table 4.4. It is seen that 30 percent reduction in energy is a conservative number.

Table 4.4 Energy Use norms for GRIHA rating

Level of Star Rating	Number of Building Rated	Build Up Area in Square Metres	EPI Reductions (%)
5 Star	6	261120	41-64
4 Star	4	117898	30-56
3 Star	4	134644	32-57
2 Star	3	1630800	12-73

4.4.4 Experience of Energy Saving

Experience with few large rated buildings by IGBC is summarized in Table 4.6. These buildings show energy savings in addition to ECBC-ASHRAE compliant buildings of 19 to 60 percent. No systematic study of savings from the shell of the building is available. It is estimated by experts to be between 12 to 30 percent.

The energy saving that can be expected from green buildings, including from energy efficient equipments is at least 30 percent, which has been taken in the model of Chapter 2. It is seen that when firms take interest in energy efficiency, the savings can be much more than the 30 percent assumed in the projections.

Table 4.5 Energy Savings in Green Buildings

Name	Location	Year	Built-up area (sq.m) excluding parking	Rating Achieved	Actual Energy Consumption (kWh)	% Energy savings over buildings designed as per ECBC / ASHRAE	Energy Saving (Tonne of Oil Equivalent)	Comments
Corporate office buildings								
CII-Green Business Centre	Hyderabad	2003	1,850	Platinum	1,60,000	54%	16.34	25% of energy is through solar energy.
Suzlon One Earth	Pune	2010	70,891	Platinum	49,55,941	33%	212.23	250,000 kWh / annum of energy generated through onsite wind-solar hybrid renewable systems
Bayer's EcoCommercial	Noida	2012	883	Platinum	76,100	40%	4.37	Net-zero energy building. 100% energy requirement met through onsite solar PVs
Spectral Services Consultants Office	Noida	2007	1,394	Platinum	1,95,224	49%	16.13	
ITC Green Centre	Gurgaon	2004	15,794	Platinum	19,31,600	45%	134.86	
CII Suresh Neotia Centre of Excellence for Leadership	Kolkata	2009	3,103	Silver	2,06,965	45%	14.47	
Enercon India Pvt Ltd	Mumbai	2008	3,475	Gold	7,11,504	23%	18.35	100% power is through off-site wind energy
Tech Parks								
SDB I, Infosys, Pocharam	Hyderabad	2012	24,730	Platinum	19,32,017	60%	251.77	Radiant cooling technology installed to reduce air-conditioning load
Wipro Limited	Gurgaon	2005	16,854	Platinum	34,34,096	28%	117.45	
GE India Technology Centre 'Phase V'	Bangalore	2009	30,606	Gold	44,64,700	19%	90.34	
Olympia Tech Park	Chennai	2007	1,67,225	Gold	3,17,14,354	23%	818.08	
Hotels								
ITC Gardenia	Bangalore	2009	67,379	Platinum	89,14,407	35%	411	
Hospitals								
Kohinoor City Hospital	Mumbai	2009	21,137	Platinum	33,63,739	38%	180.36	Medical equipment load very high

A detailed modeling study, see Box 4.1, carried out for different types of building sin Jaipur confirms this.

Box 4.1 The MNIT Jaipur Study

The study conducted by MNIT Jaipur on six different types of existing buildings concluded that there is a vast potential for energy savings through implementation of ECBC in the country. The study was conducted through simulation models developed taking details of six different types of buildings including hotel, retail mall, hospital, institutional building, private office building and government office building located in Jaipur, and examining through modelling, the potential of energy savings through adoption of ECBC in these six buildings. It was observed that different buildings have different energy saving potential depending on the construction specifications, usage, systems and equipment installed, conditioned area and other factors. Analysed buildings show the energy savings potential ranges from 17 to 42 percent. The study also indicates that there exists further more potential for energy saving through adoption of advanced energy conservation measures; however, it might not be financially attractive for the general public at this stage due to their economy of scale.

In the prescriptive option of compliance, the code also provides a well formulated trade-off option for removal of costly provisions for building envelope against better performance of cheaper energy saving measure for the building envelope. For example, insulation on wall, if found costly or eating up commercially usable space, can be traded-off against better use of shading devices, or glass specifications or roof insulation, and vice versa.

Even if the building is built using prescriptive specifications of the code, and without using the simulation or trade-off method, the incremental cost of the building is likely to be up to 15 percent over common practice case. The resulting energy savings in most cases, offer a payback period of 2 to 4 years over the investment.

4.4 Retrofitting

In addition to new buildings, retrofitting of old buildings also offers substantial scope for energy saving experience shows many options with payback period of two years. (See Box 4.1 examples of retrofitting of old buildings in Mumbai). A special window should be opened in housing finance companies and banks to provide loans to ESCOs and owners for retrofitting of buildings. One can also set up a Carbon Trust type agency that prepares project reports and finances retrofitting.

Box 4.2 Retrofitting Existing Buildings for Energy Efficiency

The Bureau of Energy Efficiency (BEE), "Star Rating" system is based on the use of electricity per m2 per year or an Energy Performance Index (EPI). The "star rating" depends on the location of a city and its humidity levels. For Mumbai, a building that uses 200 kWh/m2/yr gets "1 Star".

The ratings go to 2, 3, 4 and 5 as the EPI values drop to 175, 150, 125 and 100 kWh/m2/yr. The examples below show that retrofitting old buildings can save energy and make economic sense.

Bombay House, Mumbai

The headquarters of Tata Group, Bombay House in Mumbai, built in 1924, began with energy audit and followed it up to implement several efficiency measures.

After the first audit in 2010, the EPI was found to be 172 kWh/m2/year enabling Bombay House to get a rating of 2 Star. The following modifications were carried out:

1) Old Chillers and pumps were replaced by energy Efficient machines
2) Energy efficient T-5 lamps with electronic ballasts were installed in 90% areas
3) Variable Frequency Drives (VFD) were installed on Cooling Water pumps
4) Individual Energy metering is done for 90% offices in the building
5) A Building Management System (BMS) was installed and is operational

With these modifications, the EPI has dropped to 145 kWh/m2/yr. Thus Bombay House is eligible for a "3 Star" rating from BEE. The estimated expenses for the modifications were around Rs 35 Lakh but they are saving an estimated 1, 40,000 kWh/yr. The payback period for this investment will be 2 years since the electricity tariff at Bombay House will be around Rs 12.5/kWh over the two year period. Bombay House is pursuing further savings to obtain eventually a 5-star rating and bring down in EPI to 100 kWh/ m2/yr.

Godrej Bhavan, Mumbai

Just two years after the company Godrej & Boyce upgraded its six-story building built in 1970, electricity costs have plummeted by 28 percent, while total electricity use has dropped by 12 percent. The company stands to recover the costs of its energy-efficiency retrofits (INR 5,384,000) in as little as 4.7 years. The building will start accumulating savings and 15 years after the 2010 upgrade, Godrej & Boyce could realize up to 6,980,000 in electric bill savings

The upgraded HVAC system alone represents an average of 32 percent in the overall electricity savings for FY 2010-2012. This new system, equipped with a screw chiller, water-cooled condenser, and electronic expansion valve, has a double coefficient of performance (COP) of 5.5, compared to the former 35-year old direct-expansion unit with 2.2 COP. Elsewhere in the building, high-efficiency T-5 fluorescent tube lamps and increased natural lighting improve lighting efficiency. Double-glazed clear windows and shading devices also reduce heat. With the newly installed Building Energy Management System, the building's maintenance managers can now track and adjust electricity usage for maximum efficiency.

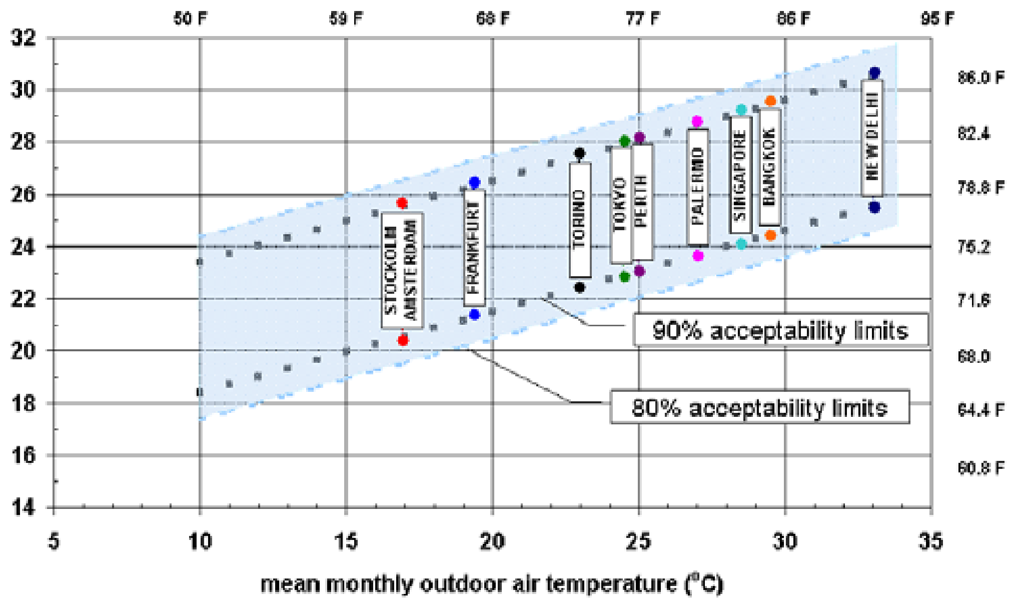
4.5 Implications and Policy

As mentioned in the first part of this section, BEE in India has enacted an energy conservation building code (ECBC), which is mandatory for large commercial buildings. It has been mandatory in 7 states as of April 2014 and 16 more states are in the process of enacting legislation to do so. The boom in the service sector has created a large requirement for office space and many air conditioned buildings are being built at a rapid pace.

In addition to new buildings, retrofitting of old buildings also offers substantial scope for an energy saving experience with many options providing a payback period of two years. The challenge is to have policy measures that encourage builders and owners to take the required measures.

Central Government and some State Governments have decided to have all their buildings ECBC compliant and also retrofit their existing buildings.

Figure 4.5 Source: ASHRAE 55-2004,



To promote uptake of green and energy efficient building standards by others requires first that owners are incentivised.

Property tax rebate may be offered. However, how does one make sure that this is not claimed without complying with the ECBC code? Building codes are implemented by local municipal authorities and they may be subject to various pressures.

One way would be to insist that the municipal authority incorporates ECBC code in the municipal bye-laws and that it obtains a BSS certificate saying that it has appropriate mechanism for certification in place. In turn the municipality could be incentivized by insisting on such certification as a precondition to releasing funds under JNNURM.

The problem with residential buildings as also with some commercial property development is that the builders and eventual tenants or buyers have split incentives. Since tenants or buyers want a low upfront cost, builders have little incentive to invest more in building a green building.

Even more effective could be quickening the process of approval of building plans and reducing the cost of obtaining building permits. The hidden costs of delays for builders and tenants are large and these may prove adequate incentive to go for green buildings. Once again making sure that local authorities have the needed mechanism in place to do this effectively becomes important.

Among the barriers that need to be removed are knowledge gaps about green building technologies among builders, architects and users as well as poor availability of needed building materials. For this:

- *Promote training programmes and knowledge dissemination about green building technologies, materials and advantages.*
- *Strengthen the supply chain of green building materials.*

Some large private firms are also retrofitting their buildings. The difficulty will be with smaller establishments. For them finance for retrofitting existing buildings may be a problem. To overcome *it a special window should be opened in housing finance companies and banks to provide loans for retrofitting of buildings.*

One can also set up a UK's Carbon Trust type agency that pays up front to prepare project reports and recovers the cost if the project is implemented and finances retrofitting.

Apart from ECBC compliant buildings, a measure that can significantly reduce energy consumption is following Japan's lead. Today in India, many offices, hotels, conference rooms, and auditoriums are usually chilled to uncomfortable degrees.

We recommend that law should stipulate that in public places including offices, the AC temperature should be set between 25 and 27 degree Celsius.

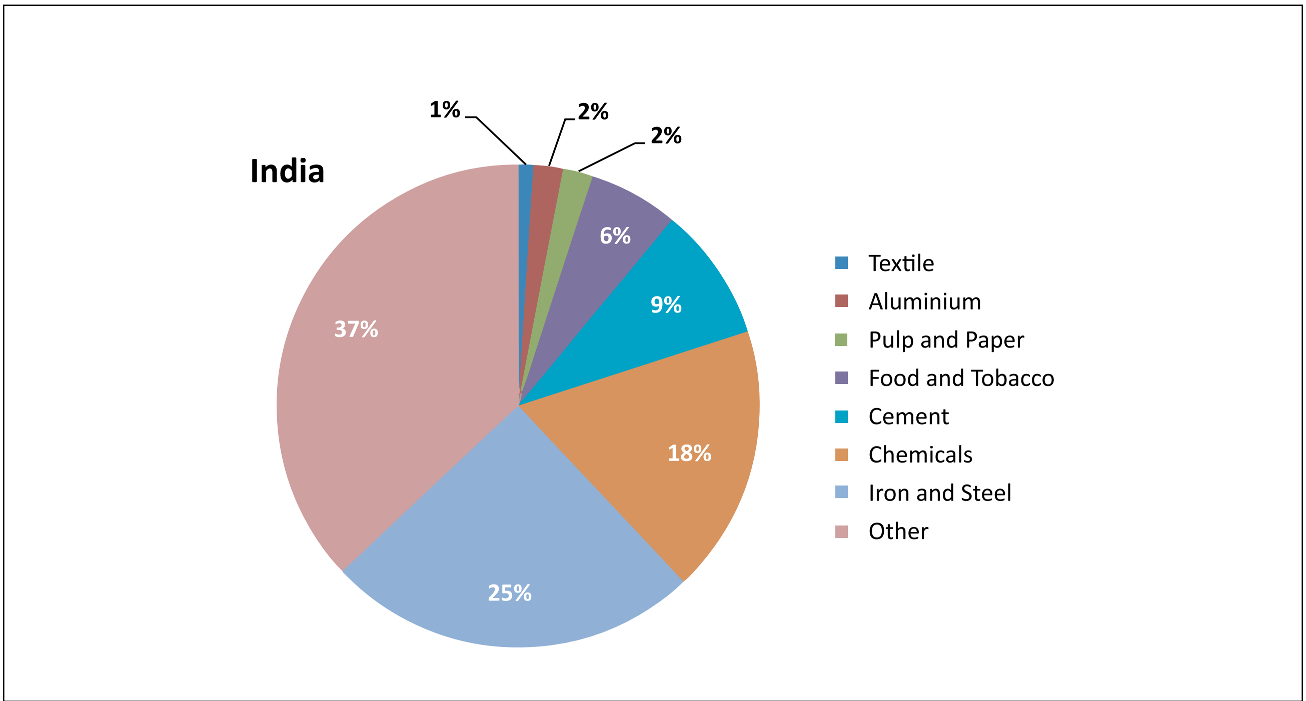
Providing fiscal incentives for developers in the form of additional Floor Area Ratio (FAR), reduced property tax and reduced stamp duty for green buildings can reduce any additional cost of complying with green building standards. Financial incentives for end users in terms of reduced interest on loans for green/energy efficient buildings have been used in other parts of the world and can be applied in the Indian context.

5 Energy Efficiency in Industry

5.1 Introduction

The macro model considers several Autonomous Energy Efficiency Improvement (AEEI) options in the transition from the Baseline Inclusive Growth (BIG) to Low Carbon Inclusive Growth (LCIG) scenario. The resulting analysis indicates a reduction in 63 billion kWh of electricity, 741 MT of coal, 3 MT of petroleum products and 7 billion cubic meters of natural gas. Thus, there is considerable scope for energy savings in industries. There are eight energy intensive sectors including thermal power plants, which collectively consume 156 Mtoe. Figure 5.1 shows the sectoral share of total industrial energy consumption in India. Cement, chemical, and iron & steel sectors are the most energy intensive industries. In this report, we have mainly focused on the technology policy interventions for these two sectors.

Figure 5.1: Industrial Energy Consumption (2009), India (150 MTOE)



5.2 Iron and Steel Sector

The iron & steel sector is one of the most energy intensive manufacturing industries, consuming about 25 percent of the total industrial energy consumption (IEA, 2011) and accounting for about 117.32 Mt CO_2 emissions in 2007 (MoEF, 2010). Figure 5.2 illustrates the projected estimates for the year 2020. The industry could reach production levels of 136 Mt with a capacity of 165 Mt.

Figure 5.2: Projected Capacity and Production (2011-2020)

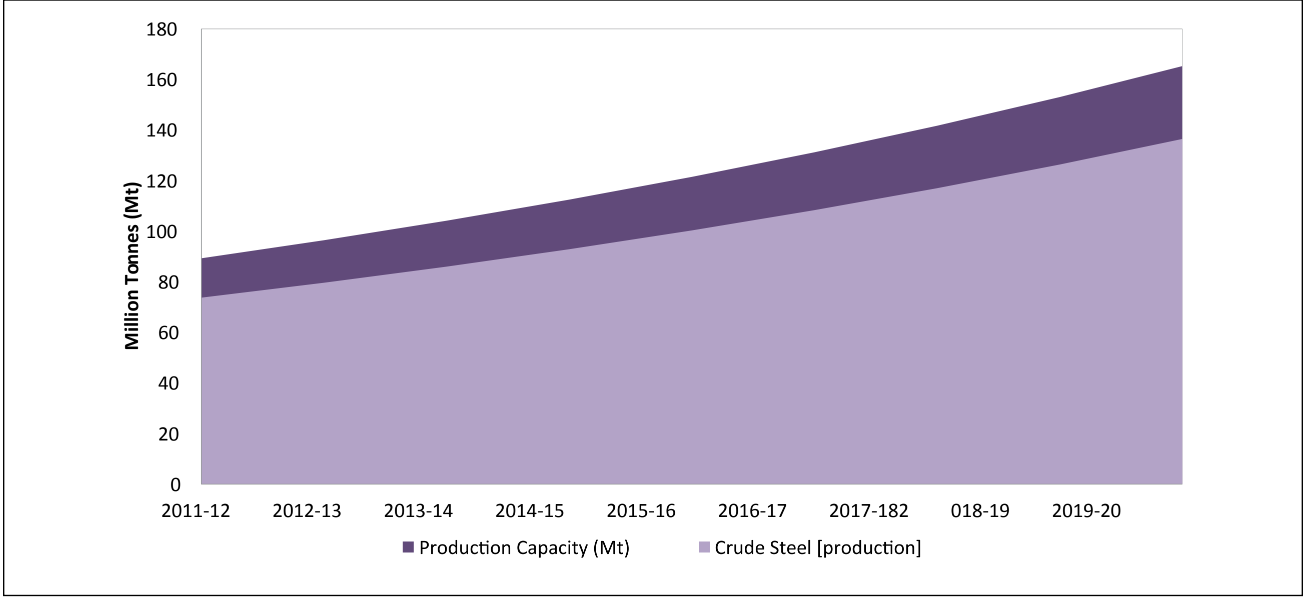
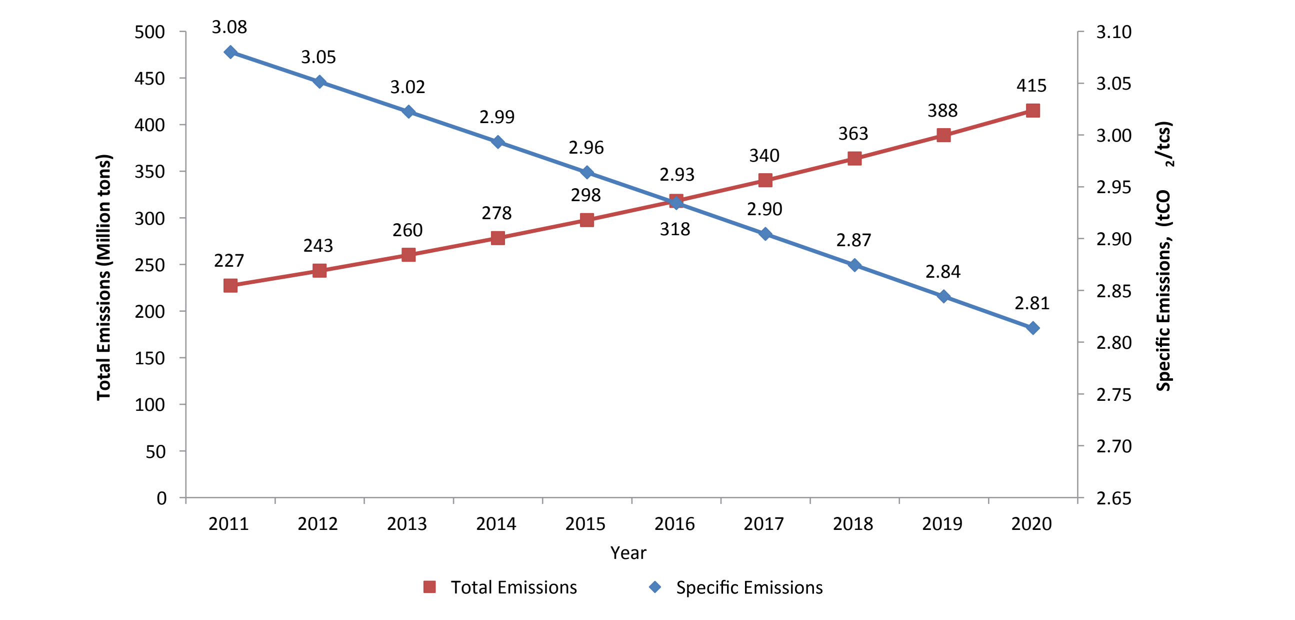


Figure 5.3 illustrates the expected trend of total emissions and specific emissions in the Indian steel industry, along the projected crude steel production. If the projected steel production trend is followed as shown in Figure 5.2, the total emissions could increase from 227 to 415 Mt.

Figure 5.3: Total and Specific Emission of Indian Iron & Steel Industry



The National Steel Policy has developed a roadmap for the Indian steel industry with the objective of attracting domestic and foreign investments. Its target is to reach crude steel production capacity of 300 Mt with a production level of 275 Mt by 2025-26[1].

[1] National Steel Policy 2012

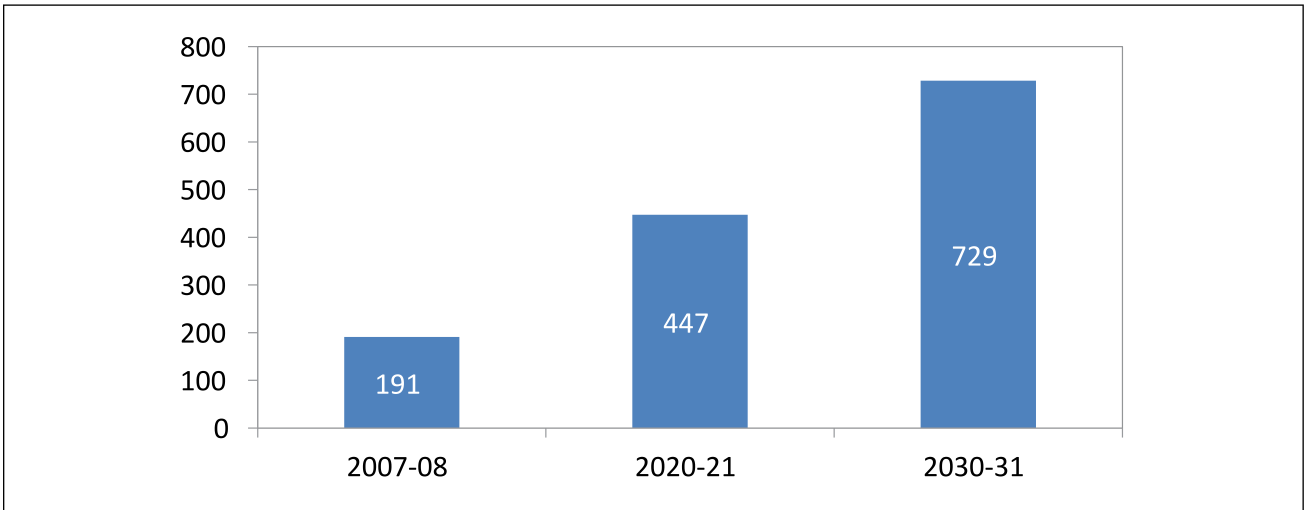
Table 5.1: Strategic Goals for Indian steel industry

Parameter/Area	Unit	Existing Level	Strategic Goal/ Projection by 2025-26
Specific Energy Consumption	GCal/tcs	6.3	4.5
CO2 emissions	tCO2/tcs	2.5	2.0
Material Efficiency	percent	93.5	98.0
Specific Make up Water Consumption (Works excluding power plant)	T/tcs	3.3	2.0
Utilization of BOF slag	percent	30	100
Share of continuous cast production	percent	70.0	95.0
BF Productivity	T/m3/Day	1.9	2.8
BOF productivity	No. of Heats/		
Converter/year	7800	12000	
R&D expenditure/turnover	percent	0.2	1.5

5.3 Cement Sector

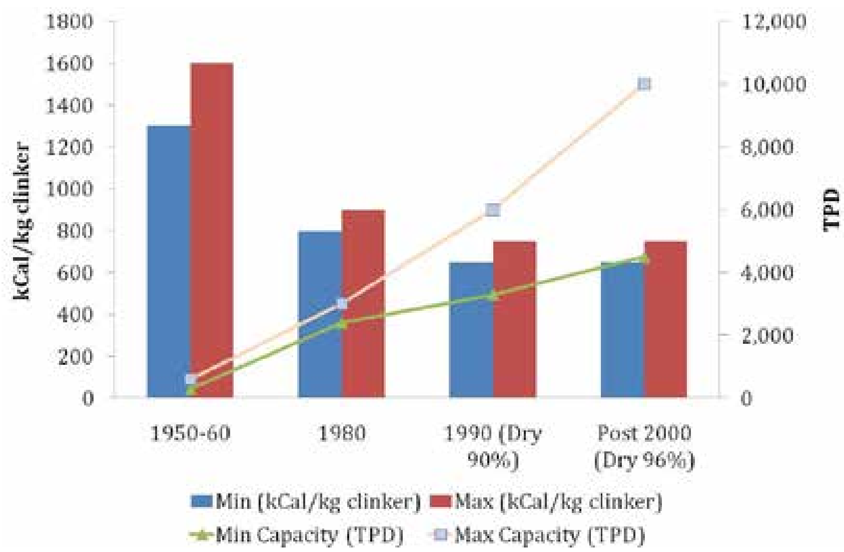
India is currently the second largest cement producer in the world. India's per capita consumption of 150 kg in 2008 was about a third of the world average (Planning Commission, 2007). However, with a construction boom and infrastructure development, this number is poised for a steady growth. Most of India's cement plants are energy efficient. However, the presence of several smaller units with high Specific Energy Consumption (SEC) raises the country's average SEC. Figure 5.4 illustrates the production estimates till 2030.

Figure 5.4: Cement Production Estimates (million tonnes)



The minimum and the maximum values for the specific energy consumption (SEC) from 1950-60 to post 2000 are illustrated in Figure 5.5.5. During 1950 – 60, wet process was the predominant technology. This was gradually replaced by Dry Process. In 1980, several cement plants had a Dry-4 Stage Preheater (PH) and Precalciner (PC) installed with the Dry process. In 1990, Dry-5/6 Stage PHs/PCs, Vertical Roller Mills (VRM) & Pre-grinders, and advanced coolers had been installed in a few plants (dry process in 90 percent of plants). Post 2000, double-stream PH, pyrostep coolers, high pressure grinding rolls, advanced kiln control system and Information Technology (IT) based plant operation were in place in some of the cement plants. Moreover, 96 percent of the plants were based on the dry process. These innovations in technology have enabled India to progressively reduce its energy intensity in the cement sector.

Figure 5.5: Historical thermal SEC over the last six decades



5.4 Energy Efficiency Interventions

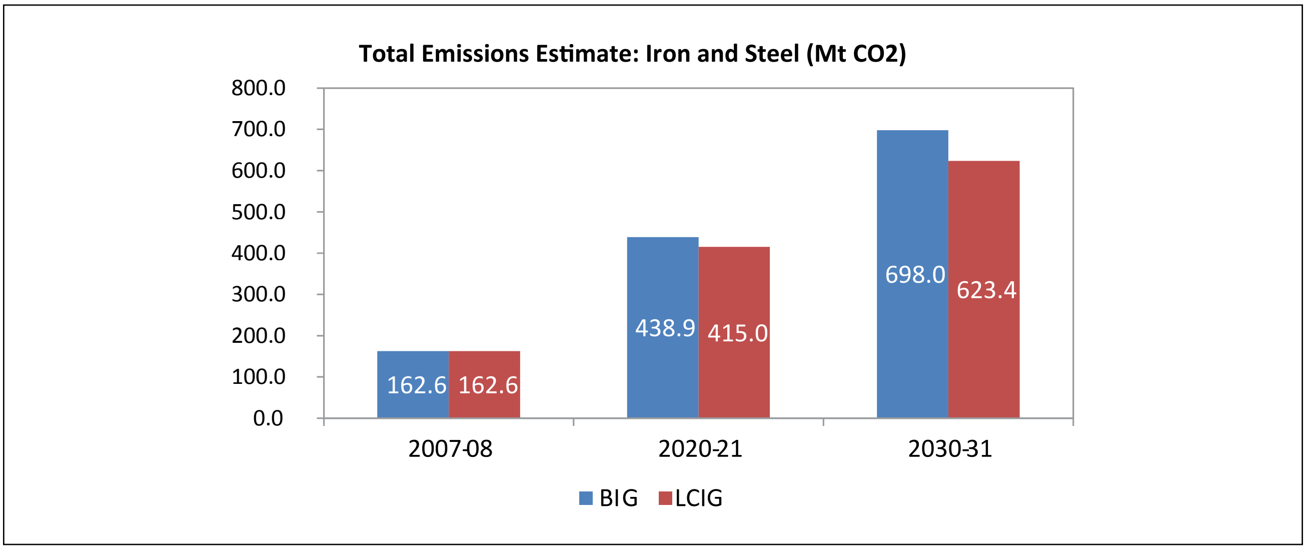
5.4.1 Iron and Steel Industry

Steel is predominantly manufactured by blast furnace and direct reduction routes. The primer is treated with oxygen based furnace to produce steel. It later requires electrical furnaces producing specialised steel by mixing with scrap and other alloys. There are several possible energy efficiency intervention options in steel industries such as the following.

- *Coke Dry Quenching (CDQ):* This measure is an alternative to traditional wet quenching of coke. It mitigates emissions, reduces dust and provides the ability to recover sensible heat.
- *Injection of Pulverized Coal into Blast Furnace:* Pulverized coal injection is a process in which fine granules of coal are blown in large volumes into the blast furnace; this intervention saves part of the coke production, thereby saving energy and reducing emissions and maintenance costs.
- *Top Pressure Recovery Turbines:* Electric power can be generated by employing blast furnace top gases to drive a turbine-generator. Although the pressure difference over the generator is low, the large gas volumes can make the recovery economically feasible.
- *Recovery of Blast Furnace Gas:* Blast furnace gas can be cleaned and stored in a gasholder for subsequent use as a fuel or alternatively to generate electricity in a gas turbine. It is often enriched with coke oven gas or natural gas prior to use as fuel.
- *Preheating of Steel Scraps:* Using this technology can reduce the power consumption of EAFs through using the waste heat of the furnace to preheat the scrap charge. Old bucket preheating systems had various problems, e.g. emissions, high handling costs, and a relatively low heat recovery rate. Modern systems have reduced these problems, and are highly efficient.

The projected emissions for cement and iron and steel sectors under BIG and LCIG scenarios are provided in Figure 6 below. The projections illustrate that in iron and steel industries, 23.9 $MtCO_2$ could be mitigated by 2020 and 74.6 $MtCO_2$ by 2030.

Figure 5.6: Iron and Steel Emissions 2030



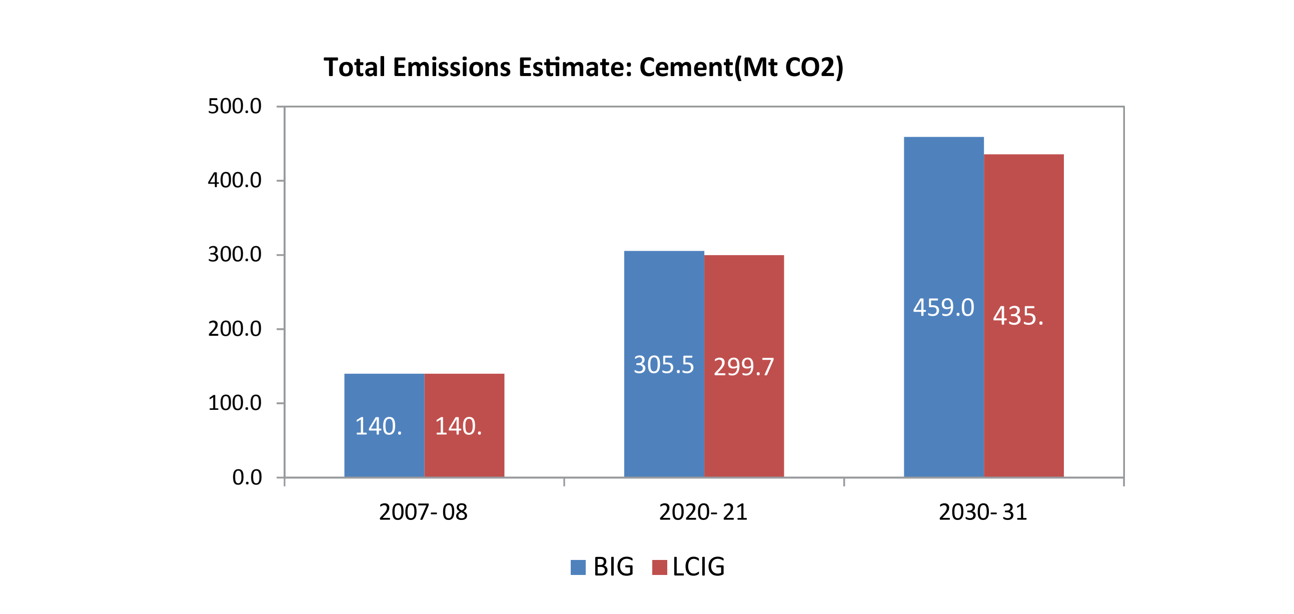
Similarly in the cement sector, from the baseline, about 5.8 and 23.3 $MtCO_2$ is expected to be avoided during 2020 and 2030 respectively.

5.4.2 Cement Industry

Cement manufacturing is a linear operation. The process largely involves making clinker from lime stone by heating it in a rotary kiln, and later mixed with additives and ground to a fine powder. Following are a few important energy efficiency measures implemented in a typical cement plant

- *Replacement of the existing fan with high efficiency fans:* There are numerous fans in a typical cement plant, and these consume large amounts of energy. Replacing these with efficient fans leads to significant energy savings.
- *Use of high efficiency crushers before the cement mill grinding:* This option leads to reduction in power consumption. Large boulders of clinkers or raw materials, which may end up in the rolling mills could consume more time to crush into powder. If a crushing mechanism is placed before the fine grinding, it leads to saving energy and time.
- *High level control system for kiln operations:* The kiln is an important equipment in a cement plant. The steady and controlled operation of the kiln is essential for producing a good quality clinker, higher level of output and lower energy consumption.
- *Reduction of RPM (Rotation Per Minute) of the Centrifugal Silo:* Optimise the air supplied to the CF silo for aeration and avoid / minimise venting of air by reducing rpm of the blowers.
- *Installing high efficiency fans at the clinker cooling section:* This intervention helps in reducing the temperature of the hot clinker faster. Additionally, this intervention could be coupled with a venting system for displacing air through a wider area.
- *Increasing the grinding chamber size:* This design intervention could take more quantity of clinker at a time for crushing and hence yield more production output.
- *Replacement of the air-lift with bucket elevator for raw metal transport to the silo:* This technology intervention eliminates the large compressor load and reduces displacement of particulate matter in the atmosphere.

Figure 5.7: Cement Sector Emissions 2030



5.5 Implications and Policy

National Manufacturing Policy – In 2011, India announced its national manufacturing policy with an objective to enhance the share of manufacturing in GDP to 25 percent with an additional job creation for 100 million. The policy encourages Public Private Partnerships (PPP) with an incentivised approach for large infrastructure projects, adopt cluster level model of self-regulation, instrumentally under National Investment and Manufacturing Zones (NIMZs).

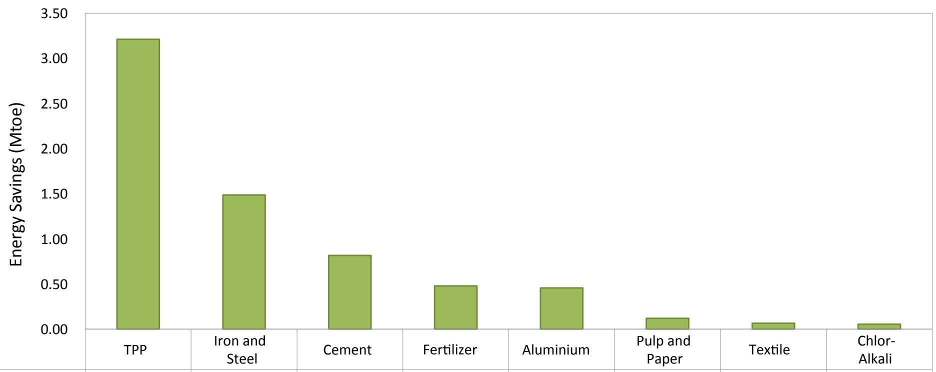
National Mission on Enhanced Energy Efficiency (NMEEE) – Under the National Action Plan for Climate Change (NAPCC), NMEEE is one of the eight missions. The objective of this mission is to perform energy conservation and mitigation of GHG emissions activities with a market based approach, allowing cost-effective technological strategies. NMEEE has four broad initiatives to include:

- *Perform Achieve and Trade (PAT):* A market based mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded.
- *Market Transformation for Energy Efficiency (MTEE):* Accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable.
- *Energy Efficiency Financing Platform (EEFP):* Creation of mechanisms that would help finance demand side management programmes in all sectors by capturing future energy savings.
- *Framework for Energy Efficient Economic Development (FEEED):* Developing fiscal instruments to promote energy efficiency

About 478 industrial units were notified as Designated Consumers. An estimated cumulative energy savings of 6.686 Million tonne of oil equivalent (Mtoe) is expected in the first round of PAT cycle by 2015.

Figure 5.8 illustrates the energy savings expected to be achieved from each sector and the baseline SEC of each sector.

Figure 5.8: Summary of Sectoral Energy Savings from First PAT Cycle



	TPP	Iron and Steel	Cement	Fertilizer	Aluminium	Pulp and Paper	Textile	Chlor-Alkali
Savings (Mtoe)	3.211	1.486	0.8160	.478	0.456	0.1190	.066	0.054
BL-SEC (toe/t)		0.549	0.088	0.394	2.005	0.656	0.166	0.393
Numbers of DCs	144	67	85	29	103	1	90	22
MAEC (toe)	30000	30000	30000	30000	7500	30000	3000	12000
Baseline Energy Consumption (Mtoe)	104.1	25.321	5.01	8.27	.71	2.09	1.2	0.88

The small and medium enterprises (SMEs) are not covered by the PAT scheme. Some of these SMEs are located in clusters. The BEE is examining some 25 clusters to see how these SMEs can be incentivized to improve energy efficiency. The SME program has an objective to improve the energy intensity in the SME sector, accelerate the adoption of energy efficient technologies, monitor and evaluate the practice at 25 manufacturing clusters across India. The main project activities are: energy use and technology analysis, capacity building, implementation of EE measures and facilitation of innovative financing mechanisms.

Currently PAT has focussed on eight energy intensive sectors. PAT initiative needs further enhancement in terms of

Widening by sectors: Inclusion of more additional sectors such as petroleum, sugar, glass, chemicals etc.

Deepening the sector: Identify more industrial units in the existing sectors and encourage them to take benefits from PAT framework. A study by Center for Study of Science, Technology and Policy (CSTEP) evaluated more than 1300 potential industrial units across six energy intensive sectors. The study estimated the likely savings that could be achieved in the next round of PAT Cycle.

Utilisation of waste/by products: Fly ash generated from power plants could be effectively utilised in cement manufacturing as a form of compound mixture. Similarly, blast furnace slag from steel industry is also one of the wastes which has potential in cement industry as well. Better policy addressing effective waste utilisation could be framed to suit specific industry.

Monitoring and evaluation mechanism: The improvements in energy efficiency by using technology need to be closely monitored and evaluated by placing an organised audit mechanism. The process and results eventually helps in benchmark the performance of equipment, process, and industry.

Considering the various challenges in implementation of the PAT scheme, in particular with the SME sector, a carbon tax could be another policy option to reduce emissions from industries. It can be gradually introduced by having fuel prices that reflect opportunity costs including the cost of CO2 initially priced at a modest level. Many studies have shown that there exist, economically justifiable opportunities for energy saving. Despite these, firms do not go for them. The barriers to seizing such opportunities are often perceived risks and availability of up front finance.

A mechanism needs to be set up to deal with these barriers. The UK has set up a fund, called

Carbon Trust, which takes care of these concerns. It gets, at its own cost, firm specific project reports which are prepared by hiring Expert Energy Service Companies (ESCOs) for improving energy efficiency. If a firm agrees to implement the project, the Carbon Trust also arranges finance. On successful completion, it charges the firm for the cost of project preparation. This mechanism has been quite successful. Enabling a similar fund to encourage and facilitate SMEs to increase their energy efficiency in addition to promoting energy efficiency in buildings could prove beneficial.

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2. MoEF. *India: Greenhouse Gas Emissions 2007. 2010.*
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6 Transport

6.1 Source of Growing Emissions

Transport is a key driver of economic growth and social development of a country. The sector is however a major energy consumer. It accounts for more than half of India's total petroleum consumption and more than 25 percent of the overall energy needs (second only to industry) (MoSPI, 2013). It is also a significant contributor to the emissions generated by the country, accounting for about 13 percent of the emissions from the energy sector. Greenhouse gas (GHG) emissions from the sector amounted to about 142 million tons of CO_2 eq in the year 2007 (Table 6.1).

Table 6.1: GHG Emissions from Transport Sector in 2007 (Mt)

Sector	CO2	CH4	N2O	CO2 Equivalent
Road Transport	121.21	0.02	0.01	123.55
Railways	6.11	0.00	0.00	6.84
Aviation	10.12	0.00	0.00	10.21
Navigation	1.42	0.00	0.00	1.43
Transport	138.86	0.02	0.01	142.04
Total (Energy)	992.84	4.27	0.06	1100.06
Grand Total (CO2 equi.)	1497.03	20.56	0.24	1727.71

Source: (MoEF, 2010)

Figure 6.1: GHG Emissions from Transport Sector in 2007 (Mt)

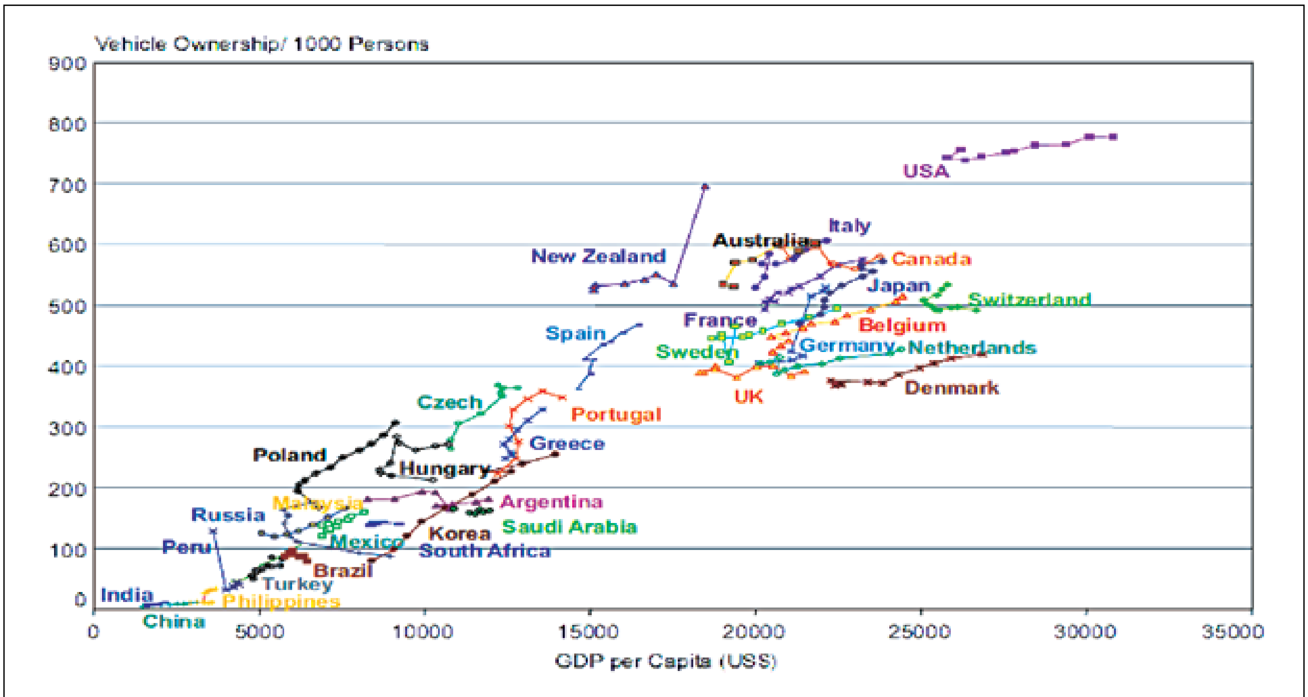
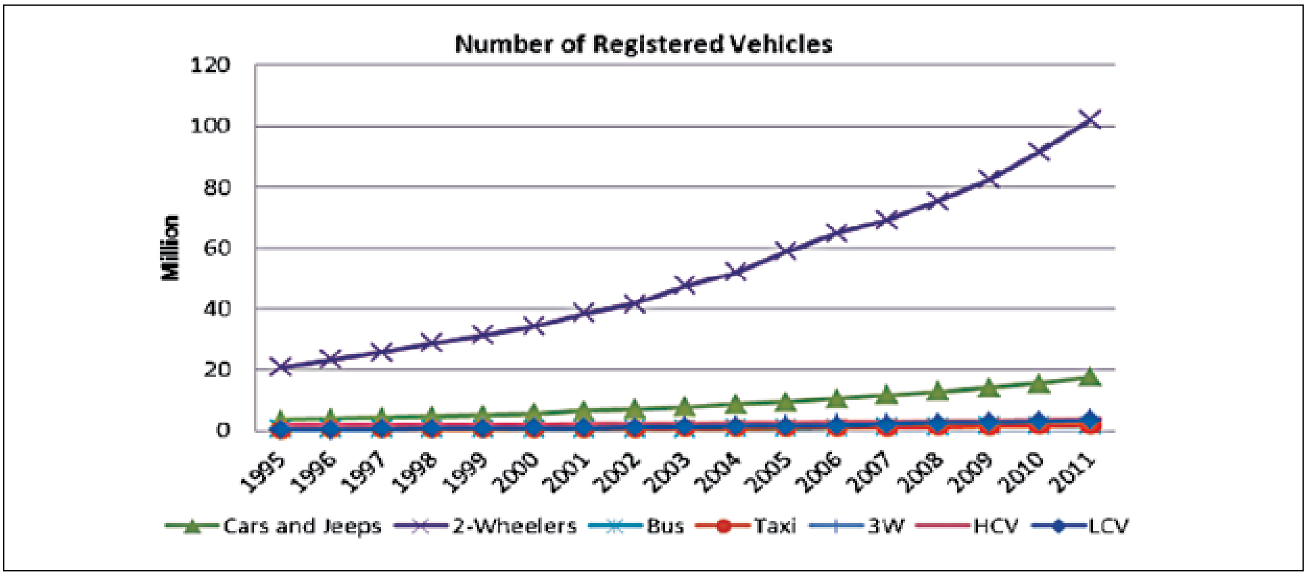


Figure 6.2: Growth in the Number of Registered Vehicles in India

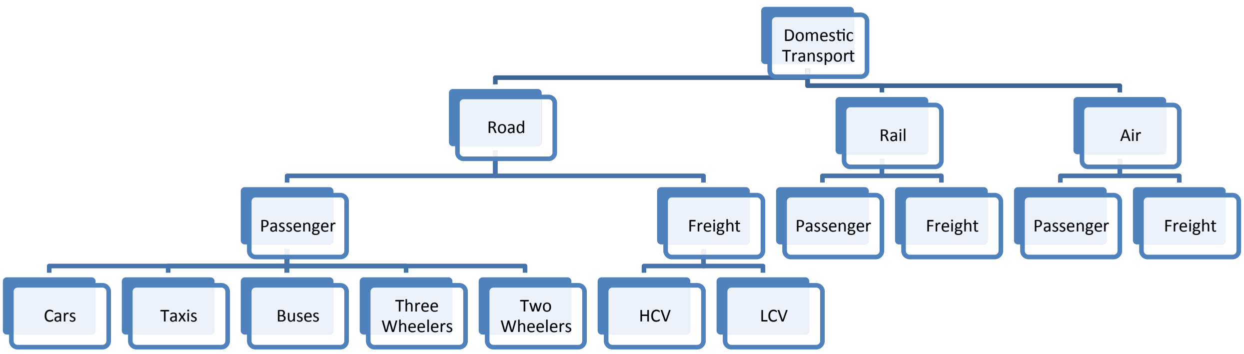


Source: *Road Transport Yearbook, 2009-11, (MoRTH, 2009-11)*

An in-depth study for quantification of energy consumption and GHG emissions from the transport sector in India would help examine the impacts that various policies might have on reducing the energy and emissions from the sector. It would also help in building alternate scenarios and analysing the implications of introducing alternate technologies. This chapter provides an assessment of various energy and emissions' reduction possibilities from India's transport sector in the year 2020 and 2030. The assessment is done by starting with developing bottom-up estimates of various national travel demand volumes, and modal shares across different vehicle types and technologies.

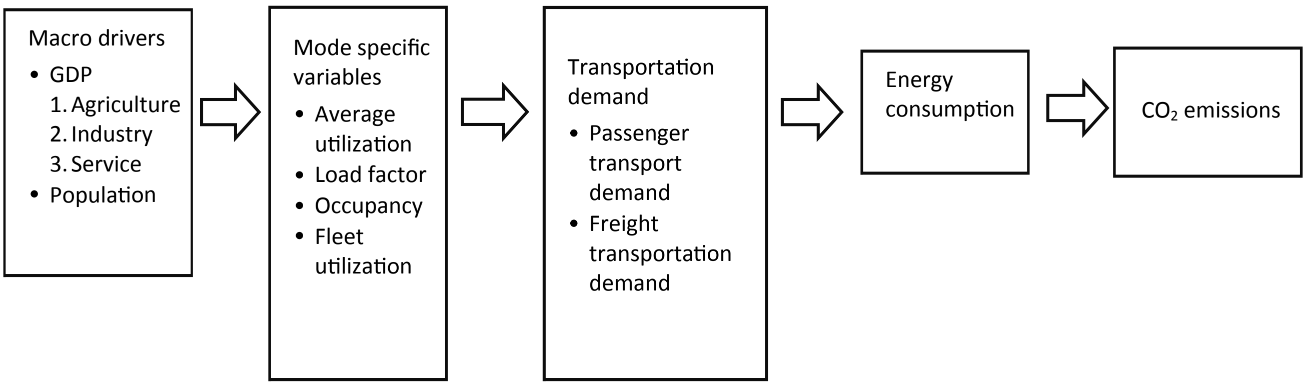
Given the need for working out a low carbon pathway for the transport sector as a stand-alone exercise for this report, a combination of a macro approach along with a more detailed bottom-up module was used. TERI's existing transport module was used and further developed as a bottom-up 'transport model' designed to examine fuel use and emissions from India's transport sector. Passenger and freight mobility by different modes were estimated and projected based on regression analysis, the energy consumption and emissions were ultimately estimated based on the projected mobility demand patterns and fuel-technology mix from across the sector. Figure 6.3 lays out the structure of the transportation sector as covered in this study.

Figure 6.3: Components of Transport Considered in the Transport Model



Projections have been made separately for road, rail and air transport. Further, the different intra-modal transport categories in road transport such as cars, jeeps, two-wheelers, buses, etc. have also been considered. Both domestic passenger and freight traffic movements have been considered for road, rail and air transport modes (water traffic moved on coastal shipping or on inland waterways have not been considered in this study). Figure 6.4 describes the framework of analysis.

Figure 6.3: Components of Transport Considered in the Transport Model



6.2 Projected Demand

The main drivers of transport demand in any economy are largely demographic and economic in nature. These are perhaps best reflected through population (rural and urban) and GDP growth rates and their distributions (agriculture, industry and services). As shown in Figure 6.4, these parameters have been used as the driving inputs for the present estimate of transport activity.

India's population grew from 1.03 billion to 1.2 billion at an average annual growth rate of 1.6 percent in the period between 2001 and 2011. The share of urbanization increased from 27.8 percent in 2001 to 29.8 percent in 2011. In this study, the projections of future population and urbanization are based on Scenario B of the Population Foundation of India estimates, according to which the urbanization is expected to rise to 33.3 percent by 2030 (PFI, 2007).

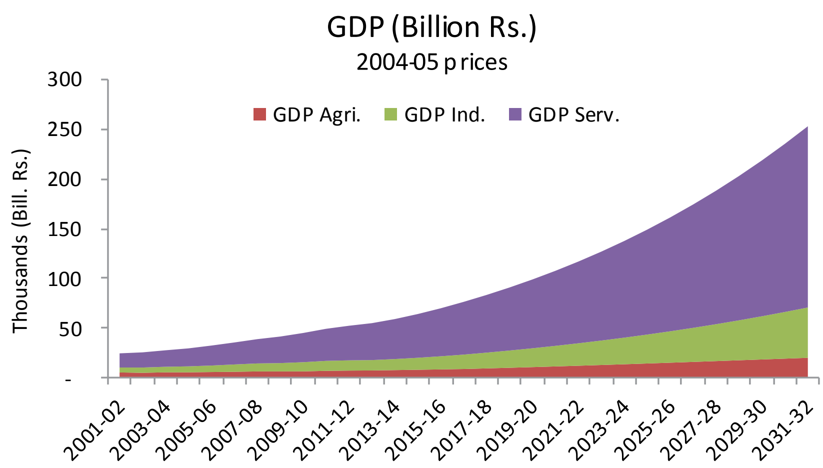
Table 6.2: Population Projection (in million)

	2001	2011	2021	2031
Total population	1028.7	1192.5	1339.7	1453.3
Rural population	742.6	834.5	907.1	951.6
Urban population	286.1	357.9	432.6	501.7

Source: Population Foundation of India (PFI, 2007)

The GDP has been assumed to grow at approximately 8.18 percent CAGR between 2011-12 and 2031-32. Figure 6.5 shows the sector-wise GDP projections till 2032 as used in the analysis.

Figure 6.4: GDP Projections Assumed Till 2031-32



The transport demands across the different modes are projected using regression analysis of the thirty year historic vehicle registration information and traffic volumes, and the resultant demand estimates are reported in Table 6.3.

Table 6.3: Projected Demand for Passenger Transport

	Passenger (BPKM)			
Year	Road	Rail	Air	Total
2005	3,041	576*	18*	3,635
2010	5,240	903*	44*	6,187
2015	7,227	1,222	73	8,522
2020	10,146	1,740	117	12,003
2025	13,222	2,325	176	15,723
2030	16,277	2,904	256	19,437
CAGR (2005-2030)	7%	7%	11%	7%

**Actuals; Sources: Indian Railways Statistical Statements, DGCA*

The total passenger kilometres are expected to increase from nearly 3,635 billion in 2005 to nearly 19,437 billion by 2030. Similarly, the estimated projections of freight demand indicate that the total tonne kilometres are expected to increase from nearly 961 billion in 2005 to nearly 6,677 billion by 2030.

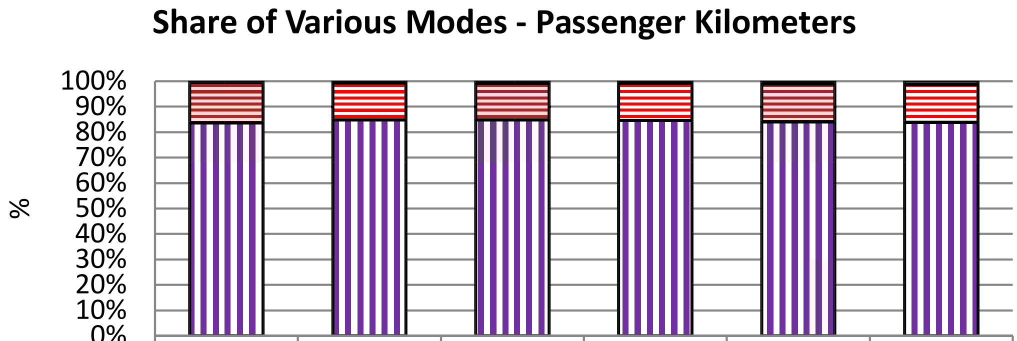
Table 6.4: Projected Demand for Freight Transport

	Freight (BTKM)			
Year	Road	Rail	Air	Total
2005	549	411*	0*	961
2010	841	601*	0*	1,442
2015	1,186	774	0	1,961
2020	1,918	1,117	1	3,035
2025	3,020	1,578	1	4,599
2030	4,517	2,158	2	6,677
CAGR (2005-2030)	9%	7%	8%	8%

**Actuals; Sources: Indian Railways Statistical Statements, DGCA*

The shares of passenger and freight transport on different modes are shown in Figures 6.6 and 6.7 worked out on the basis of regressions reported in the appendix to the chapter.

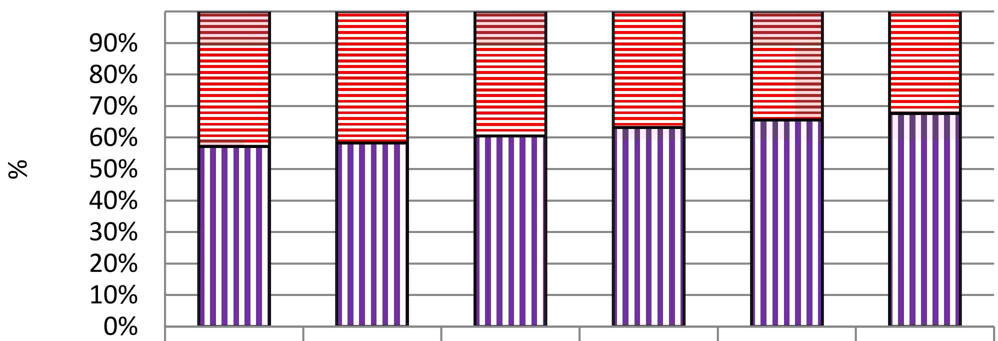
Figure 6.6 Share of Various Modes of Passenger Transport



	2005	2010	2015	2020	2025	2030
Air	0.50%	0.71%	0.85%	0.97%	1.12%	1.32%
Rail	15.84%	14.60%	14.34%	14.50%	14.79%	14.94%
Road	83.67%	84.69%	84.81%	84.53%	84.09%	83.74%

While the share of road in total passenger movement between 2005 and 2030 is expected to retain at the 84 percent mark, the share of road in total freight movement is expected to increase from about 57 percent in 2005 to nearly 68 percent in 2030.

Figure 6.7 Share of Various Modes of Freight Transport



	2005	2010	2015	2020	2025	2030
Air	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
Rail	42.82%	41.69%	39.47%	36.79%	34.30%	32.32%
Road	57.16%	58.29%	60.51%	63.18%	65.67%	67.65%

Fuel consumption will depend on the modes and the types of vehicles used for transport. It is seen that with a move towards personalized modes of transportation, as shown in Table 6.5, it is expected that there will be a diminishing share of road passenger kilometres moved by the more energy efficient bus based transport systems. This would increase the overall energy intensities of road based transport systems.

Table 6.5: Estimated Share of Passenger Kilometres by Vehicle Types

Year	Cars & Jeeps	2W	Taxis	3W	Bus/Omni-buses
2005	6%	13%	2%	4%	75%
2010	7%	14%	2%	3%	75%
2015	8%	14%	2%	3%	73%
2020	9%	14%	3%	4%	70%
2025	12%	15%	3%	5%	66%
2030	15%	16%	4%	6%	61%

6.3 Specific Energy Consumption

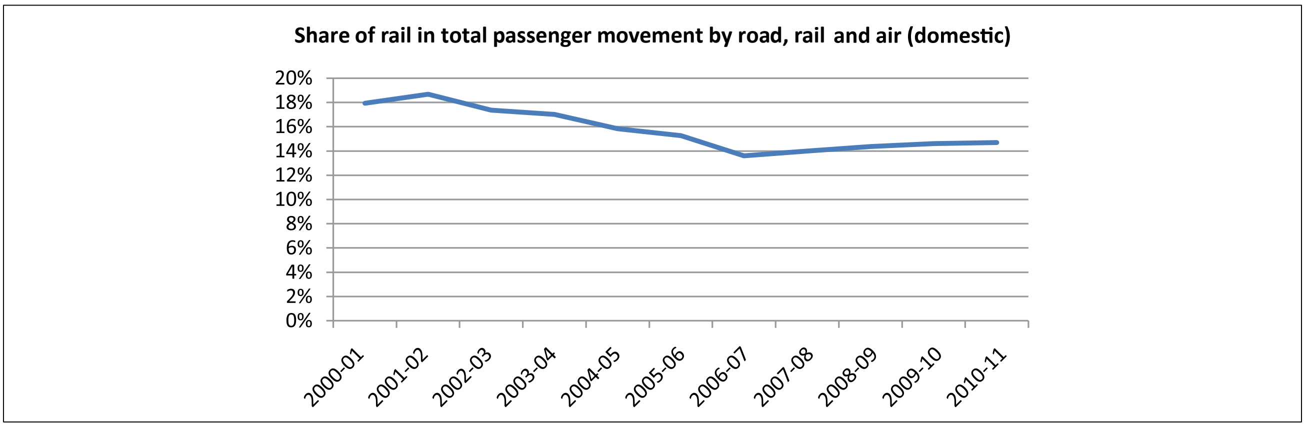
The fuel consumption from the transport sector is estimated based a mode's system specific fuel consumption values in terms of energy used per passenger kilometres as shown in Table 6.6. The efficiency of both passenger and freight operations is assumed to continuously improve through the entire horizon period at about an average rate of 1 percent per annum.

Table 6.6: Specific Energy Consumption

Specific Energy Consumption	TJ/BPKM
Passenger	2010
Cars & Jeeps	803
2W	398
Taxis	1,338
3W	619
Bus	196
Omni-Bus	502
Rail	71
Air	1,266
	TJ/BTKM

Freight	2030
HCVs	1,125
LCVs	1,143
Rail	91
Air	8,925

Figure 6.8: Share of Rail in Total Passenger Movement



Source: TERI Analysis

The estimated share of rail in total passenger movement decreased from 18 percent in 2000-01 to 14 percent in 2006-7. It recovered back some of its share by 2010-11.

Given the relative efficiencies of rail based transport, increasing the share of rail for both short distance passenger movement (regional, suburban and urban) and long distance passenger movement is vital for increasing overall efficiencies of the transport sector. The share of rail could be increased by capacity augmentation and enhancement of infrastructure and services to shift the time sensitive passengers from other energy inefficient modes to rail. The following measures are accordingly proposed:

6.3.1 Increasing the frequency and commercial speeds of passenger train services and taking similar measures to augment the load of existing trains

There is a need to identify and study the high density routes across the country and opt for appropriate options such as increasing the frequency of trains depending on the demand and augmenting the capacity of existing trains wherever needed. Increasing the commercial speeds of the railways with a view to cut down transit time could also help in attracting more passengers towards railways.

6.3.2 Introducing High Speed Rail (HSR) services

The number of passengers travelling by air has been increasing due to the easy availability of low cost airlines and the rapidly growing disposable incomes in the country. Options such as high speed rail need to be explored in addition to improving the quality of current services. There are already some suggestions for introducing high speed rail in India, by the Ministry of Railways, across six different corridors: Delhi – Chandigarh-Amritsar, Pune-Mumbai-Ahmedabad, Hyderabad-Dornakal, Vijaywada-Chennai, Howrah-Haldia, Chennai-Bangalore-Coimbatore-Ernakulam and Delhi-Agra-Lucknow-Varanasi-Patna (Indian Railways, 2009). Introduction of such services could lead to reduction in time and emissions if large shares of traffic from air or roads can be moved to HSR.

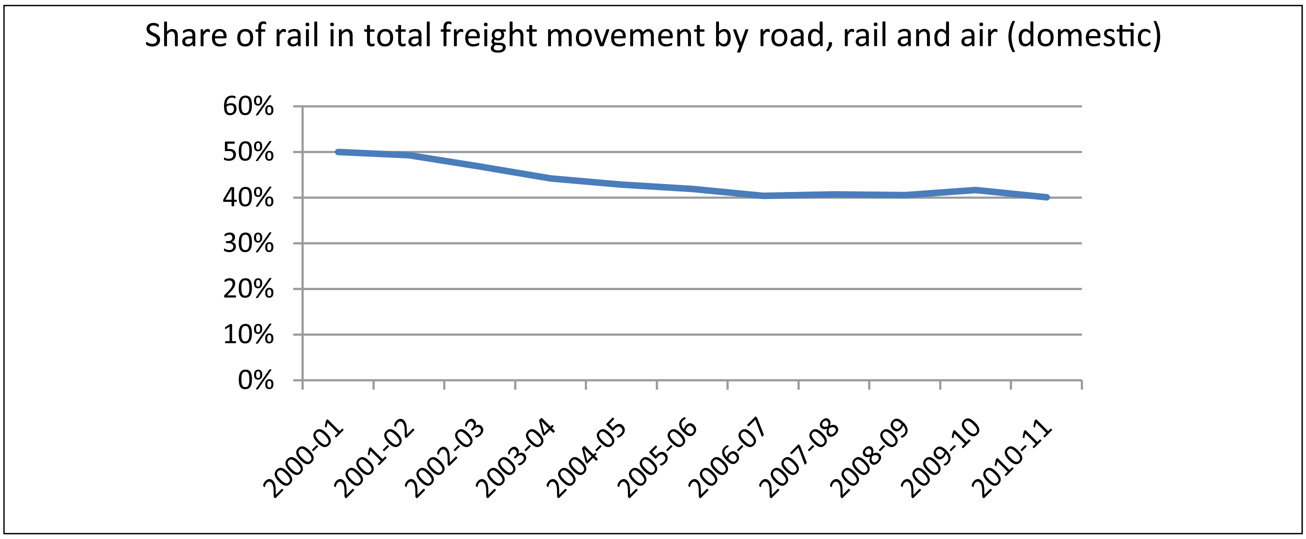
6.3.3 Increasing rail based intra urban, regional and suburban transport

Promoting rail as an option for short distance travel is also important to enhance the share of railways for passenger movement. Railways are not able to meet entire demand of passenger travel in short and medium distance segments due to capacity constraints. There is a need to either increase the railway's capacity to carry more passengers or provide exclusive rail based systems for carrying passengers. For example, people commuting to Delhi from nearby regions such as Alwar, Panipat, Meerut etc. for work every-day could be moved to rail based transport through the proposed Rapid Rail Transit Systems. There is also a great unmet demand for increasing regional rail services on branch lines of Indian Railway network. Providing faster trains can shift a lot of passenger traffic. There is a need to increase the pace of investment in such projects.

6.3.4 Increase in Share of Rail in Freight Movement

The share of rail in total freight movement has been continually on the decline. While the freight movement by railways has been increasing over the years in absolute terms, from nearly 44 billion tonne kilometres in 1950-51 to 601 billion tonne kilometres in 2009-10, the share of rail in freight movement has decreased from more than 80 percent in 1950-51 (Planning Commission, 2007) to around 43 percent in 2005-06. Figure 6.9 shows the estimated share of rail in the total freight movement by road, rail and air (domestic) in the last few years.

Figure 6.9: Share of Rail in Total Freight Movement



Source: TERI Analysis

The estimated share of rail in total freight movement decreased from a little over 50 percent in 2000-01 to about 40 percent by 2010-11.

Road based freight movement has captured much of the growing demand for freight transport, leading to an increased share of road in total freight movement. This has been a result of the greater convenience, flexibility and door-to-door services offered by road transport. A McKinsey report estimates that the total freight traffic would more than double by 2020 and in the normal course, rail share would further decline to 25 percent by 2020 (McKinsey & Co., 2010)[1]. This would have further negative implications for the country both in terms of fuel use and emissions.

The share of rail based freight movement has been declining on account of various factors. Activities in different regions with newer and diversified industrial production centres have been reducing the distance between consumption and production centres. In addition, rail capacity constraints, expansion of road network coupled with the introduction of multi axle trucks, development of pipelines, and higher rail freight tariffs have all resulted in these diminishing shares.

Table 6.7 shows a snapshot of the average leads of some of the major commodities carried by rail in 2009-10. These leads for freight movement on the railways have also been on the decline.

Table 6.7: Average Lead (Year 2009-10)

Commodity	Average Lead (in Km)
Coal	624
Iron Ore	406
Cement	577
Food Grains	1,300
Fertilizers	837
Mineral Oils	639

Source: (Indian Railways, 2012)

[1] In countries like China and the US, the share of rail is close to 50%.

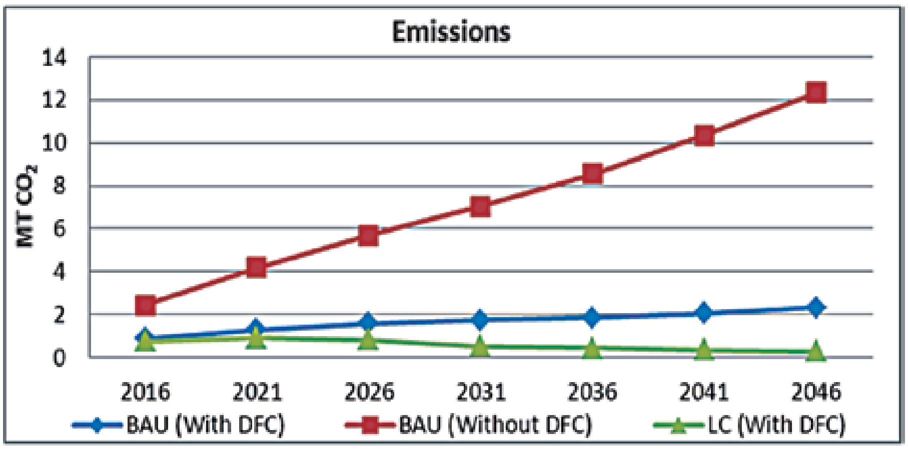
The Vision 2020 document published by the Indian Railways set out an aim of recapturing 50 percent of the freight moving over 300 kilometres and more than 70 percent of the bulk cargo moving in large volumes in the same distance range (Indian Railways, 2009). These are included in the formulation of the alternate scenarios for the present study. One of the ways of arresting the declining trend and then increasing the share is by augmenting the freight carrying capacity of the Indian Railways and by providing end to end logistic solutions for the consumers. Introduction of more Dedicated Freight Corridors, as has been proposed for the Western and Eastern corridors would also help in the process.

(i) Introduction of Dedicated Freight Corridors

The Indian Railways has already envisaged the building of dedicated freight corridors largely along the quadrilateral linking the four metropolitan cities of Delhi, Mumbai, Chennai and Kolkata, commonly known as the Golden Quadrilateral along with its two diagonals (Delhi-Chennai and Mumbai-Kolkata). These routes alone carry more than 55 percent of the revenue earning freight traffic of Indian Railways (DFCCIL, 2012). The existing trunk routes of Kolkata-Delhi on the Eastern Corridor and Mumbai-Delhi on the Western Corridor are highly saturated, with line capacity utilization varying between 115 and 150 percent (DFCCIL, 2012).

These skewed traffic ratios require an increase in the number of DFCs as are being built on the Eastern and Western corridors thus helping the Railways in getting back some of its diminishing freight traffic shares. DFCs would allow trains with heavier loads to be moved at higher speeds with significantly reduced transit times and maximum speeds of freight trains up to 100 kmph. It has also been estimated that the introduction of such DFCs would help to reduce the overall emissions from freight transport. Several studies have shown that there will be a significant drop in the emissions under the DFC scenarios [(Pangotra & Shukla); (Ernst & Young)], refer Figure 6.10.

Figure 6.10: Emissions in Various Scenarios



Source: Pangotra & Shukla, 2012

(ii) Development of Terminals including Logistic Parks

Indian Railways is currently a transport provider. As major railway systems internationally have already done, there is a need for the Indian Railways for gradually transforming itself into a logistics services provider. It is important that the Indian Railways provides the end-to-end freight movement services to increase its share in freight transport. Development of terminals including logistics parks is therefore critical to ensure that the Indian Railways does not lose out much of its share of freight transport to the roadways.

(iii) Diversification of the Freight Commodity Basket

The Indian Railways has largely become a transporter of only bulk commodities. An increased focus on diversifying the railway commodity basket to increase the share of mobility of freight on railways is crucial. Table 6.8 shows the share of various commodities in total rail based movement.

Table 6.8: Share of Various Commodities in total rail transport (Year 2011-12)

Commodity	Share (in %)
Coal	43.66
Iron Ore	6.04
Cement	9.29
Food Grains	8.69
Chemical Manures	6.56

Source: Ministry of Railways, Yearbook 2011-12

The growth of freight traffic on railways was lower than growth rate of GDP in Eleventh FYP due to slow down in core sectors such as coal, steel etc. (Planning Commission, 2012).

However, even in the movement of such bulk commodities, the railways have been losing some of its modal share to the roads. Table 6.9 shows the share of road and rail in Net Tonne Kilometres of some commodities in 2007-08.

Table 6.9: Share of Road and Rail in Net Tonne Kilometres Commodities in 2007-08

2007-08	Share in Net Tonne Kilometres	
	Share of Road	Share of Rail
Coal	3%	97%
Food grains	62%	38%
Iron and Steel	41%	59%
Fertilizers	46%	54%
Cement and Cement Structures	18%	82%
POL	38%	62%
Iron Ore	12%	88%
Limestone and Dolomite	0%	100%
Other	84%	16%

Source: (RITES, 2012)

Table 6.10: Share of Road and Rail in Net Tonne Carried of Some Commodities in 2007-08

2007-08	Share in Net Tonne Carried	
	Share of Road	Share of Rail
Food grains	90%	10%
Iron and Steel	69%	31%
Fertilizers	81%	19%

Source: (RITES, 2012)

Table 6.10 shows the share of road and rail in net tonne carried of some commodities in 2007-08.

The Indian Railways needs to enlarge its commodity basket and penetrate into the non-bulk commodity market to increase the share in the freight movement. Some of the areas where it is important for railways to focus are automobiles, chemicals and petroleum, oil and lubricants (POL), oversized consignments such as machineries (Over Dimensional Consignments), manuvfactured goods and agro-products. Table 6.11 shows the Rail and Road Shares in Inter-regional commodity traffic 2007-08 (NTKMS).

Table 6.11: Rail and Road Shares in Inter-regional commodity traffic 2007-08 (NTKMS)

Rail and Road Shares in Inter-regional commodity traffic 2007-08 (NTKMS)		
	Road	Rail
Three Wheelers and Two Wheelers	100.00	0.00
Chemicals (All Types)	95.17	4.83
POL Products (Liquid*)	60.10	39.90
Heavy machineries, Tractors etc.	99.42	0.58

** Excluding pipelines; Source: RITES, 2012*

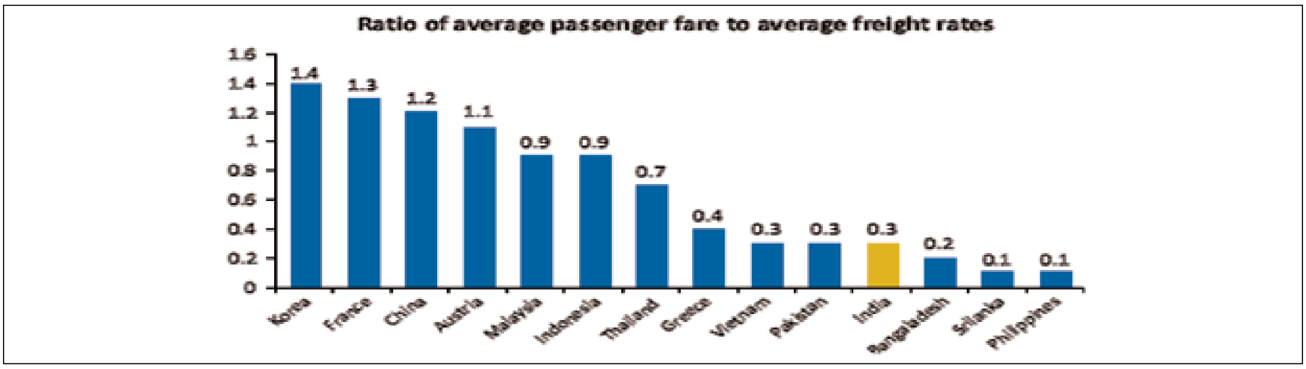
(iv) Increased Capacities to Handle Container Traffic

The increasing economic growth in the last decade has caused an increase in the demand for movement of white goods in India. This has led to the growth of container traffic across India. Therefore, the Indian Railways also has to take adequate measures to ensure that such traffic is not lost to the roadways due to the lack of rail based infrastructure to handle container traffic. The formation of the Container Corporation of India and the subsequent permissions to allow private players in the market has helped increase this traffic on the Indian Railways only to a certain extent. The increasing traffic would require the railways to take measures for retaining and further enhancing its share in container traffic.

(v) Better Pricing of Freight Services

The rail freight tariff in India is much higher compared to many other countries such as Russia, China and Japan due to the cross-subsidization of the freight revenues for passenger businesses. On an index of 100 (assuming average freight revenue per tonne kilometre in USA to be 100), the average freight revenue per tonne kilometre is 395 in case of India, the number is 122, 185, 207 in case of Russia, China and Japan respectively (Indian Railways, 2009). The fare freight ratio[2] in India has decreased from 0.326 in the year 2004-05 to 0.273 in the year 2009-10[3].

Figure 6.11: Ratio of Average Passenger Fare to Average Freight Fares



Source: White Paper, Indian Railways, 2009-10

[2] Fare Freight Ratio= (Average rate charged per passenger kilometre/Average rate charged per tonne kilometre)

[3] Source: Ministry of Railways (Data Source), Author's Calculations

The ratio is 1.4 in case of Korea and 1.2 in case of China (Source: White Paper, Indian Railways, 2009)

Figure 6.12: Passenger and Freight Yields

Passenger Service Yields in some Major Economies

Country	Passenger Service Yield US Cents/ Passenger-KM at nominal prices	Passenger Service Yield US Cents/Passenger-KM adjusted for PPP (India=1)
India	0.6	1.0
China	2.4	2.7
Russia	5.2	6.7
Japan	19.0	9.4
Germany	12.6	6.2

Freight Yields in some Major Economies

Country	Freight Yield US Cents/Total Tonne-KM at nominal prices	Freight Yield US Cents/Total Tonne -KM adjusted for PPP (India=1)
India	2.11	1.00
China	1.49	0.58
Russia	2.20	0.75
USA	2.28	0.51

Source: Planning Commission, 2012

Better pricing mechanisms need to be evaluated and introduced by the railways to induce more freight traffic onto the railways.

6.3.5 Increase in Share of Public Transport

The share of public transport is estimated to have declined over the years against private cars, two wheelers and para-transit modes such as three wheelers, rural transport vehicles and mini buses operated by private operators. However, public transport is an important element in the low carbon strategies of the country and can play a crucial role in providing sustainable mobility in Indian cities.

Figure 6.13: Estimated Share of Various Modes in Total Passenger Movement by Road

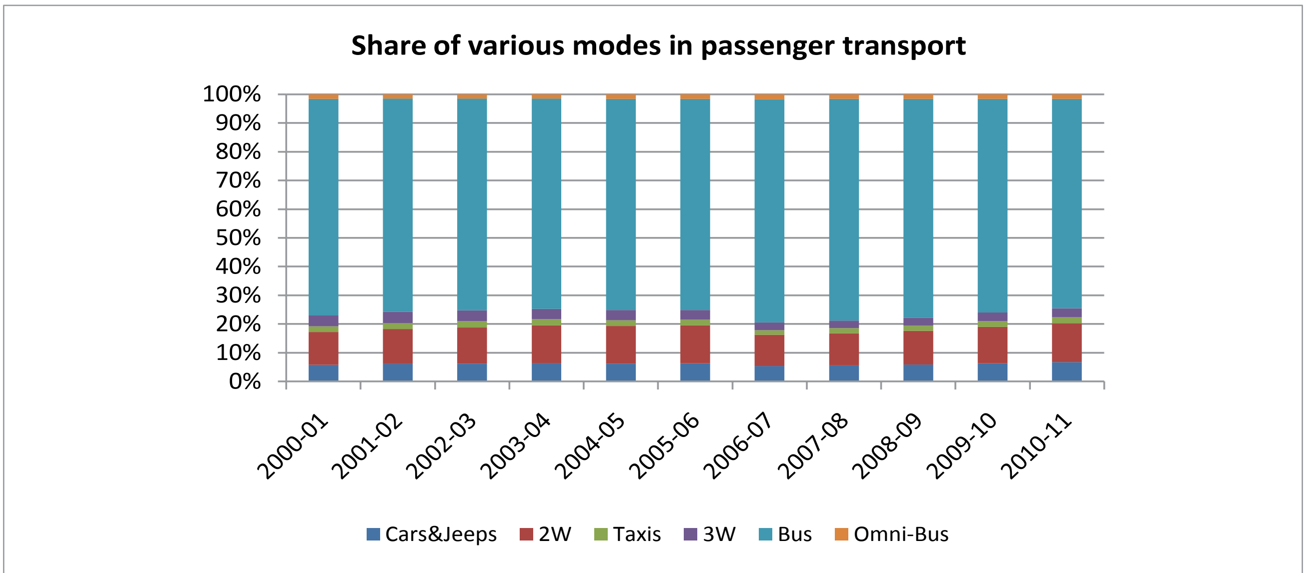


Figure 6.13 shows the share of various modes in total passenger movement in passenger kilometres by road in past few years.

The challenge lies in improving public transport systems so as to augment the share of buses in the total passenger kilometres. In addition to reducing CO2 emissions from the transport sector, augmenting the share of public transport is considered socially desirable because it provides higher mobility to poorer sections of the society who cannot afford personal vehicles such as cars and two wheelers. Therefore, expansion of public transport in the form of large capacity buses, light rail transit and metro or suburban rail can be feasible emissions' mitigation options for the transport sector.

Bus based public transport systems may be more appropriate for a country like India with serious capital constraints. Successful examples of bus based public transport systems can be found in Latin American countries such as Bogotá, Curitiba and Mexico City. Ahmedabad has also set up a network of BRTS (bus rapid transit system) roads.

Accordingly, in the low carbon scenario, the share of passenger movement by buses in total passenger movement is assumed to increase.

6.3.6 Increase in share of alternative fuels in overall fuel mix

Clean fuel can play a significant role in reducing vehicular particulate emissions in India, particularly for criterion pollutants. Given that vehicle and fuel technology for natural gas is available today at relatively affordable prices as compared to other alternative fuel vehicles, CNG might be an optional alternate fuel choice for India. In addition, increasing the share of CNG vehicles can have other strong benefits such as improving the air quality in urban areas, improving energy security and reducing government spending on fuel subsidies.

The number of CNG cars and taxies in India grew from 23,166 in 2001 to 439,250 in the year 2011. In the year 2011, Delhi (64 percent) had the highest share of CNG cars followed by Gujarat (18 percent) and Maharashtra (15 percent). According to Scenario 2 of the National Electric Mobility Mission Plan 2020 (NEMMP 2020), the share of CNG cars will be 30 to 35 percent in new vehicle sales by 2020 (Ministry of Heavy Industries, 2013).

In 1999, CNG buses were introduced in only two cities of India. However, by the end of 2009, CNG buses were operating in ten cities of India namely, Delhi, Mumbai, Vadodara, Surat, Ankleshwar, Lucknow, Agra, Kanpur, Vijayawada and Hyderabad. As a result, the number of CNG buses in India grew from 12 in 1999 to 16372 in 2009. According to Scenario 2 of NEMMP 2020 the share of CNG buses in new sales of buses will be between 30 to 35 percent. Apart from the increase in CNG vehicles, an increase in electric vehicles is also assumed in the low carbon scenario. Given that electric vehicles have higher operational efficiencies than internal combustion engines, increasing the shares of electric vehicles is expected to increase the overall energy efficiencies of the transport sector and reduction of energy demands. In fact electric vehicles in the form of electric-rickshaws are already making appearances in several urban centres across the country under largely unregulated conditions to meet unmet public needs. In addition, several large Indian auto manufacturers are already moving towards adding electric cars in their production line. But, all these shifts to alternative fuel can be sustained only with continuous Government policy interventions and support.

Even in the case of the Railways, the low carbon scenario corridor increased electrification of railway routes to get the benefits of increased efficiency of electric traction.

6.3.7 Increase in non-motorized transport

The present investment patterns in the transport sector are focussed at improving mobility of motorized vehicles rather than people. Slow moving vehicles such as bicycles and rickshaws have been assigned lower importance as compared to motorised transport modes. There is a need to rethink the conventional hierarchy of road users and better planning and designing of road infrastructure so as to arrest the decline of non-motorised transport.

A city's infrastructure should therefore be designed to meet the needs of pedestrians, cyclists and non-motorized rickshaws not only for environmental sustainability but also for social and economic sustainability. Transport and land-use patterns in Indian cities are different from cities in western countries. Indian cities consume less energy from transport and are characterised by high population densities, mixed land use, short trip distances, and high proportion of pedestrian and non-motorized transport. Therefore, ensuring safe road infrastructure to pedestrians and cyclists by measures such as segregation of road space for non-motorized transport or reducing the speed of motorized traffic will also make Indian cities more inclusive by providing mobility to urban poor who cannot afford any form of motorized transportation. Sustainable transport systems therefore need to be designed to cater to both the captive and choice riders of non-motorized transport modes such as the cycles, and infrastructure should be improved to enable more walk trips.

Given the above mentioned social and environmental benefits of promoting non-motorized transport, the low carbon scenarios assume better designed road infrastructure to increase NMT activity. The increase in the share of non-motorized transport modes in the low carbon scenario is represented by a reduction in the total passenger kilometres travelled (representative of motorized transport).

6.3.8 Improving efficiency of vehicles

The number of registered road vehicles in India has been increasing at over 12 percent between 1981-2011 (MoRTH, 2009-11). This is a huge concern from the point of view of both energy consumption as well as emissions. It is important to introduce fuel efficiency norms for the automobile industry to address both the energy and climate challenges.

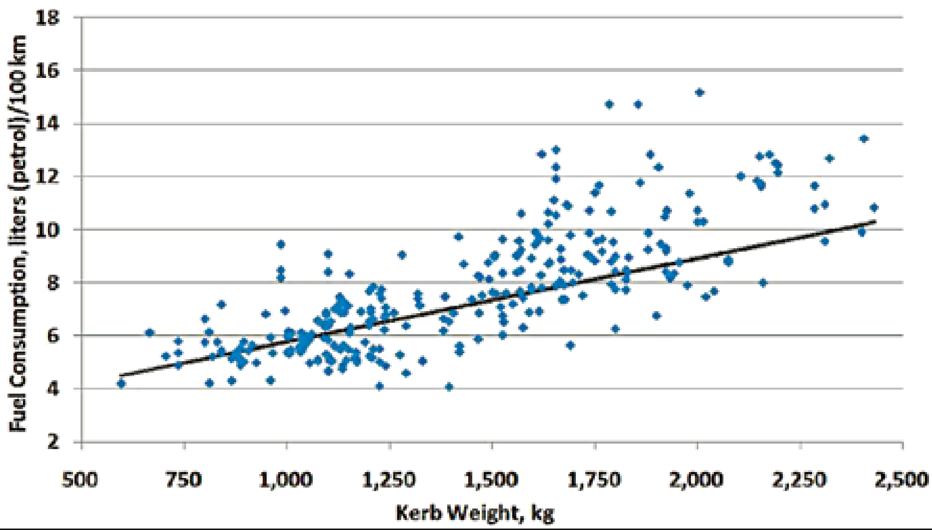
In order to accelerate the reduction in average fuel consumption of new cars introduced in the Indian market, a two pronged approach is being put into place (BEE, 2011).

- Medium and Long term fuel efficiency standards for new cars which would provide a regulatory signal to manufacturers to continuously reduce the average fuel consumption of cars sold by them over the next 10 year period.
- Labelling of new cars that are sold in the market with the labels providing the consumers with information on fuel consumption of the car model and the relative fuel consumption of the model compared to other models in the same weight class.

This strategy which combines a “supply push” with a “demand pull” could enable a large scale transformation in the automobile market (BEE, 2011). However, these measures need to be taken up as soon as possible for both passenger and commercial vehicles for best results[4].

Figure 6.14 shows the 2009-10 fuel consumption – kerb weight (i.e. unladen weight) data for all models, as well as trend line for the data.

Figure 6.14: Ratio of Average Passenger Fare to Average Freight Fares



Source: BEE, 2011

[4] It must be noted that the Bureau of Energy Efficiency, Government of India has already notified the efficiency of small passenger vehicles while this present chapter was under preparation. The notification can be found at: http://www.egazette.nic.in/WriteReadData/2014/158019.pdf

India has also been aggressively pursuing fuel emissions standards since the Auto Fuel Policy of 2002 (MoPNG, 2003). Although these emissions standards which are built on the European format are focused on the standard and quality of the fuel that is used to drive road vehicles, increasing fuel emissions standards also require advancements in engine technologies to use these fuels. Therefore aggressive implementation of fuel norms also has additional benefits of increased efficiencies.

Keeping these in mind the efficiency of vehicles in road transport sector is accordingly expected to improve every year in the low carbon scenario.

6.4 Alternative Scenarios

Based on the different low carbon alternatives as suggested in Section 6.3, a set of alternative low carbon scenarios were created over the business as usual scenario (BAU) as shown in Table 6.12.

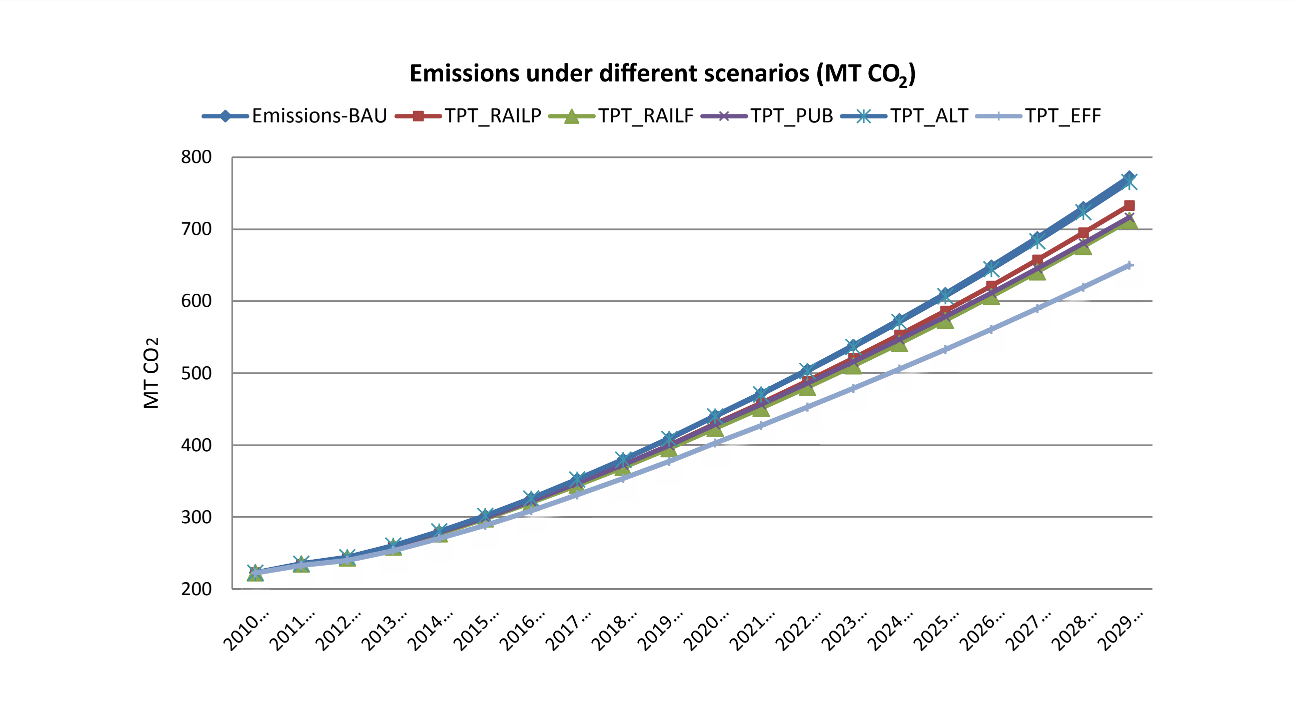
The abbreviated names for each of the scenarios are given below:

TPT_BAU	Business-As-Usual Scenario
TPT_RAILP	Increase in share of passenger kilometre by rail in total passenger kilometre
TPT_RAILF	Increase in share of freight tonne kilometre by rail in total tonne kilometre
TPT_PUB	Increase in share of public transport
TPT_ALT	Increase in share of alternate fuels
TPT_EFF	Improving efficiency of vehicles

Table 6.12 Description of the Low Carbon Scenarios

Description of Low Carbon Scenarios		
Scenario	**Overview**	**Details**
TPT_RAILP	Increase in share of passenger kilometre by rail in total passenger kilometre	Share of rail in total passenger movement by road, rail and air (domestic) is assumed to become 25% by 2031/32
TPT_RAILF	Increase in share of freight tonne kilometre by rail in total freight tonne kilometre – shift from road to rail transport	Share of rail in total freight movement by road, rail and air (domestic) is assumed to become 50% by 2031/32
TPT_PUB	3. Increase in share of public transport - Shift from private vehicles to buses	Share of passenger movement by buses in total passenger movement by road is assumed to increase to 75% by 2031/32 (shift from cars)
TPT_ALT	(i). Increase in share of CNG cars	Share of passenger kilometres by CNG cars in total passenger kilometres by cars is assumed to become 15% by 2031/32
	(ii). Increase in share of CNG buses	Share of passenger kilometres by CNG buses in total passenger kilometres by buses is assumed to become 10% by 2031/32
	(iii). Increase in share of electric cars	Share of new sales of electric cars in total new sales of cars is assumed to become 10% by 2031/32
	(iv). Increase in share of electric 2 W	Share of new sales of electric 2 Wheeler in total new sales of 2 Wheelers is assumed to become 30% by 2031/32
	(v). Increase in share of CNG Taxies	Share of passenger kilometres by CNG taxies in total passenger kilometres by taxies is assumed to become 10% by 2031/32
	(vi). Increase in share of CNG 3 W	Share of passenger kilometres by CNG 3W in total passenger kilometres by 3W is assumed to become 17% by 2031/32
	(vii). Electrification-Railways - Passenger	Share of passenger kilometres on electric traction-assumed to become 60% by 2030
	(viii). Electrification-Railways - Freight	Share of tonne kilometres on electric traction assumed to become 60% by 2030
TPT_EFF	Improving efficiency of vehicles - road transport	Improvement in efficiency - road transport by 1% every year

Figure 6.15: Emissions Reduction Potentials Under Different Scenarios



The expected reduction in emissions across each of the alternative scenarios in 2020 and 2030 is given in Figure 6.16.

Figure 6.16: Emission Under Various Scenarios in 2020 and 2030

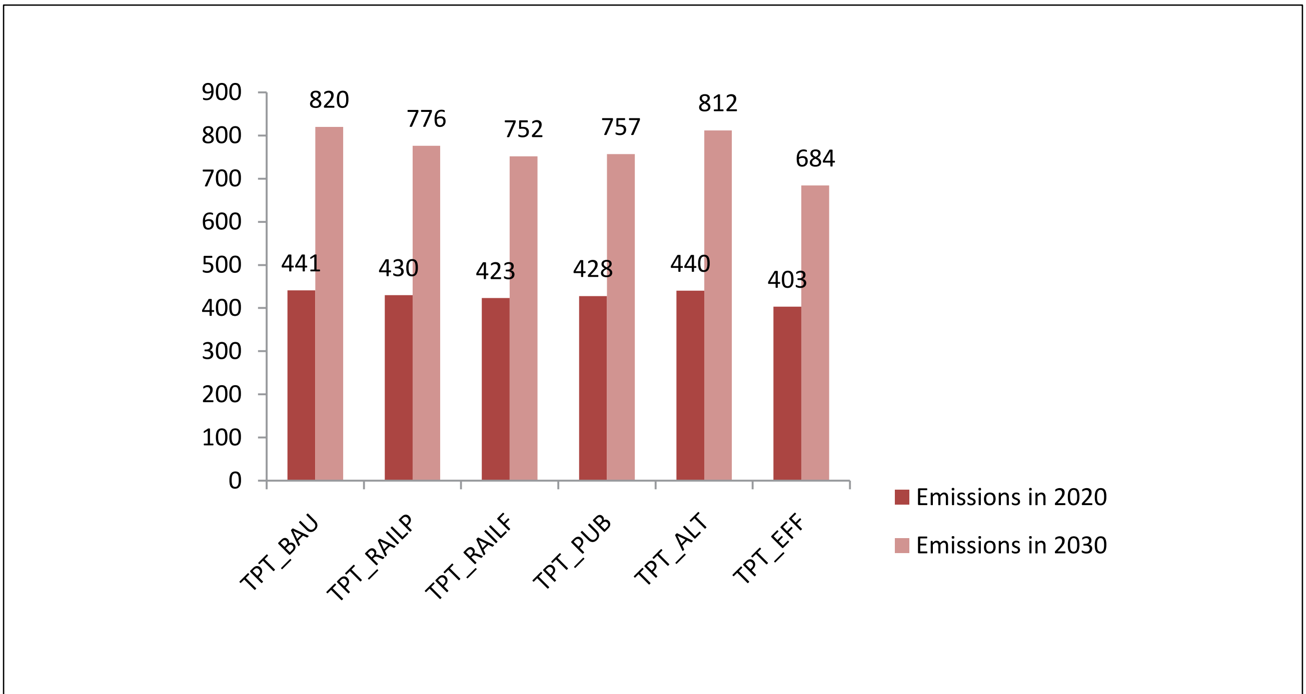


Table 6.13 Emissions levels in 2020 and 2030 under the various scenarios

Scenario	Emissions (MT CO2) 2020	Emissions (MT CO2) 2030	Percentage drop over 2020 BAU	Percentage drop 2030 BAU
TPT_BAU	441	820	-	-
TPT_RAILP	430	776	3%	5%
TPT_RAILF	423	752	4%	8%
TPT_PUB	428	757	3%	8%
TPT_ALT	440	812	-	1%
TPT_EFF	403	684	9%	17%

The total cumulative emissions reductions from the transport sector if all the alternate scenarios are implemented together is expected to be significant though it will be less than the sum of reductions in all the measures taken one at a time.

The largest impact is seen to come from increasing the efficiency of the overall vehicle stock and by moving to electric traction, with an emissions reduction potential of almost 17 percent over 2030 BAU levels. Other benefits accrue from moving passengers to public and other rail based modes of transport with potential emissions reduction of about 8 percent over 2030 BAU levels. While moving to alternate fuels for transport in India is important to reduce the reliance on single types of fuel and reduction in criteria pollutants, the analysis shows that it might not directly lead to a large reduction the carbon dioxide emissions since one fossil fuel is simply substituting another. It is therefore important that a combination of all these efforts should be pursued to get the highest reductions of emissions from the transport sector.

6.5 Implications and Policy

As seen from the various scenario results, it is clear that there is a huge potential to reduce the energy intensity from transport in the future. Increased attention needs to be focussed on the railways, as it is by far the most energy efficient mode of land transport. Necessary action should be taken to ensure that the continually declining shares of mobility on the railways, for both passenger and freight mobility are not only arrested but also increased.

For passenger mobility, with continuous increase in the value of time, it is imperative to provide people with adequate number of faster and more convenient rail based services for both intra and inter-city as well as suburban services. This would in many cases require augmenting the present rail infrastructure in terms of line and terminal capacity and rolling stock for carrying additional traffic. Investments will also be required for provision of new infrastructure in the form of metro, rapid and high-speed rail services. For freight mobility too, measures need to be taken to arrest the diminishing shares of rail based mobility. This can be done by first ensuring that the sectors where rail has a natural comparative advantage, such as in carrying bulk commodities, do not keep moving to road based transport. In addition, the creation of dedicated freight corridors along the four quadrilaterals of the country and expansion of the rail network to cater to new ports, mining and industrial areas would help to carry additional freight traffic on the railways. The most immediate measure that needs to be taken to retain the share of rail based freight is the rationalization in freight rates to ensure that businesses do not move to road because of cheaper costs.

In addition to increased provision of rail based transport systems, action should be taken to increase the availability of public transport facilities across the country. Starting by focussing on million plus cities, adequate measures need to be taken to increase the number of transport corporations offering formal urban bus services. With increasing urban sprawls, the extremities of the cities should be connected by better public transport services to ensure that the potential captive public transport users do not shift to private transport on account of inadequate availability.

With the rapidly growing numbers of private vehicles in the country, the private vehicle fleet also needs to be made cleaner. Setting up the appropriate and stringent energy efficiency norms for India, as seen in several countries across the world, would be essential for reaching a desired low carbon scenario for the country. Hand in hand with increasing energy efficiencies, a move towards cleaner alternate fuels in the overall fuel mix for transport has the potential of significantly reducing the intensity of criteria air pollutants from motorized transport in the country. Introduction of stricter fuel emissions norms also leads to an improvement in vehicle technologies which will lead to improved air quality. Although this might not lead to an overall reduction in the levels of CO2 emissions, it would help in improving the quality of health, particularly in densely populated urban environments. Further, to augment the use of urban public transport, it is critical to ensure that last mile connectivity is ensured. This need might be met by the use of regulated electric vehicles which are already visible in several cities.The recent growth in several forms of improvised road transport vehicles in rural and smaller cities are dependent on either diesel or adulterated diesel mixed with kerosene oil also. A better regulatory environment needs to be coupled with enabling policies for fuel efficient or electric vehicles to meet this growing demand.

While pursuing all these policies which are targeted at motorized modes of transport, urban centres should also be encouraged to integrate non-motorized transport as an integral part of any urban transport plan. As highlighted in the chapter, the benefits of non-motorized transport would not be limited to only achieving a lower carbon scenario for the country, but it would also have larger intangible social benefits.

Altogether, such policies as highlighted in the chapter have the potential to create a transport framework, which would be both inclusive and also one that would result in a lower carbon scenario for India.

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Annexure : Regression Results for the Transport Sector

A bottom-up approach was used for determining the sector's energy demand requirement and estimating the transport demand on each of the motorized modes. The modes considered for this exercise were road, rail and air. Within road, passenger transport was assumed to move on cars, buses, two-wheelers, three-wheelers and taxis. Freight transport on roads was assumed to move on heavy and light commercial vehicles. Using historic vehicle stock information coupled with standard utilization rates, the passenger and freight transport demands were arrived at for each of these road transport modes. Similarly, both passenger and freight transport demandswere also estimated for railways and air transport.

To project the future traffic demand on each of these modes for both passenger and freight, independent regression analysis was performed for each mode. Given the inherent serial correlation present in time series data of transport demand, the Cochrane–Orcutt estimation procedurewas adopted for these regressions. The resulting functional coefficients for each mode are shown below:

Description of Modal Regressions				Outputs			
Category of Transport	**Sub-Category**	**Dependent Variable**	**Independent Variable**	**Coefficient**	**Const.**	**Rho**	**μ(t-1)**
Road Vehicles	Cars and Jeeps	lncar	gdppc	1.91E-06	-1.71E-02	0.682	7.46E-05
	Two Wheelers	lntwowh	gdppc	6.28E-06	-5.20E-02	0.697	-9.84E-04
	Three Wheelers	lnthrw	gdpserv	8.53E-07	8.49E-03	0.952	-5.15E-03
	Taxis	lntaxi	gdpserv	2.32E-06	-2.07E-02	0.594	-2.99E-05
	Buses	lnbus	gdppc	2.43E-05	-2.26E-01	0.712	5.75E-03
	HCVs	lnhcv	gdp	8.18E-07	4.46E-02	0.932	-1.34E-02
	LCVs	lnlcv	gdpagindpc	9.34E-06	-6.70E-02	0.704	6.98E-04
Railways	Passenger	lnrailpkm	gdppc	1.06E-05	-5.25E-02	0.936	2.50E-02
	Freight	lnrailtkm	gdp	1.63E-06	1.25E-02	0.806	-7.41E-04
Aviation	Passenger	airpkm	gdpsrvpc	2.63E-03	-1.88E+01	0.824	9.94E-01
	Freight	airtkm	gdppc	1.11E-05	-1.10E-01	0.365	1.60E-04

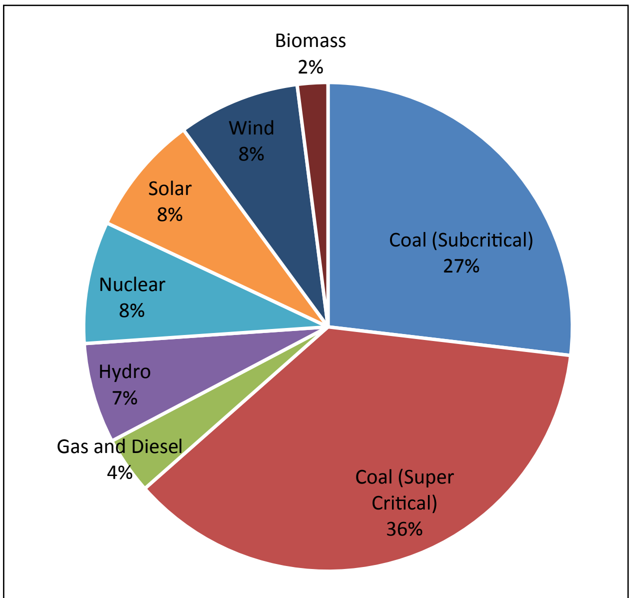
7 Power

7.1 An Overview

India's present electricity generation capacity is about 238 GW[1] and the electricity generation is 978 billion kWh[2]. Coal dominates the generation capacity[3] (141 GW) followed by hydropower (40 GW) and wind (20 GW). In addition, captive power contributes about 39 GW to the installed capacity and over 128 billion kWh to power generation[4].

The results of the Macro Model in Chapter 2 project total electricity generation of about 3400 bkWh in the LCIG scenario. These numbers compare reasonably well with the demand estimates made in several other studies. The Integrated Energy Policy, 2006 (IEP) uses historical elasticity of electricity generation with respect to Gross Domestic Product (GDP) and projects total electricity generation based on constant and falling elasticity over time for 7, 8 and 9 percent GDP growth assumptions. IEP estimates total electricity generation at around 3400 bkWh[5]. The International Energy Agency, 2011 (IEA) used a bottom-up system engineering model to predict India's electricity demand under different scenarios. Electricity demand is projected at around 3800 bkWh for the year 2031 in the baseline high-demand scenario[6]. Finally, the 18th Electric Power Surveys (EPS) conducted by Central Electricity Authority (CEA) estimates the electricity demand at around3,400 bkWh for 2030-31[7].

Figure 7.1: Fuel-wise Electricity Generation in LCIG Scenario 2030



The results of the Macro Model highlight that even in the LCIG scenario; coal continues to be the dominant source of power generation. It accounts for about 315 GW of installed capacity and 63 percent of generation. However, super critical power plants account for over half of the coal based power generation, leading to a significant reduction in the CO2 emissions. The share of renewable sources (solar, biomass and wind) increases from the present 6 percent to 18 percent in 2030. Hydropower and nuclear contribute 7 percent and 8 percent respectively. Consequently, in the LCIG scenario, fossil free sources account for 33 percent of the electricity generated in 2030 as against 23 percent at present. In terms of actual generation, fossil free generation increases nearly five-fold to 1100 billion kWh in 2030.

Thus, the LCIG scenario has a significantly different power generation mix, including a much higher share of renewable sources. In this chapter, we assess the specific policies required to facilitate the above LCIG supply mix.

7.2 Wind Power Generation

The Macro Model suggests a wind power generation capacity of about 120GW by the year 2030, which is more than six times the present installed capacity of about 20 GW. The Model thus projects an ambitious increase in the wind power generation capacity. This is reasonable to expect since wind is cost effective and the wind industry in India has reached maturity after over two decades of experience. India has the world's fifth largest wind generation capacity. However, India's installed capacity is relatively small as compared to other countries such as the US, China, and Germany. It is interesting to note that in the year 2005, India's wind generation capacity exceeded that of China and was comparable with that of the US. However, in the last decade, China and the US rapidly increased wind generation capacity to over 75 GW and 60 GW respectively. In contrast, India added only about 1 GW in the present year. This just highlights the need for India to provide an impetus to the wind industry by providing a stable and conducive policy environment.

India's wind power potential was historically estimated at 49 GW based on a wind turbine hub height of 50 meters and a land usage of 2 percent. However, rapid improvement in wind turbine technology allows higher efficiency, larger turbine size and installation at higher hub heights. Therefore, several recent studies have reassessed India's wind power potential and found it to be much higher than historical estimates. A study by Lawrence Berkeley National Laboratories (LBNL) estimated India's wind power potential at 748 GW at a hub height of 80 m[8]. Other studies focused on state-level potentials in wind rich states. For instance, Center for Study of Science, Technology and Policy (CSTEP) evaluated wind power potential in Karnataka and Andhra Pradesh[9]. Recently, Center for Wind Energy Technologies (CWET), Government of India, also revised the wind potential to 103 GW at 80 m hub height and assuming 2 percent land utilization.

The above studies have to be validated with field measurements of wind speeds and also land availability. Nevertheless, these studies suggest that wind resource availability per se is not a limitation. Since wind is cost-effective, it can be a very important contributor to India's electricity generation mix and plays a crucial role in meeting India's aspirations for energy security and low carbon inclusive growth. It needs to be supported with appropriate and stable policies. This report proposes the following policy options for rapid wind power development:

National Wind Mission

Rapid wind power development in India requires a mission mode approach with the creation of a favourable policy environment, which incentivizes private sector investments in the sector. Thus there is a need for a National Wind Mission (NWM) to provide the desired impetus. There is mention of the NWM in the Twelfth Five Year Plan as well. Even though wind power development will occur in the states concerned, the centre has a major role because coordinated development of wind power depends on several issues that transcend state jurisdiction. The Mission should address the below aspects of wind power development.

Wind Zones:

In order to realize the estimated potential in the five wind-rich states, MNRE, in coordination with State nodal agencies should identify high wind power potential zones (more than 1000 MW each) and develop sites to attract investment. A few states have already made progress in developing such zones. This will help accelerate project deployment by investment grade analysis of wind potential, create common transmission infrastructure, and enable balancing through national level resources and better scheduling and forecasting.

Tariff Fixation:

The wind tariff currently specified by CERC is based on a cost-plus model. This acknowledges the wide variation in returns from different wind zones. However, most states, have established flat tariffs leading to several disputes with the generators. This creates the possibility of two options: (1) State identifies and notifies land on which wind projects can be set up and calls for investment via a bidding route, or; (2) State collects generation related data and adjusts tariffs based on wind zone and generation. Either way, there is a need for a more rational mechanism for tariff fixation, which depends on the wind resource. In the long run, wind zones as mentioned above, will help in discovering the price and help pave the way for a transparent competitive bidding framework of project allocation.

Fiscal Incentives:

Accelerated Depreciation (AD) and Generation Based Incentive (GBI) were two important incentives, which led to rapid wind power development in India. AD in particular, was helpful for medium and small scale businesses, which contributed to most of wind power capacity. These were discontinued in 2012, which led to a decline in capacity addition in last few years. A GBI of Rs 0.50 per kWh has now been reintroduced recently.

In the long run, wind should not require any central incentives since it is a cost effective energy source. Also, rationalization of state level tariffs should adequately compensate the wind power generators. However, in the interim, it is necessary to restore AD and GBI to provide necessary policy impetus to investors. These incentives should be gradually phased out in due course when appropriate state level tariffs have been established to compensate the generators.

Repowering:

Most of the best wind sites in the country are already tapped with wind turbines (greater than 500 kW) installed over a decade ago. There is merit in replacing the older machines with taller, larger and more efficient turbines. This may require providing appropriate fiscal incentives to developers for undertaking repowering in those sites in order to make it economically viable where necessary.

Transmission Infrastructure and Load Balancing:

The earlier analysis projects a wind based generation capacity of 120 GW by the year 2030. Most of this will be concentrated in the Southern parts of India. However, these states on their own may not be able to absorb the power generated and it will have to be dispersed to other parts of the country. This will require developing transmission lines for the evacuation of power. Due to the intermittent nature of wind power, transmission charges could be on a per MWh basis, instead of the current per MW basis, with additional costs socialized over the entire system.

Further, wind generation being intermittent, is characterized by seasonal and diurnal variations. This variability is predictable to a certain extent, and recent international experience has indicated that errors in prediction may be considerably reduced, with appropriate sizing of the balancing area. With increased contribution of wind to the generation mix, more suitable forecasting and scheduling mechanisms may be devised over a larger balancing area. Additionally, wind power development will have to go hand in hand with developing other fast ramping sources such as pumped storage to manage the intermittency.

7.3 Solar Power Generation

The Jawaharlal Nehru National Solar Mission (JNNSM) has set a target of 22 GW (20 GW of grid-connected and 2 GW off-grid/decentralized) of solar power by 2021-22. The Macro Model in this report estimates solar capacity of over 100 GW by the year 2030. The main reason for this is because the cost of solar power has reduced significantly in the last few years. Prior to the commencement of the JNNSM, the Levelized Cost of Energy for solar PV was around Rs. 18 per kWh. However, following the reverse bidding auctions, the LCOE has now come down to about Rs. 6 per kWh. In addition, the cost is expected to reducefurther and solar power is expected to achieve grid parity in the coming few years.

The rapid reduction in solar prices provides an opportunity of using solar energy for decentralized power generation, close to load centers, both urban and rural. Solar energy could therefore be an important source for inclusive growth. This will require developing innovative business models for decentralized solar power as against the utility scale solar being pursued as of now. Developing utility scale solar power plants may be difficult in the long run given that they require large amount of land and water (in case of solar thermal). An attractive option is to develop a large number of 100 kW to 500 kW solar plants located close to rural load centers and also roof top PV systems in urban areas. These permit direct utilization of solar energy with minimal distribution losses.

This section discusses several policy options for rapid growth in solar power:

Fiscal Incentives:

At present, the Government of India is providing Viability Gap Funding (VGF) for solar power plants under JNNSM. This is a form of capital subsidy provided to solar plant developers to ensure bankability of grid-connected plants. A developer can avail a maximum of 30 percent of initial investment, or Rs. 2.5 crores/MW as VGF, which is distributed in several stages. The tariff is fixed at Rs. 5.45/kWh and Rs. 4.95/kWh for PV developers not availing fiscal incentives in the form of Accelerated Depreciation (AD) and those availing AD respectively.

The corpus required to achieve the targets of JNNSM keeping in mind the division of central and state level targets (at around 2:3) is estimated at around INR 18,560 crore by 2022[10]. This is expected to come out of the National Clean Energy Fund (NCEF).Clearly, the VGF scheme is a short term incentive provided to help achieve the targets under JNNSM. It cannot (and should not) sustain the solar capacities mentioned in this report. In the long run, VGF will have to be replaced with a more performance-based incentive. In due course, the states should take on the responsibility of setting appropriate tariffs for purchasing solar power directly.

Solar Parks:

Developing solar parks and associated transmission infrastructure are important options being explored by several states. The state provides a common evacuation infrastructure along with the allocated land to the developers. Recently two 4 GW parks have been sanctioned in Gujarat and Rajasthan, and an efficient transmission network to support the parks has also been proposed. These efforts need to be emulated in other states as well and “smaller” parks, with an installable capacity of around 1 GW could also be considered.

Decentralized and Rooftop PV:

Decentralized solar energy applications are attractive since these generate solar power close to the load center and have minimum transmission losses. Based on national census surveys and GIS analysis, the potential of rooftop PV in the country (commercial, residential, industrial rooftops and rooftops of airports, railway stations, metro stations and bus stations) has been estimated to be in the range of 60-94 GW.

Residential rooftops in urban spaces are eligible to avail the 30 percentcapital subsidy. Apart from this, to make the business case more attractive, some states are introducing the net-metering mechanism. If a consumer generates more than the monthly consumption, the local distribution company reimburses the difference at a stipulated rate fixed by the State Electricity Regulatory Commission (SERC). If the generation is lower than the consumption, then the consumer pays the distribution company for the difference at stipulated tariff slabs. Since several state distribution companies are financially unstable, targets for residential rooftop PV need to be increased gradually and ramped up once grid-parity is attained.

Rooftop PV systems on industrial units generate power for captive purposes. Since the areas of the rooftops are larger, systems above 100 kWp can be installed. Hence, RPO for captive consumers can be invoked for these systems and the subsequent sale of RECs used to improve financial viability. If the industry owners do not want to invest in rooftop PV systems, third party independent power producers (IPPs) or system integrators can lease the rooftop area, set up PV systems and sell the electricity to the industry owners. Similarly for rooftop PV systems, set up in public spaces such as airports or railway stations, IPPs can lease the rooftop and sell the electricity directly to the distribution company under the scheme of a Feed in Tariff.

Decentralized PV systems could be an attractive proposition even in grid-connected villages. The RGGVY policies are mainly directed for “off grid” villages. However, it is important to realize that even though close to 95 percent of the villages are “grid connected, these do not receive reliable electricity supply. The present policy framework doesn't adequately incentivize investors for developing decentralized power plants in grid connected villages. In these cases, policies should be introduced to encourage mini and micro grids to be set up along with small scale PV (less than 1 MW) and CSP (1-3 MW) plants.

Solar Thermal Energy Applications

So far, the focus of solar power has been mainly on electrical applications. However, there is a great potential of solar thermal applications in industries and waste heat recovery systems. This needs to be supported with adequate policy measures. The policy measures include using solar process cooling for refrigeration and chilling (cold storage) in rural spaces; and desalination. At present, MNRE provides capital subsidies on solar collectors used in these applications based on the area of the collector. However, there is a need to align the subsidy scheme with the efficiency of the collector and not the area. Another possibility is to consider a market based mechanism, similar to the Renewable Heat Incentive (RHI) that has been introduced in the United Kingdom. This monetizes the amount of thermal energy that is generated and utilized by any process heating application using solar thermal energy which will require that the development of Renewable Heat Energy Certificates gained can be normalized into existing RECs.

7.4 Nuclear

The model's results suggest that nuclear power is a crucial component of a future low carbon energy mix. As it can provide steady base load power generation at a high PLF,itis vital in managing the intermittency associated with solar and wind power.

India's present nuclear power generation capacity is 4,780 MW, almost entirely from Pressurized Heavy Water Reactors (PHWR). The Twelfth Five Year Plan also has a target of 5,300 MW for the years 2012-17. Two 1000 MW Light Water Reactors (LWR), are ready for commissioning in Kudankulam. Further, four 700 MW PHWRs are under construction in Rajasthan and Kakrapar and should get commissioned in the next two years. Finally, a 500 MW Prototype Fast Breeder Reactor (PFBR) is under construction in Kalpakkam. These reactors, when complete, will take the nuclear power capacity to about 10 GW by the year 2017.

As per the analysis in the earlier section, nuclear power generation capacity should increase to 40 GW by the year 2030. This is rather modest when compared with the Department of Atomic Energy's projections of 63 GW by the year 2030 and 275 by the year 2050, mainly from Fast Breeder Reactors. We have chosen a rather modest capacity addition because of the following reasons:

- In the past, actual capacity addition is much lower than the projections.
- There is public concern about the safety and economic aspects of nuclear power.
- Large scale development of Fast Breeder Reactors depends on the success of the PFBR presently under construction.

Therefore, while nuclear power is important as a source of carbon free energy, the likely capacity addition is taken at around 40 GW by the year 2030. In other words, nearly 30 GW would have to be added in the period after the Twelfth Plan (for the years 2018-2030). It is justifiable to expect that most of this capacity addition will be from thermal reactors, and a small contribution from the fast reactors. For nuclear power to increase to about 40 GW by the year 2030, several policy initiatives are required. Some of these are discussed as below:

Promoting PHWRs:

India's domestic Uranium reserves are adequate to build and operate only about 10 GW of PHWRs for 40 years. However, the Indo-US agreement for cooperation in Civil Nuclear Power enables India to import Uranium under international safeguards for fuelling thermal reactors. India has considerable experience in building indigenous PHWRs and these are economical as compared to imported LWRs. Therefore, there is a case to expand the PHWR program beyond the earlier limit of 10 GW.

Civil Liability:

There are plans to build up to 40 GW of imported LWRs. However, some of the foreign suppliers have expressed concern about the provisions of Nuclear Civil Liability Act, which places unlimited liability on equipment manufacturers. Therefore, the government will need to take a decision on the Nuclear Civil Liability Act, specifically amending the clause pertaining to extended warranty demand put on the suppliers. India should also ratify the Convention on Supplementary Compensation (CSC). These are in accordance with the international civil liability provisions.

Public Acceptance:

Large-scale expansion of nuclear power will occur only when the public accepts and understands that nuclear power is a safe and clean source of energy. At present, there is considerable public concern about the safety, economics and waste disposal aspects of nuclear power program. Addressing these concerns will require more transparency on part of DAE and AERB in addressing issues pertaining to safety. This will eventually be a determining factor in the expansion of nuclear power program.

Reprocessing program:

Large-scale fast breeder reactor development requires adding commensurate reprocessing capacities. India could also explore the possibility of having the spent fuel reprocessed in global reprocessing facilities. This will help accelerate the fast reactor program.

7.5 Advanced Coal

India's coal based power generation capacity is expected to increase to about 315 GW in the low carbon scenario. Thus, coal power will remain the primary source of electricity generation in the country even in a low carbon scenario. It is important to note that 50% of the expected installed capacity in the year 2030 is projected to be from supercritical coal technology. Almost all of new coal based capacity addition should be from super critical and possibly ultra super critical power plants. This would help in reducing emissions from the sector, as supercritical and ultra-supercritical technologies are less carbon intensive.

The observed heat rates of Indian coal plants are usually much higher than their designed heat rates. As a result, they burn more coal in order to generate the same electricity and emit more CO_2. Several causes have been identified for this, such as lower quality of coal, low plant load factor, and dearth of skilled staff. Chikkatur and Sagar suggest efficiency-based tariff setting in order to incentivize improvement in observed heat rates. This involves the following components: 1) set the tariff based on the median heat rate rather than the design rate. This would encourage plants near the median heat rate to improve their efficiency and push the median heat rate lower; 2) incentivize improvement in performance over time. This would encourage plants across the spectrum, including those that are more efficient, to improve their heat rates; 3) conduct periodic energy audits to measure efficiencies.

These measures would also promote coal beneficiation. Indian coal has high moisture and ash content, reducing its quality. Coal beneficiation or washing reduces moisture and impurities in coal, thus increasing its calorific value. Further, as the equivalent mass of coal reduces, transportation also becomes cheaper. It has been found that up to 50 percent washed coal improves the economics of power generation, especially when the coal is transported to higher distances. However, both the installed capacity and utilization of coal washeries is low. While incentives for higher efficiency should increase the demand for washed coal, steps should also be taken to increase its supply - through improving utilization of existing washeries and adding capacity as well.

Over the last decade, increase in domestic coal production has not kept pace with growth of installed capacity of coal power. As a result, several existing coal plants face fuel shortages. Fuel Supply Agreements (FSAs) with existing coal plants should be prioritized over e-auctions in order to improve the capacity factor of current installed capacity.

Research is required in advanced coal technologies such as underground coal gasification. This could help in extracting coal in locations, which are not conducive for conventional mining. In situ combustion helps in reducing the emissions as well.

7.6 Renewable Purchase Obligation/ Renewable Energy Certificates

Several state electricity regulatory commissions have announced renewable purchase obligations (RPOs) to promote renewable energy development. In addition, Renewable Energy Certificates (REC) is a market based incentive available to developers. However, though the State Electricity Regulatory Commissions (SERCs) have voluntarily announced their RPO targets, enforcement of RPO targets has been weak. To provide visibility and commitment, the states should be encouraged to enforce RPOs. We recommend the following measures to improve the functioning of RPOs.

a) Fixing of long-term RPO targets by SERCs: The adjustment of previously declared RPO targets by SERCs has created uncertainty in the RPO/REC based market developments. To create certainty about solar power requirement, RPO targets should be declared 5-10 years ahead of time.

b) Visibility of Floor & Forbearance Price: At present, RECs have price visibility only till March 2017. The uncertainty of revenue stream for the debt repayment period beyond 2017 weakens the bankability of such REC based projects. The floor price and forbearance prices should be for at least 10 years to facilitate financial closure for RE plants and should be set at a levels that provides adequate return to RE producer.

c) Penalty for non-compliance: For the development of RE capacities to meet RPO requirement, strict penalty for non-compliance should be introduced by SERCs. The penalty amount for non-compliance which goes to the government should be passed on to RE power generators.

d) Multi time trading & banking of REC: At present the trading of REC is one-time and can only be undertaken by renewable energy (RE) project generators within one year of issuance of REC. This restricts price discovery and long term multi-time trading of RECs. The trading of RECs should be allowed for more than one year and it should be multi-time tradable. Banking of RECs for a period of three years should be permitted.

7.7 Domestic Manufacturing

Indian solar manufacturing industry lags behind the Chinese and US industries in cost of production of solar cells. Despite the Domestic Content Requirement (DCR) in JNNSM, thin film modules from the US have a large share in the Indian market. In the short term, India is unlikely to achieve significant cost reductions in cell manufacturing and may continue to import cheaper cells. But, in the long term, India can possibly develop new and ground-breaking technologies thereby leapfrogging the learning curve and securing a fair share of the domestic and global demand.

The following recommendations can help domestic manufacturers in the RE sector especially solar by providing a level playing field and creating a sustainable, reliable and long term demand.

1) Capex Support for Solar Manufacturing: National Manufacturing Policy has been identified solar as one of the sectors of strategic importance. Sectors of strategic significance should be given special thrust in terms of capex support in the form of long term non-recourse loans.

2) Technology Upgradation Schemes for Solar Manufacturers & Suppliers: A technology up-gradation scheme for solar energy sector should be introduced to promote induction of the state-

of-the-art or near-state-of-the art technology in the sector. Such a scheme to support the solar energy industry for improving efficiency, productivity enhancement and attracting new investments could be supported via the NCEF corpus.

3) Public Debt Financing: EXIM bank loans for foreign equipment are available at 8 percent interest rate (including hedging) with tenures of 18 years as compared to 13 percent interest rate and 10 year tenures of Indian banks. Public debt financing can be used as a mechanism to promote indigenously manufactured solar equipment, which will allow part of the debt to be funded at low interest rates and longer tenures.

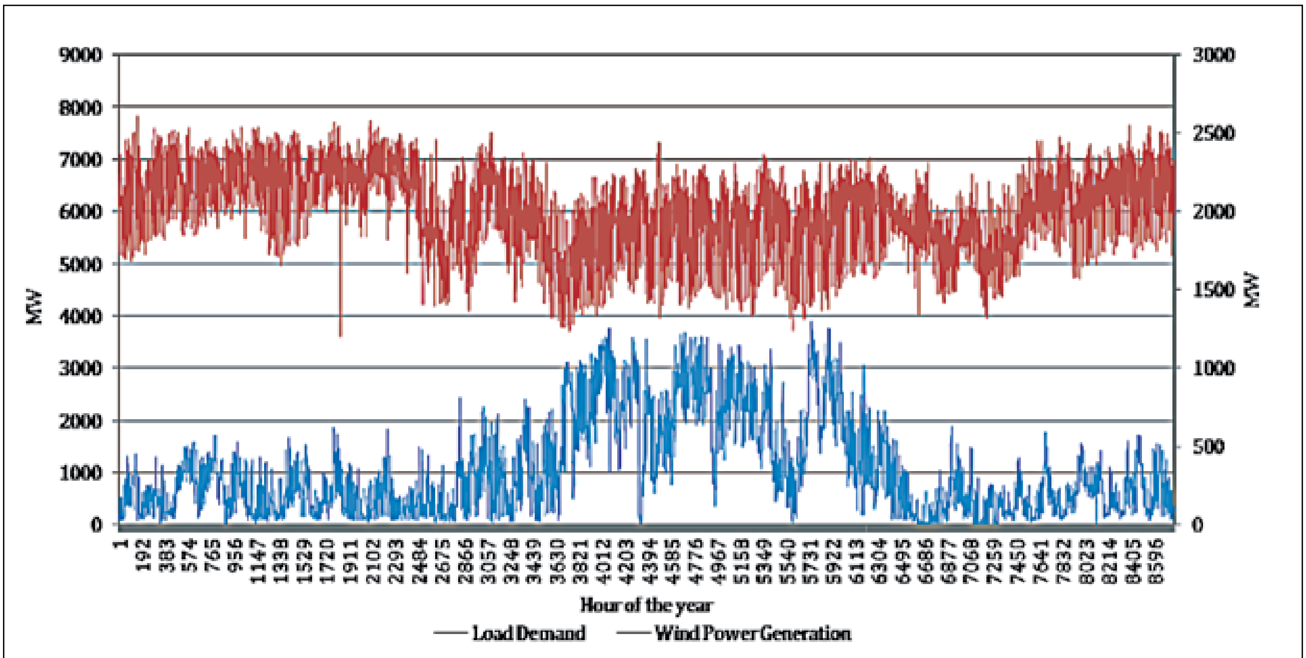
4) Tax and Duty Rationalization: There is a need to rationalize taxes and duties on the solar thermal and solar photovoltaic value chain to make Indian solar manufacturing industry competitive and to bring down cost of solar power.While certain capacities should be developed through promotion of local manufacturing, some components will have to be imported in near future. Tax and duty rationalization of these components will help in interim.

7.8 Renewable Integration

The macro model suggests over 100 GW each of wind and solar power by the year 2030. Wind and solar power are inherently variable, and are therefore non-dispatchable. Thus, integration of large scale wind and solar power requires additional enabling technologies, which can ensure smooth grid operation, especially power delivery during peak demand.

We present an illustration of the impacts that intermittent sources can have on the operational flexibility of the Indian utility systems in case of Karnataka, which has nearly 2 GW of installed wind power capacity (Figure 7.2). This shows that wind generation exhibits seasonal and diurnal fluctuations. Wind power generation is highest during the Monsoon months (July – September). This also coincides with the period of reduced loads because of lower demand from agricultural and residential sectors. The load curve is high during the months February–May, during which period wind power generation is also low. Thus significant renewable penetration is likely to pose two main challenges to the power grid: Supply-demand mismatch and need for frequency regulation.

Figure 7.2: Hourly load demand and wind energy generation in Karnataka (2011)



At present, a few Indian states, which have high renewable penetration, manage supply-demand mismatch by curtailing wind generators during times of surplus power. This results in a reduction of the effective capacity factor and consequent loss of revenues for the generator. During times of power deficit, the utilities try and use fast ramp up generation sources such as hydro or are forced to resort to load shedding.

Therefore, integrating large scale renewable sources to the Indian grid requires careful planning and synergistic approach from various stakeholders. This approach should constitute methods for: (1) enhanced flexibility and utility cooperation; and, (2) energy storage.

7.9 Enhanced Flexibility and Utility Cooperation

The Indian grid of the year 2030 will need enhanced flexibility of base load and load following units in responding to load fluctuations. One way to prevent renewable curtailment is to increase the flexibility of base load power systems so that more wind and solar can be accommodated in the power supply. High levels of wind and solar can be accommodated by increasing the size of balancing areas and cooperation between utilities to maximize geographical smoothing of the associated variability. However, nationwide utility cooperation will require an interconnected grid comprising of high capacity transmission networks. The linking up of the Southern grid to the rest of India`s North-East-West (NEW) grid in January 2014 is a step towards achieving inter-regional power transfer by creating a giant frequency-integrated grid. Further, the Power Grid Corporation of India Limited (PGCIL) is currently implementing a number of high capacity transmission corridors across the country. The Indian grid of the year 2030 will require more of such transmission infrastructures to facilitate geographical smoothing by enabling inter-regional power transfer and synchronization of variable renewable power with conventional power stations.

7.10 Energy Storage

Most utilities manage the intermittency associated with renewables by using hydro and gas generation. India's present hydropower installed capacity is about 39 GW and there is an estimated potential of 150 GW. Most of this is in the North Eastern regions and it is not clear how much of this could be exploited given the environmental and ecological constraints. The LCIG scenario projects a hydropower capacity of 75 GW by the year 2030. A detailed analysis will help assess whether this is adequate to manage the variations associated with solar and wind capacity exceeding 200 GW. Such analysis is beyond the scope of this study as it will require detailed granular data on the seasonal availability of wind and hydro resources and also projections of future load curves. However, it is clear that the grid will require Energy Storage Systems (ESS) to prevent costly renewable curtailment.

Pumped Hydroelectric System (PHS) is one the cost effective and proven option for energy storage. It is a mature technology and has low operating costs. There is an estimated potential of 94 GW of pumped storage in India. The PHS system has a long lifetime and is easy to operate. However, it is not clear how much of the estimated potential can be achieved given that PHS systems are capital intensive with associated environmental and ecological challenges. Moreover, PHS systems are location specific and are often land intensive. Therefore, alternate storage systems may be necessary to augment the PHS systems.

Grid level batteries are an option to consider. Batteries are fast-ramping devices and can be used to control ramp rates before feeding power to the grid and avoid Unscheduled Interchange (UI) charges. Batteries are portable, can be customized and are easier to install, thus making them increasingly attractive for grid level storage. However, they still have high capital costs with continued innovation and bigger production scales; large-scale battery storage should become more economical.

Na-S, Flow Battery and Li ion battery systems are among the leaders in the international grid level battery sector. Detailed studies are required to ascertain their viability under Indian conditions. The critical aspects to be evaluated are technical parameters such as round trip efficiency, self-discharge rate, cycle life, specific energy, specific power, energy density and economic parameters like capital and O&M costs. It is important to conduct studies of a range of storage scenarios based on different levels of centralization and connectivity to existing grids in India. The levels of power generation and energy storage at the grid, small community and individual building levels should also be considered.

Presently, there are no Na-S battery manufacturers and installations in India. Na-S technology has been demonstrated at over 190 sites in Japan totalling more than 270 MW with stored energy suitable for 6 hours of daily peak shaving. The largest sodium sulphur installation is a 34 MW, 245 MWh pack for wind stabilization in Northern Japan. Several projects are under development in Europe, as well as in Japan and the US.

However, this battery has problem of corrosion related to molten sulfur electrode container (stainless steel) after few years of battery operation. The battery operation reactions lead to the formation of sodium polysulfides, which are highly corrosive to the stainless steel at high operating temperatures (above 300 degree Celsius). This leads to loss of battery capacity and cycle-life. Hence, research efforts are needed to identify better container for molten sulfur. Parallel efforts are required to find out alternate electrolytes, which can perform at lower temperatures.

7.11 Smart Grids

Smart grid is the evolution of the electric grid with advanced communications, automation and IT systems that can monitor and control power flows, as well as, match production and consumption in real time. Smart grid also provides the intelligent control systems required for integration of intermittent energy from renewable generation sources and integration of electric vehicles.

In India smart grid technology could deliver additional benefits of peak load management through curtailing load at peak time (instead of load shedding), enhance access to electricity for millions of households and reduce huge network losses in the present electric grid through increased visibility and control on power flows.

Ministry of Power (MoP) has recently finalized a Smart Grid Vision and Roadmap for India with a timeframe of fifteen years (2012-27) for the transformation of the Indian power system to into a secure, adaptive, sustainable and digitally enabled ecosystem by the year 2027 that provides reliable and quality energy for all with active participation of stakeholders. Smart grid technologies have the potential to achieve multiple functionalities in the power sector. For instance, these can help in ensuring lifeline supply (six to eight hours every day) to all households in the country, by curtailing consumption of other categories of consumers during peak hours. This will eliminate the need for standby generation/storage arrangement at residential consumers' premises and also help un-electrified households to shift to electric lighting from kerosene lamps and other carbon emitting forms of lighting. These can also help in improving the quality of power supply and thereby eliminate the need for voltage stabilizers and other inefficient equipment at consumer premises. Large-scale renewable power integration requires smart control systems for effectively managing the load demand with supply options. The Smart Grid Vision will help with demand response for high volume consumers in a phased manner, which contributes to "mega-watts" and also bring about higher levels of energy efficiency.

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1 CEA (2014). Monthly All India Installed Generation Capacity Report, February 2014.
2 CEA (2013). Load Generation Balance Report, 2013-14.
3 CEA (2014). Monthly All India Installed Generation Capacity Report, February 2014.
4 MoSPI (2013). Energy Statistics, 2013.
5 Total electricity generation at 7 percent and 9 percent GDP growth rates is 2772 bKWh and 4198 bKWh respectively in 2031.
6 Other scenarios are baseline, blue-map, and blue-map high demand, and project considerably lower electricity demand by 2031 than baseline-high demand scenario.
7 The electricity demand so obtained is at bus-bars, after netting out auxiliary consumption, but including T&D losses. Therefore, actual generation needs to be higher.
8 Phadke, Amol; Bharvirkar, Ranjit; Khangura, Jagmeet (2011). Reassessing Wind Potential Estimates for India: Economic and Policy Implications. Ernest Orlando Lawrence Berkeley National Laboratory.
9 Sudhakar, Meera; Swamy, Deepthi; Mohd., Saquib; Sastry, Abhijith; Jain, Ritesh; Mazumdar, Bishal Madhab (2013). Wind Power in Karnataka and Andhra Pradesh: Potential Assessment, Costs, and Grid Implications. Center for Study of Science, Technology and Policy.
10 This is based on a ceiling of Rs. 2.5 crores/MW for SPV projects. Given falling capital costs of SPV, the actual requirement may turn out to be lower.

8 Carbon Sequestration

8.1 Introduction

Forests and tree vegetation play an important role in the mitigation of climate change by absorbing CO_2 from the atmosphere and turning it into biomass comprising of microbes, herbs, shrubs, climbers and trees. Carbon is stored aboveground in biomass, and underground in biomass and soil. Use of forest products as fuel wood and in manufacture of household fixtures and furniture is also capable of enhancing the mitigation service provided by forests. The increase in mitigation can be affected by direct actions like increase and improvement of forest and tree cover; and also by indirect actions like promoting use of wood in household fixtures and furniture, and encouraging adoption of fuel efficient stoves to economize on use of fuel wood.

Forestry assumes added significance as investment in this sector doubly reduces emissions intensity; firstly, by increasing the forest carbon sink, and secondly, by increasing the GDP. In a nutshell, the forestry sector positively influences the numerator as well as the denominator of emissions intensity. Thus, the forestry sector can reduce emissions intensity in two ways; by expanding and improving the present forest and tree cover to increase sequestration, and by promoting more efficient use of fuel wood and replacing energy intensive metal and plastic products with wood substitutes in the building sector.

The responsibility to report on changes in forest and tree cover in India vests with the Forest Survey of India (FSI), which brings out the State of Forest Report (SFR), every two years. According to the FSI, the forest and tree cover in India has been registering an upward trend. The SFR 2009 shows that the forest cover grew from 69.02 mha in 2005 to 69.09 mha in 2007. The increase in tree cover for the same period has been estimated at 9.17 mha in 2005 to 9.28 mha in 2007. The general trend of growth in forest and tree cover of India indicates an increasing forest carbon sink.

The National Forest Policy of India, 1952, aimed to bring 33 percent of land under forest cover. India has launched the national Green India Mission which aims to bring 10 million hectares of additional land under forest cover by 2021. See Box 8.1.

Box 8.1 GREEN INDIA MISSION

The Green India Mission (GIM) is one of the eight Missions recommended by the Prime Minister's Council on Climate Change under the National Action Plan on Climate Change (NAPCC), in 2008. The Mission provides Rs. 44,000 crores for 'greening' 10 million ha in India. The Green India Mission recognizes the potential that forests and other natural ecosystems have on climate adaptation/mitigation, food, water, environmental, livelihood security of forest dwellers specifically, and the nation at large, in the context of climate change. The Mission is therefore in a unique position to significantly contribute towards sustainability.

Over the past decades, national policies for conservation and sustainable management have transformed the country's forests into a net sink of CO_2. From 1995 to 2005, carbon stocks stored in our forests are estimated to have increased from 6245 m tons to 6622 m tons, thereby registering an annual increment of 37.68 million tons of carbon or 138.15 million tons of CO_2 equivalent. This annual removal by forests is enough to neutralize 9.31 percent of total GHG emissions in year 2000 (Kishwan, et al. 2009).

The Mission aims at addressing the issue of climate change by enhancing carbon sinks in the forests and attempts simultaneously to increase resilience capacity of the forest ecosystem while enabling forest dependent communities for adaptation in the face of climatic vulnerability. The overarching objective of the Mission is to increase forest and tree cover to 5 million ha and improve quality of forest cover for another 5 million ha between 2010-11 and 2019-20 through afforestation and eco-restoration activities by strengthening local community institutions like JFMCs and FDAs. Thus, the Mission will help in improving ecosystem services in 10 million ha of land, and increase flow of forest based livelihood services, and income of about 3 million forest dependent households. The Mission is innovative in several respects:

- First, it proposes a fundamental shift from our traditional focus of merely increasing the quantity of our forest cover, towards increasing its quality and improving provision of ecosystem goods and services.
- Second, the Mission proposes to take a holistic view of greening, not merely focus on plantations to meet carbon sequestration targets. There is a clear and more important focus on enhancing biodiversity, restoring ecosystems and habitat diversity.
- Third, there is a deliberate and major focus on autonomy and decentralization.

The Mission will be implemented through an autonomous organizational structure with a view to reducing delays and rigidity, while ensuring accountability. The mission will help local communities at the heart of implementation, with the Gram Sabha as the overarching institution overseeing Mission implementation at the village-level. The Joint Forest Management Committee would be revamped as Committees of the Gram Sabha. This is in consonance with the fact that forests are a source of livelihood for over 200 million people in the country, and hence centrality of their participation is critical. A key innovation is the idea of engaging a cadre of young 'Community Foresters', most of whom will be from scheduled tribes and other forest dwelling communities, to facilitate planning, implementation and monitoring of Mission activities at local level.

8.2 Sequestration Potential

8.2.1 Forest Stocks and Bali CoP Definitions

Practices for management of wildlife protected areas and other specifically conserved forest areas resulting in saving and maintenance of existing forest carbon stocks can be grouped under conservation (CN) forests. These are best areas for carbon service. Other forest areas which are subject to harvests and are managed according to prescribed working or management plans can be put under sustainably managed forests (SMF). CN and SMF are the terms used in the Bali Action Plan in the context of Reducing emissions from deforestation and forest degradation (REDD)[1]. Management practices of CN and SMF over a period of time would not only result in maintaining existing forest carbon stocks, but would also affect an increment in their quantum due to natural process of growth of conserved vegetation. Use of improved and more energy efficient wood-burning cooking stoves can also help in saving wood biomass and thus contribute towards conservation of forests and trees. Enhancement of forest carbon stocks can be achieved by increasing the forest area, or the carbon density and/or increasing the pool of carbon stored in a given forest or wooded area. In this case, the basic actions would comprise afforestation, reforestation, agroforestry, and energy plantations (fuel wood and biodiesel).

Carbon emissions in other sectors like energy can also be avoided to some extent by burning sustainably produced and harvested biomass instead of fossil fuels, e.g., using energy plantations to run a power plant, substituting industrial products that are currently fossil-fuel intensive in their manufacture (e.g., substituting cement by lumber) with wood products. Summary of carbon sequestration estimates of different forestry mitigation options is given in Table 8.1.

[1] Reducing emissions from deforestation and forest degradation (REDD) is a mechanism that has been under negotiation by the United Nations Framework Convention on Climate Change (UNFCCC) since 2005, with the twin objectives of mitigating climate change through reducing emissions of greenhouse gases and removing greenhouse gases through enhanced forest management in developing countries.

Table 8.1 Summary of Carbon Sequestration Estimates of Different Forestry Mitigation

Option	Net Carbon Sequestration
Conservation and Improvement of Existing Forests	
(1) Protected Areas (PAs)	Avoided emissions from deforestation and forest degradation through conservation of existing protected areas (PAs) covering 16 mha of forest land and accounting for 5 percent of the geographical area of the country are capable of adding 2 tonne of dry biomass per ha on an average every year. Continued protection of PAs will add 47 mtCO_2eq to forest carbon sink every year. (16*2.0*0.4= 12.8 mtC= 47.0 mtCO_2eq)
(2) Sustainable Management of Forests other than PAs	Unlike PAs where no harvests are allowed, other forests (53 mha) in general are subject to sustainable harvests. However, quantity of wood removed is less than annual increment resulting in net addition of forest carbon stocks. Such managed forests are capable of adding 0.8 tonne of dry biomass per ha every year. These forest areas being managed for sustainable harvests are adding 62.0 mtCO_2eq to the forest carbon sink every year. (53*0.8* 0.4= 16.96 mtC= 62.0 mtCO_2eq)
(3)Improvement in Forest and Tree Cover	Aims at improving 1 mha area each of open forests and medium dense forests with a view to upgrading these forests to the next higher category, i.e., open forest (OF) to medium dense forest (MDF), and medium dense forest to very dense forest category (VDF). Underlying assumption of carbon enhancement is that upgradation of OF to MDF and MDF to VDF will respectively add 0.2 and 0.3 tonnes of dry biomass per ha every year. This improvement is capable of adding 7.3 mtCO_2eq to the forest carbon sink every year. (10*(0.2+0.3)*0.4= 2.0 mtC= 7.3 mtCO_2eq)
(4) Improved Wood-burning Cookstoves	Avoided emissions from excessive use of fuel wood in cooking stoves in rural areas (800 million people or 160 m families) can significantly contribute to increase in forest carbon stocks by replacing ordinary cooking stoves with improved fuel efficient cooking stoves. Carbon sequestration is enhanced because of fuel wood saved due to use of improved cooking stoves. Presuming that 75 percent of the fuel biomass used in rural areas comes from forest, and also that cooking stoves can reduce the fuel wood consumption by about 30 percent by improving energy efficiency, each rural family using fuel wood for energy can save about 300 kg of fuel wood annually, and consequently will not extract that much quantity of biomass from the forests. Since the forests from where the fuel wood is extracted are usually degraded, and still growing, the entire quantum of fuel wood saved would result in equal amount of biomass left intact in the forests, thereby offsetting corresponding amount of emissions equal to 58.2 mtCO_2eq. (160*0.75*0.3*0.4=14.4 mtC*44/12=52.8 mtCO_2eq).
Afforestation	
(5) Increase in Forest and Tree Cover in Forest Fringe Villages	Additional area of 17 mha can be added by creating forest and tree cover in and around 170,000 forest fringe villages. Every year, on an average, 1.7 mha can be afforested/ reforested every year. This option will sequester an additional 1 tonne of dry biomass every year. The village forests will include energy plantations raised for the purpose of replacing fossil fuel with renewables like fuel wood and biodiesel. Agroforestry can also substantially contribute in increasing the tree cover in and around forest fringe villages. For calculating, CO_2eq sequestered, it is presumed that 50 percent of the biomass every year will be removed by the villagers for meeting their household needs. This option has the potential of adding 12.5 mtCO_2eq to the forest carbon sink every year. (17*0.5*0.4=3.4 mtC*44/12=12.5 mt CO_2eq)
(6) Green India Mission	Although the mission is yet to be finalized, on a very conservative estimate, at least 6 mha of degraded forest lands can be planted under the Green India Mission under the Ministry of Environment and Forests.
Wood Products Use Management	
(7) Harvested Wood Products Management (as substitutes)	Wood products store carbon for a long time, and encouraging their use in building construction substituting cement by lumber, and metallic door and window frames and wall cabinets with wood based products has the potential of saving 2 tonnes of CO_2 eq emissions for each cubic m of metallic hardware replaced
(8) Replacement of office and domestic furniture using metals with wooden furniture	It is estimated that at present 35 percent of furniture used in office and homes is made of metals and plastics (Anon. 2008). Replacing metallic and plastic furniture with wooden products would not only enable storage of carbon in wooden furniture, but would also replace more energy intensive metal and plastic furniture. Presuming that 50 percent of the furniture made of metals and plastics can be substituted by wood based furniture every year, such action would result in replacing about 1.5 million cubic m of metal and plastic furniture, sequestering an additional 3 million tonnes of CO_2eq every year.

The proposed mitigation actions in the forestry sector should be completed by 2030.

8.2.2 Costs of Actions

Mitigation actions proposed in this report are estimated to cost Rs. 11,400 crore every year over an action period of 10 years. The total amount required for the 10 year period will be Rs. 114,000 crores. The break-up for the annual cost of Rs. 11,400 crore is given below:

Addition of 1 mha @ Rs. 50,000/- per ha=1mha*50,000

= Rs. 5,000 crores per year

Upgradation of 2 mha of forest land

@ Rs. 20,000/- per ha=2mha*20,000

=Rs. 4,000 crores per year

Addition of 100 ha of forest in forest fringe villages

@ Rs. 10,000/- per ha=1.7 mha*10,000

=Rs. 1,700 crores per year

Improved 1 crore cookstoves

=Rs. 300 crores per year

@ Rs. 300/- per piece

Wood based products as substitutes (lump sum)

=Rs. 300 crores per year

Total cost of forestry mitigation actions

=Rs. 11,300 crores per year

The activities that can contribute significantly in providing additional mitigation service over and above the present level of contribution in forestry sector are following:

i) ***Increase in forest and tree cover by 1 mha every year:*** By afforesting/reforesting 1 mha of area every year, either under Green India Mission or otherwise, additional sequestration of 14.7 mt CO_2eq every year can be achieved.

ii) ***Creation of 100 ha of forest in 170,000 forest fringe villages:*** This initiative will be able to capture additional 12.5 Mt CO_2eq every year.

iii) ***Improvement in forest cover:*** Upgradation of 1 mha of open forest to medium dense forest, and another 1 mha of medium dense forest to very dense forest category can help in capturing an additional 7.3 Mt CO_2eq every year.

iv) ***Harvested wood products as substitutes:*** If every year, 1 million cubic m of metallic hardware products are replaced by wood based products, an additional emissions reduction of 2 Mt CO_2eq every year can be achieved.

v) ***Replacement of office and domestic metal and plastic based furniture:*** Replacement of all metallic and plastic furniture by wood based products is capable of reducing emissions by 3 Mt CO_2eq every year.

vi) ***Use of improved wood burning cooking stoves:*** This is a very potent initiative and has the capability of reducing emissions by 52.8 Mt CO_2eq every year (NSSO. 2002).

If the aforesaid options taken up simultaneously, there is a potential of capturing an additional 92.3 Mt CO_2eq every year, by the year 2023 onwards, thus neutralizing the quantum of emissions annually. The additional mitigation service provided will be able to offset an additional 5.3 percent of India's emissions at 2007 levels. This performance can be further accelerated if the industry comes forward as part of its corporate social responsibility. The industry sector could create awareness amongst village communities about raising tree plantations and orchards on private and community lands with a view to improve the socio-economic conditions of the rural people, and also contributing towards climate change mitigation. Needless to say, the initiative would be a win-win situation for both, local community as well as the industry sector. The former will benefit by enhanced income generation and latter by having access to increased availability of the wood based industrial raw material.

Total cost of forestry mitigation actions is estimated at Rs. 11,300 crore per year, whereas the value of additional mitigation service[2] after 2023 will be worth

[2] Value of forest mitigation has been calculated at USD 10= Rs. 550 for each tonne of CO2eq added to the forest carbon sink.

Rs. 5077 crore every year. If the value of present mitigation by India's forest and tree cover (138.2 MT CO2eq) is added to the additional service by the measures proposed in this report, the total mitigation service from forest sector will be worth Rs. 12678 crore (7601+5077) annually 2023 onwards.

Role of coordinating and implementing agencies will respectively be discharged by the Government of India in the Ministry of Environment and Forests (MoEF) and Forest Departments (FDs) of the State Governments. MoEF will be the central nodal agency for guiding, coordinating and monitoring implementation of the options. At the State level, this role will be discharged by the Forest Departments.

8.3 Estimate of Sequestration

While the above describes the possibilities, we make an estimate based on somewhat modest assumptions. Table 8.2 describes GHG sequestration as per estimates in India's national communication. We use these rates implied by this.

Table 8.2: GHG Sequestration in 2007 by Forests (Million Tonnes per Year)

	Forests	Crop Lands	Grasslands	Firewood	Total
MT of CO2	67.8	207.52	-10.49	-87.84	176.99
Area in Million Ha	67.8	181	61.3		

Source: MOEF (2010)

While the Green India Mission (GIM) targets may increase forest cover, pressures on land may reduce grasslands. We have assumed a reduction of 10 million hectares in grass land cover. We have also assumed that the use of fuel wood for cooking will go down as incomes go up and as a part of inclusive growth clean cooking fuel in the form of LPG is provided as an entitlement to all households. Of course some amount of fuel wood burning will continue. Table 8.3 shows the projections.

Table 8.3: Projected GHG sequestration from LULUCF (in million Tonnes of GHG/year)

	Forests	crop lands	grass lands	Firewood	Total
2005	65	205	-10	-85	175
2010	69	207	-10	-90	176
2015	73	207	-10	-90	180
2020	83	207	-9	-75	206
2025	90	207	-9	-60	228
2030	90	207	-9	-60	228
2035	90	207	-9	-60	228

Notes:

2007 data from India's GHG Emissions in 2007, MoEF

Per hectare forest sequestration from green India Mission in Interim report

Crop land assumed to change little in net sown area basis

grass land loss assumed to stop at 10 million ha

Fuel wood use will reduce as LPG is provided though some will continue

Other Ecosystem Goods and Services:

Carbon sequestration is only one among the many ecosystem services provided by the forests. The other services from forests support and supplement livelihood needs like fuel wood, fodder, food supplement and medicinal herbs, etc. for a large number of forest dependent people, especially rural and tribal communities. Forestry actions aimed at reducing emissions intensity and described in this report take due note of this reality, and ensure that forestry mitigation options do not result in any hardship to the local communities on account of their livelihood needs. It may be mentioned that quantum of ecosystem goods and services is directly related to the extent of the forest and tree cover. Therefore, any efforts aimed at increasing and improving the mitigation potential of forests will have a positive bearing on all goods and services flowing from these forests. (See Box 8.2)

Box 8.2 An outline for Measuring Ecosystem Services from Green India Mission

A Case Study of Paderu Project in Andhra Pradesh

Under the guidance of the Ministry of Environment and Forests (MoES), Government of India, the pilot phase of Green India Mission is being implemented in the state of Andhra Pradesh. During the current year, this is being implemented in one landscape identified in the Schedule V area of Paderu Forest Division in Visakhapatnam District. The landscape selected in Paderu Division has 23 habitations spread over 4985 ha out of which forests constitute 3200 ha (64.19%) and outside Forest area 1785 ha (35.81%). Each Grama Sabhas (GS) has a Vana Samrakshana Samithi (VSS) which functions as the forestry committee of the GS, the total number of GIM Gram Sabha/VSS village's 23. Integrated Research and Action for development (IRADe) in collaboration with Gesellschaft für Internationale Zusammenarbeit (GIZ) worked to develop a strategy for Measuring Ecosystem Services from Green India Mission Paderu Project in Andhra Pradesh. A Monitoring and Evaluation (M&E) framework was developed that enables monitoring at GS, Division, Circle and State level. The concept of green accounting was also incorporated in the M&E framework. The objective of the study were:

- To measure the increase in forest and tree cover area in Paderu division
- Measurement and valuation of goods and services
- Value NTFP and increased forest based livelihood income for forest dependent households

Based on primary surveys and stakeholder consultations the report provides a detailed framework for collecting data, monitoring and evaluation techniques used and results. The results indicate that there is a great deal of role of Gram Sabhas. It also pointed out which species and use is more valuable for whom and particularly for women. This may mean that the species should be selected by them depending on what they need most. This is critical if GIM is to lead to inclusive development.

Source: Parikh Jyoti and Wankhade Shwetal (2012)

8.4 Implications and Policy

Apart from implementation of the Green India Mission, the green cover can be enhanced by a number of measures that can augment sequestration.

The government should allocate adequate resources under NCEF towards GIM.

A framework should be evolved wherein the industry sector may be asked to allocate a certain percent of CSR funds for enhancing green cover in urban areas (city forests) and villages (village forests).

Sequestration can also be increased by curtailing use of fuel wood for cooking by promoting use of improved wood burning cook stoves in rural areas and by replacement of wood burning cook stoves with less emission intensive fuels like LPG. Provision of clean cooking fuels is an important element of inclusive growth. While provision of LPG to all rural households may take time, other low emission and clean cooking technologies may be promoted.

As growing forests sequester more carbon than a mature forest, the sequestration rate can be increased by harvesting the wood and locking up the carbon by using timber in building construction or furniture. This would also help in promoting sustainability by replacing cement, steel and plastics. However, implementing this requires a practice of sustainable forestry.

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9 Development Linkages

9.1 Significance

The Macro Model (Chapter 2) has evolved a Low Carbon Inclusive Growth (LCIG) trajectory, which is based on a dynamic optimisation approach that maximizes private consumption subject to commodity balance constraints combined with inclusive policies that improve human well-being. The report has highlighted costs involved in the pursuit of low carbon measures and has also evaluated the cumulative impact of this pursuit on growth outcomes for the country. Further, sectoral analysis in the chapters that follow evaluates the possible impact on GHG emissions, while hinting at some co-benefits, as well as co-costs (i.e. possible development impact or additional cost burden that is non-monetary).

This chapter places different low-carbon inclusive growth policies within a broader development context; recognizing that for India, poverty alleviation and socio-economic development remain the priority objectives, and that efforts towards decarbonisation need to be placed within the context of those objectives. The various LCIG options presented in the previous chapters require sustained and substantial levels of investment, and appropriate instruments of financing from public and private sources, both domestic and international.

9.2 Framing Linkages with Development

There is now increasing recognition in the scientific and policy communities that response to climate change needs to be placed and viewed within the broader context of sustainable development. For example, in the Cancun Decisions, the UNFCCC noted that "addressing climate change requires a paradigm shift towards building a low-carbon society that offers substantial opportunities and ensures continued high growth and sustainable development, based on innovative technologies and more sustainable production and consumption and lifestyles, while ensuring a just transition of the workforce that creates decent work and quality jobs", (UNFCCC, 2011, Decision 1/CP16).

A similar approach is reflected in the India's National Action Plan on Climate Change, which notes that "India's development path is based on its unique resource endowments, the overriding priority of economic and social development and poverty eradication, and its adherence to its civilizational legacy that places a high value on the environment and the maintenance of ecological balance" (NAPCC, 2008). More recently, the 12th Five Year Plan Document of the Government of India recognizes the need to adopt low-carbon strategies to improve the sustainability of the growth processes, with carbon mitigation being an important co-benefit (Planning Commission, 2013).

In such a "development first" framing, mitigation of GHG emissions is seen as a co-benefit of a sustainable development policy, rather than as the principal objective. Consequently, rather than develop policies specifically for mitigating GHG emissions, the approach prioritizes those development strategies that yield greater decarbonisation – the development imperatives being equal. As Jooste et al (2014) note, "The 'right to develop' is the overriding policy priority in developing countries albeit expressed and implemented in varying ways. This development imperative then becomes the critical factor when considering climate mitigation efforts within these countries."

A consequence of a focus on sustainable development implies that just as identification and quantification of mitigation co-benefits of different development policies is important, it is important, equally, to consider the full range of co-benefits and co-costs, associated with the spill-over effects of policies on other social and economic objectives. Indeed, the emphasis now shifts from a co-benefits approach to a "multiple benefits" approach – where a preferred strategy is one that enables multiple objectives to be achieved simultaneously. These objectives could include, for example, issues related to the local environment such as air and water quality, social issues such as equity in energy access, and economic issues such as job creation and energy security. Such an approach was adopted in a recent, comprehensive assessment of the global energy system – the Global Energy Assessment (GEA, 2012). The GEA identified pathways for energy system transformation that permitted energy security, climate protection and energy access goals to be achieved, while also identifying the multiple benefits and development linkages of such transformational pathways.

While it is important to recognize the co-benefits and co-costs of low-carbon strategies, it is likely that the global GHG mitigation goals may not be met simply by considering the ancillary benefits of development policies. While prioritizing policies for their mitigation co-benefits, it is important to recognize that even production co-benefits have a cost, and this cost would be far larger for policies that are primarily aimed at producing GHG emissions reductions. At the same time, developmental co-benefits of mitigation policies, while important, may not be adequate to justify their implementation, in the absence of multilateral mechanisms for finance and technology transfer to support such actions in the developing world. Finally, not all ancillary effects may be beneficial, some policies may have negative spill-overs as well – and these co-costs will need to be identified and explicitly considered while evaluating choices and assessing financing needs.

In other words, a holistic assessment of LCIG pathway requires consideration of various externalities (positive and negative), which have not been directly considered in the optimization model. For instance, many low carbon options have direct benefits and may also involve additional co-costs. The net impact should also account for the activities these measures replace, which may also have had some benefits and costs. Thus, ideally, one would need to assess the net benefits, costs and even risks. However, measuring and valuing these pose methodical and conceptual challenges. Economic benefits may be easier to assess as long as there is an impact on goods and services traded in the market, but there may also be indirect impacts[1]. Non-market impacts such as, on air quality and human health, wild life, bio diversity, ecosystem etc. may be much harder to value.

In this chapter, we have adopted a qualitative assessment framework, to enable a directional understanding of the trade-offs as well as synergies of the low carbon measures proposed in previous chapters. A detailed quantitative assessment is beyond the scope of this report and requires detailed research, both theoretical and empirical.

For each low carbon measure identified in the sectoral chapters, a review of secondary literature was undertaken to ascertain the likely co-benefits grouped in three categories, namely, economic, environment and others. Though economic considerations have already been covered in Chapter 2, this has been retained in the current matrix to illustrate temporal considerations, particularly with respect to impact on employment and inclusion. The macro model has also considered the impact on global environment, through GHG emissions. However, the LCIG pathway will also impact the local environment, particularly the quality of air, land, water and ecosystems. Some of the low carbon measures are likely to have a bearing on other considerations such as energy and food security, or political ramifications. These too have been identified qualitatively wherever relevant.

Table 9.1 provides an indicative and qualitative analysis of co-benefits and co-costs that could impact the major policy initiatives associated with the chosen inclusive growth trajectory. The analysis captures direct as well as some possible systemic impacts.

[1] For example, a carbon tax may reduce the profitability of producing some product, which may discourage new entrants in to producing it. This may raise its price, give market power to incumbents and adversely affect consumers.

Table 9.1: Co-Benefits Framework for Low Carbon Strategy

S. No	Thrust Area	Co-Benefit Sought	Brief Qualitative Assessment of Co-Benefit Potential
Power			
1.	Advanced Coal Technologies	Growth	Positive – Although costs are marginally higher, coal is used more efficiently; energy security and reduced import dependence.
		Inclusion	Neutral or mildly negative if power costs increase and are passed on to low income consumers.
		Local Environment	Positive - Reduced emission of SOx, NOx and particulate matter.
		Carbon Mitigation	Positive - 10 GW of Ultra Supercritical coal plants can reduce emissions by ~ 15% compared to current plants.
2.	National Wind Energy Mission	Growth	Positive – Can substitute for fossil fuel imports and provide energy security. Indigenous manufacturing for large capacities can lead to job creation and growth.
		Inclusion	Neutral – Can be mildly negative if average electricity costs increase; could also be mildly positive through creation of a decentralized energy industry.
		Local Environment	Positive– Although land is required for wind installations, policy can enable mixed land use; noise pollution could be a concern.
		Carbon Mitigation	Positive - Zero emissions power.
3.	National Solar Mission	Growth	Mildly positive – Can substitute for fossil fuel imports, decrease import bill and provide energy security.
		Inclusion	Neutral – Can be negative at present costs, which are higher than other sources; could also be mildly positive through creation of a decentralized energy industry.
		Local Environment	Positive – Decentralized rural applications substitute diesel, kerosene and firewood. For large projects, dedicated land and water requirements may be a concern due to competing uses. However, solar power does not emit local air pollutants.
		Carbon Mitigation	Positive - Zero emissions power.
Industry			
4.	Technology Improvement in Iron and Steel Industry	Growth	Positive - Less fossil fuel consumption, reduction in import of fossil fuels; improved domestic and global competitiveness.
		Inclusion	Neutral – Mildly positive, if MSME also benefits esp. the sponge iron industry; mildly negative, if cost of output increases.
		Local Environment	Positive - Usually, improved technologies provide increased environmental performance such as reduction in noise, particulate matter, SOx, NOx; reduction in slag and other waste.
		Carbon Mitigation	Positive – Reduced emissions per unit of iron and steel produced.
5.	Technology Improvement in Cement Industry	Growth	Positive - Less fossil fuel consumption; reduction in consumption of raw material per unit of cement produced.
		Inclusion	Neutral – Mildly positive if price of cement reduces with higher clinker substitution; mildly negative, if cost of output increases due to technology costs.
		Local Environment	Positive - Usually, improved technologies provide increased environmental performance such as reduction in noise, particulate matter, SOx, NOx etc.; reduction in fly ash, slag and other waste and reduction in landfill.
		Carbon Mitigation	Positive – Reduced emissions per unit of cement produced.
6.	Energy Efficiency Programs in the Industry	Growth	Positive – Less fossil fuel consumption, reduction in import of fossil fuels; improved domestic and global competitiveness.
		Inclusion	Positive – Potential price reduction over a longer term due to increased efficiency; lower consumption could reduce peak power or energy deficit.

		Local Environment	Positive – Improved technologies provide increased environmental performance such as reduction in noise, particulate matter, SOx, NOx etc.; reduced waste as by-products of energy feedstock are utilized.
		Carbon Mitigation	Positive – Reduced production intensity of fossil fuels.
Transport			
7.	Vehicle Fuel Efficiency Program	Growth	Mildly positive – Reduced fuel imports, enhanced energy security. Savings on fuel expenditure could be invested domestically.
		Inclusion	Neutral, unless it results in significant improvement in bus efficiencies which could lower fares.
		Local Environment	Reduced Air Pollution - As tail-pipe emissions decrease.
		Carbon mitigation	Moderately positive - Fuel consumption would reduce, unless undermined by increased driving patterns.
8.	Improving the Efficiency of Freight Transport	Growth	Positive – Savings on fuel expenditure, reduced fuel imports. May facilitate enhanced trade.
		Inclusion	Mildly positive - Transport cost of goods would reduce, thus impacting overall prices.
		Local Environment	Positive – Decreased emissions either through modal shift or improvements in efficiency of road transport.
		Carbon Mitigation	Improving freight transport efficiency will have a positive impact on carbon mitigation.
9.	Better Urban Public and non-motorized Transport	Growth	Mildly positive – Reduced fuel imports and savings on fuel expenditure could get invested domestically
		Inclusion	Positive - Mobility for the poor would improve significantly.
		Local Environment	Positive - Reduced local emissions
		Carbon Mitigation	Positive - Reduced consumption of fossil fuels.
Others			
10.	Lighting, Labelling and Super-Efficient Equipment Program	Growth	Mildly positive – Energy efficiency is typically cheaper than new power generation, bringing down average cost of electricity
		Inclusion	Neutral – Positive, if appliances supported are used by relatively poor populations; negative, if predominantly used by the rich.
		Local Environment	Positive – Energy efficiency substitutes for thermal power generation and brings down local air pollution.
		Carbon Mitigation	Positive – Carbon mitigation as energy efficient appliances substitute for thermal power generation.
11.	Faster Adoption of Green Building Codes	Growth	Neutral or mildly positive – Decreased energy costs lead to lower investments in higher cost power infrastructure.
		Inclusion	Neutral; negative if green building codes raise costs.
		Local Environment	Positive – Energy efficiency substitutes for thermal power generation and brings down local air pollution.
		Carbon Mitigation	Positive - Carbon mitigation occurs as energy efficient appliances substitute for thermal power generation.
12.	Improving the Stock of Forest and Tree Cover	Growth	Neutral or mildly positive – Forest enhancement can increase ecosystem services.
		Inclusion	Neutral or negative – Depends on the existing use of land; and whether afforestation causes displacement and loss of livelihood.
		Local Environment	Positive or negative–depending on the type of forest cover.
		Carbon Mitigation	Positive – Forests sequester carbon.

Source: Planning Commission (2013), *Twelfth Five Year Plan: 2012 – 2017, Chapter 4.*

Table 9.1 suggest the likely co benefits and risks associated with the LCIG pathway. We reemphasize that this analysis is qualitative and therefore indicative, and needs to be substantiated with quantitative assessments. In some cases, data availability could be a potential challenge, and therefore there is a need for assumptions and parametric models. What also needs to be emphasized is that these externalities are important and need to be factored in while designing specific policies. Some of the negative ones could be taken care of with modest cost and the required measures should form part of the overall policy package. An alternative approach is outlined in the Appendix. This considers a qualitiative assessment of the impact of low carbon options on various factors such as output, employment, inclusion, land, water, air quality and also their political implementability.

9.3 Financing Low-Carbon Inclusive Growth

Assessment of the mitigation costs is a difficult task; however, it is clear that these costs are significant, and will likely rise in future if adjustment actions are delayed. Though no ready estimates are available, several studies[2] suggest that incremental economic or investment costs incurred for reducing emissions intensity will be sizeable and may divert resources from other critical sectors of our economy.

Given that energy supply and end-use technologies are evolving rapidly, policy instruments should reflect the contemporary state of technology. A key issue in financing is the matching of the sources of finance with the need and characteristics of the mitigation technology option. Whether a technology will be viable, and adopted widely, depends on the private discount rate, the social discount rate and monetization of net co-benefits. Table 9.2 below illustrates the evaluation of the economic viability of some technology options, and matches them with possible policy & finance approaches. Similar framework can be adopted for other low carbon technology options.

Table 9.2 Evaluation Framework for Low Carbon Technology Options

Technology Examples	Viability using private discount rates	Viability using social discount rates	Social discount rates + monetized mitigation benefits	Policy Approach
ECBC, CFL, Supercritical Coal Tech.	Viable	Viable	Viable	Mandatory Standards + Information labeling
Super-efficient Appliances	Unviable	Viable	Viable	Incentive to Manufacturer and/or incentive to Consumer
LED's & Ultra-supercritical Coal Tech.	Unviable	Unviable	Viable	Domestic or International Carbon Finance (grant/loan)
Carbon Capture & Storage	Unviable	Unviable	Unviable	Pilot Project on 100 percent grant basis

[2] "Energy and Environmental Sustainability: An Approach for India", Mckinsey& Co., New Delhi, 2009; "National Energy Map for India, Technology Vision 2030", The Energy Resources Institute, New Delhi, 2006

We have already seen in Chapter 2 (with the benefits of externalities not counted) that cost to the economy of low carbon strategies is about US $ 834 billion (in constant 2011 dollars) over twenty years from 2011 to 2030. This is about 1.5 per cent of the cumulative GDP over this period. Even if benefits of externalities are accounted for, the resources required would be substantial. In developed industrialized countries, local environment quality and levels of air pollution, water pollution and land degradation are under control, without extensive reliance on renewable low carbon technologies.

Table 9.1 suggests the likely co-benefits and risks associated with the LCIG pathway. We reemphasize that this analysis is qualitative and therefore indicative, and needs to be substantiated with quantitative assessments. In some cases, data availability could be a potential challenge for such analysis and therefore there is a need for assumptions and parametric models. Nevertheless, the table does highlight a few important points regarding LCIG pathway. What needs to be emphasized is that these externalities are important and need to be factored in while designing specific policies. Some of the negative ones could be taken care of with modest cost and the required measures should form a part of the policy package.

Low carbon strategies will not only require enhanced deployment of renewable and clean energy technologies, but also capital finance for improvements in technology. Some of these objectives may be met through regulatory interventions and use of market mechanisms, in which case the required budgetary support may be small, but indirect and un-quantified costs for economy may be large. In other cases, adequate financial outlays will be needed to implement policies and measures that can achieve specific mitigation outcomes in the individual sectors.

Before deciding on the optimal strategy it is important to answer questions like whether the incentive will actually be passed on to the consumer, whether the income transfer to the consumer would result in increased demand, what will be the impact on risk-sharing, information asymmetry, moral hazard etc. Where markets exist, signals could be delivered through either price or quantities. Where they don't exist, and externalities are paramount; markets may need to be created as well as deepened. In this context, the relevance of regulatory measures as appropriate instruments to reflect externalities, and trading as a possible way of minimizing the economic costs need to be carefully balanced.

9.3.1 Cap and Trade vs. Carbon Tax

At this juncture, it is important to examine the difference between Cap-and-Trade vs Carbon Tax approach. Cap-and-trade programs often are designed to achieve greater reductions over time, so the cap may be lowered in subsequent years to enable market participants achieve emission reductions gradually. To achieve compliance with the capped emission level, market participants are allocated allowances to emit (1 ton per allowance) with the total number of allowances summing to the level of the cap. Market participants can purchase allowances from other participants to cover excess emissions, or sell allowances, if they reduce emissions below their allocation. Such trading increases economic efficiency.

A carbon tax is an alternative to a cap-and-trade. It can be given other names like cess, surcharge, levy etc. A negative carbon tax can also be given as subsidies for some identified low carbon effort, for example generation based incentive for supply of renewable power. Although both cap-and-trade and carbon trade policies generate a carbon price signal, there is a fundamental difference in the way in which the level of carbon price signal is determined under the two regimes (see Table 9.3 below). A carbon tax fixes the price of carbon and allows the quantity of emissions to adjust in response to the level of tax. In contrast, a cap-and-trade system fixes the quantity of aggregate emissions, and allows the price of CO_2 emissions to adjust to ensure the emissions cap is met (Stavins, 2008). UK's Climate Change Levy (CCL) and Australia's Clean Energy Package are examples of carbon tax.

Table 9.3 Cap & Trade vs. Carbon Tax

Cap and Trade	Carbon Tax
It sets a steadily declining ceiling on carbon emissions, and by creating a market that rewards companies for slashing CO2 (corporations that reduce emissions below their allotment can sell them on the open market); it uses the free enterprise system to achieve emissions reduction.	Uncertainty about how much it will reduce carbon emissions. However, tax linked to benchmarks of energy or emissions intensity can help improve certainty with respect to mitigation.
It does not provide cost certainty as price of permits fluctuates and could be highly volatile in the spot market.	Carbon Tax provides cost certainty by setting a clear price on carbon emissions for many years ahead.
It needs a market monitoring agency to examine issues such as rent seeking, cornering the market etc.	It's simple to understand and implement.
The design leaves out many small and medium organizations (who together may release significant portion of the emissions)	Carbon Tax covers the entire economy, including automobiles, households and other units impossible to reach in a cap-and-trade.
The revenues are likely to be bargained away well before the first trade ever takes place	Carbon Tax raises a clear amount of revenue, which can be used for targeted purposes or rebated to the public.
It can be more easily manipulated to allow additional emissions; if the permits become too pricey, regulators would likely sell or distribute more permits to keep the price "reasonable".	The chances of manipulation are remote. The structure of the tax doesn't allow periodic regulator intervention.
The long-term signals from cap-and-trade are less powerful, and the behavioural changes (e.g. choice of the type of power plant) could turn out to be far fewer.	Clear signals and impetus for behavioural changes
Political pressures could lead to different allocations of allowances, which affect distribution, but not environmental effectiveness and cost effectiveness.	Political pressures could lead to exemptions of sectors and firms, which reduces environmental effectiveness and drives up costs.
It will be a difficult process to adopt different international allowances and make it at par with the domestic allowance.	Carbon-taxing nations can easily offset import price differences with a "border tax adjustment".
The setting of the price (in an open market) could be very opaque.	The process is more transparent and trustworthy.
One of the immediate consequences are the design of financial and legal instruments	This directly rewards innovation in engineering.

Source: Yale Environment 360; 2009

9.3.2 Domestic Resources

The most obvious source of financing for climate change action is the government budgetary support. Most of it would come as sectoral finance since some of the resources for adaptation and mitigation are built into the on-going schemes and programmes. Although carbon mitigation is sometimes an important co-benefit, the deployment of resources for such purposes is largely guided by the overall availability of resources with the respective Ministries. Some prominent examples are budgetary support for super-critical thermal power plants, for dedicated freight corridor, for urban public transport etc. This is supplemented by internal and extra-budgetary resources of public enterprises like NTPC, Ministry of Railways, Metro-Rail Corporations etc. Additional allocations are available to the state governments as grants from the central government on the recommendation of the Finance Commissions, for example, for forest cover, renewable energy and the water sector.

While the budgetary resources indicated above flow through the Consolidated Fund, Government of India has created another window for climate action through the Public Account. With a view to generate additional resources, a cess at the rate of Rs. 50 per tonne of both domestically produced and imported coal was first announced in Union Budget 2010-11. The cess has become operational and its revenue (of the order of about Rs. 3,000 crore every year) goes to a newly created National Clean Energy Fund (NCEF), which will be used to finance innovative projects in clean energy technologies and to harness renewable energy sources to reduce dependence on fossil fuels. NCEF could be a valuable source to remove financing bottlenecks in the rapid deployment of clean energy.

However, it is not yet utilised adequately. In order to meet our rapidly expanding demand for clean energy financing, the guidelines of NCEF utilization must be revised at the earliest to enable quick disbursal and fuller utilisation into areas where existing budgetary and non-budgetary sources are unable to bridge the financing gap. In view of the absence of a separate exposure limit to renewable energy, providing a thrust to the sector for creating additional funding mechanisms becomes an imperative.

Given the importance of supporting the development of clean energy technologies, a separate window could be opened in the Fund to support development of early stage technologies and/or supporting diffusion, deployment and adoption of commercially available but high cost climate friendly technologies. Such measures could be taken in the mode of public-private partnerships. A separate window would ensure that funds are earmarked for renewable energy and the process to access funds is simplified.

National Clean Energy Fund

- An interest subvention expressed as a percentage per annum could be made available for eligible projects, and routed through the lenders to such projects. Thus, borrowers would get lower interest rates for the loans (not a reimbursement) while the lenders directly receive the subsidy.
- Since there is no industry-wide benchmark interest rate, domestic lenders typically lend on semi-fixed rate i.e. interest rate linked to a base rate, which is reviewed from time to time. Such fluctuation in the rate of interest is borne by the borrowers. The lenders may be incentivised to provide fixed interest rate loans for 3-5 years by providing an additional interest subsidy (e.g. 1-2 percent p.a. higher than the regular interest subsidy).
- NCEF can be used to create a support fund which can act as an intermediary to hedge the foreign currency (ex. USD-INR) exposure to renewable energy projects. This would help bring down the hedging cost as credit profile of sovereign would be better than stand-alone renewable projects. Such structures have worked in countries such as Spain, Italy and Chile in the past.

State Clean Energy Funds

Though the legislative provisions for State Clean Energy Funds don't exist, the Electricity Conservation Act (2001) mandates SCEFs for promoting energy efficiency and harnessing clean energy development at the state level. Various states have conceived SCEFs in the recent years, including Maharashtra, Gujarat, Rajasthan, Haryana and Kerala. The Urja Ankur Fund (2006) by Maharashtra Energy Development Agency (MEDA) was one of the earliest in this regard, and promoted bagasse, small-hydro, municipal solid waste and geothermal based energy. The projects were supported through INR 0.04 per unit of electricity sold to commercial and industrial units. Total fund corpus was INR 418 Crores, including matching contributions from the State government. The Gujarat Clean Energy Fund (2011) was set up along similar lines with a cess of INR 0.02 per unit of electricity from consumers with a connected load of 1 MW or above. Given the local demand for finance from DSM programs, such as awareness campaigns, energy-auditing, efficient agricultural pump-sets, efficient street- lighting, etc., the funds must be generated and administered locally to ensure best utilization. SCEFs are mandated for precisely this purpose, and if implemented diligently, could go a long way in ensuring energy efficient transformation in the medium-term.

Funds can also be established outside the Government. This is particularly important for private sector industry, even more so for small and medium enterprises, who will find it difficult to access the National Clean Energy Fund in the Government Public Account. It would be simpler and more useful to set up a 'Carbon Trust' or a 'Low Carbon Fund' managed by an autonomous body like the Bureau of Energy Efficiency, into which collections from an 'Energy Efficiency Surcharge or Levy' could be deposited. The collections, even though small, could be supplemented by block grants from the National Clean Energy Fund under the Government, and indeed some international sources of finance. This could go a long way in meeting the demands of the private industry.

We could also create a 'priority' credit facility through the scheduled commercial banks to help finance their low carbon efforts, while interest subvention could be dovetailed with the Trust fund suggested above. To summarize, a clearly planned strategy and mechanism for supporting diffusion, deployment and adoption of climate friendly technologies should be formulated and launched at the earliest.

9.3.3 International Sources

The intensity of domestic mitigation response depends rather significantly on the multi-lateral response to climate change. According to the UNFCCC, international financial support is to be provided to developing countries to enable them to take voluntary actions for mitigation and adaptation. Even though resources are scarce, India has been making specific budgetary outlays to address the challenge of climate change. However, domestic resources fall far short of the actual requirements. The Expert Group on Low Carbon Strategies has explicitly stated in both Interim and Final Reports that aggressive mitigation cannot be achieved unless substantial international help, both in terms of financial resources and transfer of technology, is forthcoming.

A major channel for mobilizing funds to the developing countries is likely to be the Green Climate Fund that is still being operationalised. At the same time, the World Bank (Climate Investment Fund) and other multilateral agencies are offering their funds to be used for climate action on the basis of agreed terms and conditions. The expected flow of funds from the Green Climate Fund, and other bilateral and multilateral channels, should enhance India's capacity to address the climate challenge. It is important to ensure funds flowing through these sources are indeed 'new and additional resources', and their terms of finance are in accordance with the multilateral rules of climate change. Unfortunately, the promises made through the Conference of Parties and recommendations of the High Level Panel on Climate Change Finance are yet to be fulfilled.

One way of differentiating between domestic and international sources of finance is the co-benefits framework mentioned above. Policy measures that generate adequate development co-benefits should be funded domestically, while those which primarily provide climate benefits should be funded by international sources. Even measures with adequate co-benefits may require international financing, if the initial investment is very large. To put it another way, actions which generate climate benefits along with development co-benefits should be the ones that should be categorized as the Nationally Appropriate Mitigation Actions (NAMAs).

Clean Development Mechanism is an international mechanism for emissions trading that helps developing countries gain some financial resources through sale of emission reduction certificates to developed countries, while enabling them to meet their emission reduction targets. The market for such trading is either compliance-based such as the one created under Kyoto Protocol, or voluntary in nature. India has been an active player in the Clean Development Mechanism and the National CDM Authority (NCDMA) in the Ministry of Environment & Forest has accorded Host Country Approval to over 2000 projects. Interestingly, most of the projects in India are unilateral in nature, wherein the project entity itself undertakes the initial investment, and aims to sell the Certified Emission Reduction (CER) units in the spot market rather than selling them in the forward markets.

Efforts are being made to increase participation of financial institutions/banks in financing voluntary projects, including the bundling of small projects which may reduce transaction costs and increase the average project size. A programme for capacity building to help industry adopt new and more efficient methodologies, such as programmatic CDM projects, is also being considered. However, the ability of international carbon markets to act as a stable source of adequate finance for domestic mitigation actions in developing countries is limited, because of the uncertainties about the scale of emissions reduction in the 2nd commitment period under the Kyoto Protocol. Further, in some of the key markets such as that of EU, unilateral restrictions are being imposed on sale of CERs from major developing countries in terms of eligibility, additionality criteria, sectoral caps etc. In brief, the contribution of CDM to real technology transfer is limited, and as market prices remain depressed and volatile, considerable uncertainty prevails over its future.

The potential for these domestic measures to link with global carbon markets remains unclear, largely due to lack of clarity in the international negotiation process. Until such clarity emerges, the most that can be expected are loosely linked regional markets. We must be prepared to link with them, though we cannot expect substantial resource flow from this source in the short term.

The significant additional investment required for low carbon power plants leads to diversion of resources and lowers the growth rate. India needs to be compensated for this by the global community. The international fund requirement could be reduced, however, if new developments in technology are made accessible at lower costs.

Appendix

In this table, the labels (+), (-) denote a likely positive cost or benefit and negative cost or co-cost, while the label (?) denotes a lack of directional understanding of the positive and negative impacts, taken together, due to uncertainty of net value.

Table A.1: Co–Benefits and Co-Costs of Suggested Measures

Suggested Measure	Economy			Environment				Others		
	GDP	Employment	Inclusion	Air Quality	Water	Land	Ecosystem	Energy security	Food Security	Political
1.Rating of Appliances	(+) Lower investment in power generation implies improved investment in other sectors	(+) Higher growth means higher employment	(+) Higher growth implies higher income for poor	(+) Reduction in coal based generation	(+) Less water consumption for coal based generation	(+) Less mining and less land requirement	(+) Less forest loss	(+) Lower energy demand and lower import of fossil fuels		
2.Replace Incandescent Lamps by CFL	(+) Investment effects improve GDP and employment in the long run	-do-	-do-	(+) Reduction in coal based generation	(-) Mercury contamination from CFL in runoffs	(-) Mercury from CFL in land fills	-do-	-do-		
3. ECBC Compliant Commercial Buildings	(?) High capital costs of green buildings offset reduced investment in capacity addition	(?) Saving in capacity addition offset by incremental costs for green buildings	(?) Negative if GDP slows down	(+) Reduction in coal based generation	(+) Less water consumption due to reduction in electricity demand	(+) Less mining of coal and less land requirement	-do-	-do-		
4. Larger Share of Solar and Wind	(-) Short run- Higher investment reduces growth									
(+) Long run- Savings on fossil fuel expenditure	(-) Short run- Lower employment (+) Long run- Higher employment	(-) Lower growth lowers income of poor								

Suggested Measure	Economy			Environment				Others		
	GDP	Employment	Inclusion	Air Quality	Water	Land	Ecosystem	Energy security	Food Security	Political
(?) Electricity available to poor sooner but more expensive	-do-	(+) Reduction in overall demand for water (-) Solar thermal water demand in arid regions	(?) Higher demand for renewable projects;lower demand for coal mining	(-) Pumped hydro could adversely impact ecosystems	-do-					
5. Nuclear Power	(-) Higher investments than coal generation could slow GDP	-do-	(-) Lower growth lowers income; coastal communities negatively impacted	-do-	(-) Nuclear waste in runoffs	(-) Higher demand for siting renewable projects		(+) In the long run, thorium reactors could be crucial for energy security		(-) Nuclear liability bill may need to be reviewed, politically difficult
6. Advanced Coal Technologies	(-) Higher cost of supercritical plants	(-)		(+) Higher efficiency, reduced fuel combustion and emissions	(+) Higher efficiency implies lesser cooling water generated	(+) Lower demand for fossil fuels and mining		(+) Higher efficiency would reduce fuel imports		
7. Peform, Achieve and Trade scheme	(?) Increased investment on efficiency slows GDP (+) Saving on fuel expenditure		(-) Low skill jobs will be lost	(+) Lesser burning of coal for thermal and electrical uses; lower pollution	(+) Lower water for coal-based generation and waer saving technologies	(+) Less land for mining coal ; and for siting power plants		(+) Less fossil demand for process heating and electricity generation	N.A.	(+) High political acceptance
8. Modal Shift of Freight to Railways	(+) Impact on GDP owing to overall reduction in transportation costs		(+) Reduction in transport costs of goods hence lower overall price	(+) Lower road freight share lowers pollution				(+) Reduction in oil imports	(+) Reduction in time taken for transport and lower food spoilage	(-) Road freight collectives/ trade unions may oppose the change
9. Fuel Efficient Vehicles	(+) Lower fuel costs increase GDP		(+) Higher efficiency in transport vehicles could lower fares	(+) Lower PM, SOx and NOx emissions			(+) Lower pollution and Reduced acid rains	(+) Reduction in certain fuel imports		

Suggested Measure	Economy			Environment				Others		
	GDP	Employment	Inclusion	Air Quality	Water	Land	Ecosystem	Energy security	Food Security	Political
10. Improved Public Transport	(-) Short run- Higher investments reduce GDP (+) Long run- Savings on fuel expenditure		(+) Higher inclusion owing to greater affordable mobility options	(+) Lower air pollution from the sector				(+) Reduction in oil imports		
11. Clean Energy for Cooking	(-) Higher demand for modern fuels will increase expenditure and lower GDP	(+) Higher opportunity for paid productive work for women	(+) Improved health outcomes for poor households	(+) Improved indoor air quality			(+) Reduced demand on forests for fire wood	(-) Increase in fuel imports		
12. Increasing the Stock of Forest Cover			(-) Afforestation activities displace local populations, leading to loss of livelihoods.	(+)			(?) Depends on type of forest cover			

10 Policy Recommendations

The Final Report targets ambitious emissions reduction, going forward up to the year 2030, while also achieving fast and inclusive growth. The report takes the 2007 National Communication as the base year, and proposes a set of low carbon strategies, which require design and implementation of specific policies. Policy interventions can be pursued along two parallel and complementary routes, we call the first, “chasing the targets,” and the second, “use of policy instruments.”

10.1 Chasing the Targets

The Final Report has identified twelve specific low carbon targets for the year 2030. The present as well as the desired status of these targets is given in Table 10.1 below. The Expert Group recommends that the Planning Commission should monitor these targets on a yearly basis and produce a status report to be placed before the Union Cabinet annually.

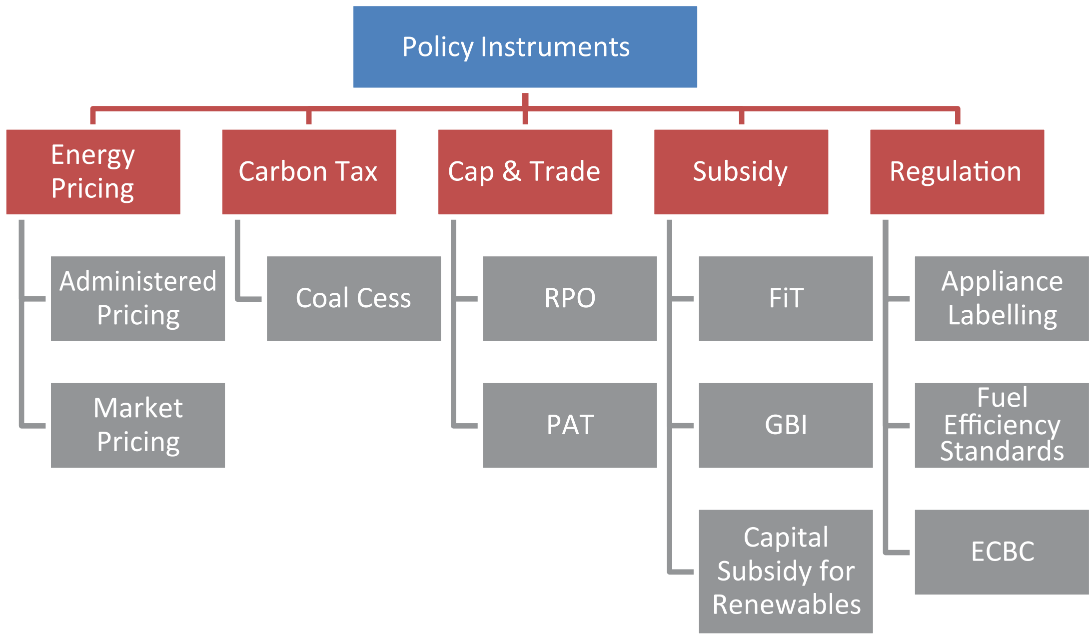
Table 10.1 Chasing the Targets

Sr. No.	Low Carbon Strategy	Present Status	Target by 2030
1	Advanced Coal Technologies	11 Super Critical Units with an installed capacity of 7.4 GW, which is only 6 percent of the coal-based generation capacity.	Super Critical and Ultra Super Critical Coal Plants should account for at least half of the coal based power generation capacity.
2	Hydroelectric Power Generation	Installed capacity of 40 GW.	Installed capacity of 75 GW.
3	National Wind Mission	Installed capacity of 20 GW.	Installed capacity of 120 GW.
4	National Solar Mission	Installed capacity of 2 GW.	Installed capacity of 100 GW.
5	Nuclear Power	Installed capacity of 4.8 GW.	Installed capacity of 40 GW.
6	Dedicated Freight Corridors (DFCs)	The Delhi-Mumbai Corridor is under construction.	DFCs along the quadrilateral linking the four metropolitan cities and their diagonals
7	Urban Public Transport	Only metropolitan cities have been taken up for modern public transport.	All cities should be covered with efficient means of public transport
8	Efficiency of Vehicles	Only private vehicles are currently compliant to Euro 4 standards.	Both private and commercial vehicles should be compliant to Euro 6 standards
9	Energy Efficiency in Industry	About 478 industrial units are notified as Designated Consumers for PAT.	PAT Scheme for designated consumers only and Energy Conservation Fund for all non-PAT industrial units.
10	Energy Conservation and Building Codes	For commercial buildings only: Rajasthan, Odisha and Puducherry have notified ECBC; other states like Chhattisgarh, Karnataka, and Uttarakhand & Uttar Pradesh have notified amended ECBC.	All States and Urban Local Bodies to mandate ECBC for commercial buildings and residential apartments.
11	Appliance Labelling Programme	The Star Labelling Programme is only applicable to Ceiling Fans, Air Conditioners, Refrigerators and Color Televisions.	The Star Labelling Programme to cover all electrical appliances. Near Universal Coverage of Super Efficient Lighting (CFLs+LEDs).
12	GHG Inventory and Data Management System	India’s GHG inventory preparation and reporting has been rather infrequent. The last GHG inventories were prepared only in 1994 and 2007.	Inventories of GHG gases such as CO2, CH4, N2O, HFCs, PFCs and SF6 should to be prepared and reported annually.

10.2 Policy Instruments

Policy measures to reduce emissions fall into two categories, namely: reducing energy requirement by promotion of energy efficiency, and by increasing the use of low carbon energy sources in the supply mix. Policy instruments can essentially be classified into five categories: Energy Pricing, Carbon Tax, Cap & Trade, Subsidy and Regulation. This framework contextualises the policy instruments with reference to the LCIG scenario proposed by the Expert Group.

Figure 10.1: Types of Policy Instruments



To design an appropriate mix of policy instruments, an analytic framework is necessary. This will help us understand the channels through which policy interventions affect the equilibrium outcomes. The policy instruments can be complements or substitutes. Very often, a lot of energy is spent in choosing between instruments that are in effect substitutes, and complementarities emanating from similar alternatives are neglected. An analytic Framework that can be used for designing an appropriate mix of policy instruments is suggested in the box below:

Box 10.1: Analytic Framework

A. Changing the Cost Curves (Producer Side Strategies)

- Capital Costs : Capital subsidy, interest subvention, depreciation rules
- Variable Costs: Output based incentive (Feed-in-tariffs, generation based incentive, drawback of commodity taxes, PAT Scheme)
- Technical Progress: Lower capital and/ or input costs, new technologies

B. Changing the Demand Curves (Consumer Side Strategies)

- Purchase Quotas (Renewable Purchase Obligations)
- Guaranteed Procurement (Public Procurement Policy)
- Purchase Based Incentives (Purchaser Rebates)
- Information Asymmetry: Appliance Labeling

10.2.1 Energy Pricing

Energy pricing is a critical policy instrument that promotes efficient use of energy and leads to selection of appropriate technology and energy mix. Fossil fuel prices are better understood in a four levels framework. Administered price is typically below the competitive market price, but very often, administered prices with specific taxes, may not be far from what would prevail if domestically competitive markets were allowed to evolve and operate freely. Many experts would recommend that prices of fossil fuels should reflect their full opportunity cost, which means not just market price levelised for the general level of taxation, but also with the shadow price of externalities added to it. Since this would be a tall order for the Indian polity at present, the Expert Group recommends that we should, in the first instance, move as soon as possible to a domestically competitive market for fossil fuels and transfer targeted subsidies directly to the poor through the best means available. This has been accepted, in principle, by the government, and some measures are being taken. The movement towards market pricing, however, is slow, and the process needs to be accelerated without any further loss of time.

The advantages of competitive market pricing are: (a) signalling role in the markets; (b) lowering of the gap between low-carbon energy sources and fossil fuel energy sources, which reduces the subsidy burden on the government, in addition to generating funds for low carbon projects; and (c) providing incentives to the users to opt for low carbon energy supply options such as renewables. The disadvantages are that it may result in an increase in energy prices for the short term and disadvantage the poor. However, continuing with distorted prices over time might raise inflation and lower growth rate putting a larger burden on the poor. The simultaneous pursuit of multiple goals i.e., economic efficiency, equity and inflation control, necessitates balancing between these objectives. The inflationary effect could be moderated via phased implementation, while the regressive effect on the poor can be minimised by giving direct cash transfers to the poor households, for which biometric unique identification (UID-Aadhaar) can be a useful tool.

10.2.2 Cess on Fossil Fuels

Government of India has imposed a coal cess at the rate of Rs. 50 per tonne of coal produced or imported in the country, which collects an amount of almost Rs. 3,000 crore every year. This is routed to the National Clean Energy Fund, which is part of the Public Account. The Coal Cess is essentially a low rate Carbon Tax, except that it is only on coal and not on the other fossil fuels which also emit carbon. While it does not fully compensate the negative externality of carbon, it is an important source of revenue that can be used to meet the demand of subsidies from the renewable energy sector. This is useful, because cess is a pseudo-tax, which cannot be used as general purpose revenue, but only for specified purposes. The Expert Group recommends that, adjusted for the carbon content, cess equivalent to the Coal Cess should be extended to all fossil fuels. While the revenue generated may be smaller than the additional investment required for pursuit of low carbon strategies, it can be used to leverage other policy instruments mentioned here. In particular, subsidies for renewables, like generation based incentive, capital subsidies, interest subventions etc. can be effectively funded from this route.

10.2.3 Energy Efficiency in Household Use of Electricity

Energy efficiency has a transcendental role in any modern economy. Labelling and Star Rating has been found to be effective in promoting the use of more energy efficient appliances. Consumers seem to react rationally to energy saving. We, thus, recommend that the labelling programme should cover more appliances and equipment with clear, easily understandable, and, informative labels. It is suggested that the appliances, which account for one half or two thirds energy consumption, should all be included in the labelling programme. The periodic tightening of labelling standards should be extended beyond air conditioners and refrigerators to capture the benefits of technological improvements. Widespread consumer awareness should also be simultaneously created.

While private individuals and firms would make an economically rational choice, it is not easy for procurement officers of public sectors firms or government departments to do so. They are required to buy on lowest first-cost basis. Thus, we recommend that government and public sector procurement officers should be empowered to buy on life-cycle cost basis. Identifying appliance specific price advantage, for different star ratings, will be helpful, and the procurement rules for governmental institutions should be suitably modified in this regard.

Energy efficient lighting has already found acceptance with the public, as can be seen from the rapid growth in the sale of compact florescent lamps (CFLs). The rapid reduction in the cost of light emitting diode (LED) lamps promises further cost reduction in lighting energy without the danger of mercury pollution that may occur when CFLs are not properly disposed. It is recommended that BEE should step up its programme to promote LED lighting, including periodic bulk procurement through competitive bidding, to enable rapid price discovery with the advantage of economies of scale.

10.2.4 Policy for Energy Efficient Buildings

The potential for energy saving in annual energy use for commercial buildings has been estimated to be around 30 percent. The ECBC has already been made mandatory for large commercial buildings in some states. The Central Government and some State Governments have also decided to comply with the ECBC code and retrofit their existing buildings. While an enforcement mechanism to facilitate ECBC implementation should be developed concurrently, the stringency of the ECBC Code should be enhanced periodically.

To promote uptake of green and energy efficient building standards, the owners need to be properly incentivised. Property tax rebate may be offered to those who comply with ECBC or obtain certain ratings from the pool of green ratings available. However, how does one make sure that this is not claimed without complying with the ECBC? Building codes should be implemented by local municipal authorities and subjected to compliance pressures. One way would be to insist that the local authority incorporates ECBC in the municipal bye-laws and obtains a BEE certificate saying that it has an appropriate mechanism for certification in place. In turn, the municipality could be incentivised, by insisting on such certification as a precondition for releasing funds under JNNURM.

The problem with residential buildings, as also with some commercial property development, is that the builders, and eventual tenants or buyers, have split incentives. Since tenants or buyers want low upfront cost, builders have little incentive to invest in a green building. It will be more effective to quicken the process of approval for building plans and reducing the cost of obtaining permits. Ensuring that local authorities have the necessary mechanism in place to do so effectively is important. Incentives for developers could be provided in the form of additional Floor Area Ratio (FAR,) reduced property tax, stamp duty for green buildings and any additional cost of complying with green building standards. Financial incentives for end users in terms of reduced interest on loans for green buildings have been used in other parts of the world, and can be applied to the Indian context.

We recommend that all buildings (commercial and residential) and government buildings are encouraged to enhance their energy performance. Energy Service Companies could be used to provide this up-gradation and to bear the initial cost for project preparation and project implementation. The investment could be recovered over a period of time if the energy retrofits continue to be more efficient than the equipment they have replaced. BEE may suitably strengthen its list of empanelled Energy Service Companies that can provide these services, and Energy Efficiency Services Limited (a company set up by BEE) may take the lead as a market creator.

Other barriers are knowledge gaps about green building technologies among builders, architects and users, as well as poor availability of the required building materials. There should be adequate knowledge dissemination about green building materials and technologies, and training and capacity building programmes need to be promoted. The supply chain of green building materials across the country should be strengthened. To overcome the difficulty faced by smaller establishments in retrofitting their buildings, a special window should be opened in housing finance companies and banks to provide loans for retrofitting of buildings.

Apart from ECBC compliant buildings, a measure that can significantly reduce energy consumption is by following Japan's example in this area. Presently in India, many offices, hotels, conference rooms, and auditoriums are usually air conditioned to uncomfortably low degrees of temperature. We recommend that the air conditioner temperature points should be set to a default value of 25 degree Celsius, and public places and offices should be asked to operate air conditioners in the 25-27 degree Celsius range. While implementation of such a simple measure may seem difficult initially; over time, public awareness and pressure will ensure compliance.

10.2.5 Promoting Energy Efficiency in Industry

Since Indian industries are growing rapidly, the industrial capital stocks will double every seven to eight years. Thus, concentrating on new industries to set up energy efficient plants is useful. Endorsement labelling of energy efficient industrial equipment such as waste heat recovery units, back-pressure turbines, variable speed drives, etc. should be encouraged as these inform investors' to select economically attractive equipment on their own. Energy efficient equipment can be promoted more effectively if energy prices are competitively determined. This, hopefully, will happen in the due course of time.

To promote energy efficiency in industries, a Perform, Achieve and Trade (PAT) Scheme has been introduced by the Bureau of Energy Efficiency. The PAT scheme covers some 400 large designated consumers (DCs) in 9 sectors including power generation. These together consumed 231 MTOE of energy, which is about 54 percent of the total commercial energy consumed in the country in the year 2007-08. BEE has made a heroic effort in getting DCs to agree on reduction targets, and over the first three-year period of 2012 to 2015, an energy use reduction target of 6.6 MTOE has been set, reflecting a reduction of around 1 percent per year.

The main challenge is in setting firm specific mutually agreed upon energy targets. Energy consumption in a firm depends on the source and quality of raw materials, product mix location of plant, scale of operation, processes, vintage, capacity utilisation, etc. This will provide incentives and opportunity to firms for negotiating a low energy reduction target. The outcome of the PAT scheme should be carefully monitored and eventually adapted in line with the feedback of implementation experience in the first cycle.

Another challenge is posed by the lakhs of small and medium enterprises and other industry not covered by PAT scheme, which the Twelfth Plan Document calls the non-PAT Industry. The Energy Conservation Act provides for an energy conservation fund to incentivise energy efficiency measures in such industrial units. Some of these SMEs are located in clusters. The BEE is examining about 25 clusters to see how there SMEs can be incentivized to improve energy efficiency. The cluster approach has not worked very well with regard to the functioning of common effluent treatment plants. Thus, getting a cluster of SMEs to act in a co-ordinated manner, in situations where opportunities for free riding exist, is difficult.

The Twelfth Plan recommends that, while the PAT should continue to evolve, it would be useful to envisage a combined Energy Efficiency Package, consisting of the PAT scheme and an Energy Conservation Fund, to be implemented by a unified Central Government agency, namely, the Bureau of Energy Efficiency (BEE). The legal provision for this already exists in the Energy Conservation Act 2001, wherein under Section 13, the BEE is empowered to levy fees for services provided for promoting efficient use of energy and it conservation. Assistance for waste heat recovery systems, and preparation of detailed project reports to finance adoption of energy-efficient technologies, are particularly important for non-PAT industrial units, which typically cannot arrange such help on their own.

Unlike the coal cess which is deposited in the Government account, the energy efficiency fee will be deposited in the Central Energy Conservation Fund managed by the BEE (Section 20 of the Energy Conservation Act). The collections from the fee could be supplemented by international funding, as well as block grants from the Central Government through the NCEF. Energy Conservation Fund could be used to leverage and/or finance energy-efficient technology up-gradation of the domestic industry, particularly non-PAT industry, on terms softer than commercial borrowing. While participation under the scheme would be compulsory for non-PAT industry, industrial units participating in the PAT scheme could also be permitted after one or two PAT cycles are successfully completed.

10.2.6 Policy for Transport Sector

There is a huge potential to reduce the energy intensity from the transport sector. Increased attention needs to be focussed on the railways, as it is the most energy efficient mode of land transport. Necessary action should be taken to ensure that the continually declining shares of mobility on the railways, for both passenger and freight mobility are not only arrested, but also reversed. Cross subsidisation of rail passenger tariff by rail freight tariff is a self-defeating policy that needs to be discontinued forthwith.

For passenger mobility, with continuous increase in the value of time, it is imperative to provide commuters an adequate number of faster and more convenient rail based services for both intra and inter-city, as well as suburban services. This would in many cases require augmenting the present rail infrastructure in terms of line and terminal capacity and rolling stock for carrying additional traffic. Investments will also be required for provision of new infrastructure in the form of metro, rapid and high-speed rail services.

For freight mobility too, measures need to be taken to arrest the diminishing shares of rail based mobility. This can be done by first ensuring that sectors where rail has a comparative advantage, such as in carrying of bulk commodities, are not forced to move by road based transport. Creation of dedicated freight corridors along the four quadrilaterals of the country and expansion of the rail network to cater to new ports, mining and industrial areas, would help carry additional freight traffic on the railways. The most immediate measure that needs to be taken to retain the share of rail based freight is the rationalisation in freight rates to ensure that freight businesses do not move to road because of lower costs. In the medium and longer terms, dedicated freight train corridors should be completed as soon as possible.

In addition to increased provision of rail based transport systems, action should be taken to increase the availability of public transport facilities across the country. Starting by focussing on million plus cities, adequate measures need to be taken to increase the number of transport corporations offering formal urban bus services. With increasing urban sprawls, the extremities of the cities should be connected by better public transport services to ensure that potential captive public transport users do not shift to personal motorised transport on account of inadequate availability.

Construction of public transport facilities are often constrained by delays and costs of acquiring the right of way. To avoid this, transport and public service corridors' master plans should be prepared for medium sized cities and right of way acquired at the earliest. As and when a particular corridor is developed, the permissible floor space index (FSI) should be raised and the additional FSI auctioned for the areas served.

With the rapidly growing numbers of private vehicles in the country, the private vehicle fleet needs to be made cleaner. Setting up appropriate and more stringent, progressively tightened fleet energy efficiency norms, as seen in several countries across the world, would be essential for reaching a desired low carbon scenario for the country. Hand in hand with increasing energy efficiency, a move towards cleaner alternate fuels in the overall fuel mix for transport has the potential of significantly transforming the carbon intensity of motorized transport in the country.

While pursuing these policies targeted at motorized modes of transport, urban centres should be encouraged to integrate non-motorized transport as an integral component of any urban transport plans. As highlighted in the chapter, the benefits of non-motorized transport would not be limited to achieving a lower carbon scenario for the country, but it would also have larger social benefits. Once non-motorised transport is facilitated and public transport is provided, parking fees should be raised to reflect adequately the social cost of congestion.

Pedestrians should have the same right and entitlement to road space as motorised vehicle riders. Pavements and cycle paths of adequate width should be provided even if it means reducing space for motorized vehicles. It will encourage use of public and non-motorised transport. A suitable mix of such policies has the potential of creating a future, which is not only inclusive, but also one that would result in a lower carbon scenario for the country.

10.2.7 Renewable Energy

The renewable energy sector in India today faces numerous financial, regulatory and supply chain barriers which impede its growth. The non-availability of low cost, long term finance for renewable energy projects along with the regulatory uncertainty and absence of a sustainable domestic manufacturing base have a long term impact on the growth of this sector.

The Government of India launched the National Action Plan on Climate Change (NAPCC) in 2008 under which it has launched 8 key missions focusing on different thematic areas. The Jawaharlal Nehru National Solar Mission (JNNSM), launched in January 2010, is one of the 8 key missions under the NAPCC. The JNNSM has an ambitious goal of making solar power cost competitive with coal power and an overall target of providing 20,000 MW of grid connected solar power and 2,000 MW off-grid solar by 2022. The wind sector in India has done well in the past, but has lost the momentum it had earlier. This sector too needs a thrust to move on to the next level and increase the overall deployed capacity of wind power projects. As recommended in the Twelfth Plan, a National Wind Energy Mission should be formulated and approved at the earliest.

To make the renewable energy sector viable and provide long term stability for its growth in the country, the Expert Group makes the following recommendations:

A) Feed-in-Tariff (FiT)

FiT gives certainty to the plant owner whose cash inflows are predictable. This makes it easier to obtain finance and attain financial closure. FiT is important for renewable power projects (CSP or PV in the context of solar) that feed electricity into the grid at rates as per contractual agreement between the purchaser, which may be DISCOMS directly, or an intermediary like NVVN (for Phase 1 of JNNSM) and SECI for (Phase 2). Normally, the developers put up projects to gain profit from selling electricity to the grid. FiT generated income is the primary source of revenue for the said solar plants and allocation of capacity to developers for grid connected solar plants is done through competitive bidding for FiT under state solar policies or under the National Solar Mission. The reverse bidding for FiT has progressively brought down the level of FiT. Gujarat on the other hand, invites bids for a pre determined FiT, which it periodically revised downwards. Reverse bidding for FiT should be continued.

One disadvantage is that FiT is technology specific. To this extent, competitive efficiency may not be realized even when FiT is competitively bid, as one would not have a common bid for all kinds of renewable energy. The renewable portfolio obligation (RPO) takes care of this problem. Another disadvantage of competitive bidding is spatial concentration of renewable projects in certain areas, or a bias towards government land, when private lands can be easily used for non grid connected plants that can improve livelihood opportunities.

B) Generation Based Incentive (GBI)

In the past, renewable power such as wind power, was encouraged through accelerated depreciation. This sometimes led to construction of plants with little incentive to operate. Generation Based Incentive has been introduced in small measures to provide the needed incentives. It is based on benchmark pricing and a fixed cash incentive is available to the power suppliers. This has not been as attractive to the developers as accelerated depreciation for a variety of reasons. GBI has not been adequate and has not paid in time. To encourage Generation Based Incentive it is important to ensure that GBI is timely paid by creating a small balancing fund which can draw upon the National Clean Energy Fund from time to time. This is a classic example of complementarity in the use of policy instruments, where Feed-in-Tariffs can be combined with Generation Based Incentive, the former competitively bid, and the later made conditional on technology, region and ownership to ensure development of renewable capacity is fair and more evenly spread across the country.

C) Renewable Purchase Obligation (RPO)

To promote renewable energy, many state electricity regulatory commissions have announced that renewable purchase obligations (RPO) be made tradable through renewable energy certificates (REC). The REC is a market-based instrument introduced to promote renewable energy, and facilitate meeting of renewable purchase obligations, which legally mandate that a percentage of electricity be procured by distribution companies (Discoms) from renewable energy sources. The REC mechanism aims to address the mismatch between availability of renewable energy resources and the requirement of obligated entities to meet their renewable purchase obligations.

The FiT regime and RPO mechanism complement and mutually reinforce each other. While the RPO is a demand creating measure for renewable energy – the FiT regime ensures developers get a fixed return on their investments and renewable power.

The RPO has the advantage that all technologies compete. However, this generates lot of uncertainty about what price one would get in the future. The ability to trade may lower some risks, but the uncertainty of price and availability of buyers remains. To minimize this, we recommend the following measures.

a) Strict Enforcement of RPO: At present the State Electricity Regulatory Commissions (SERCs) have voluntarily announced their RPO targets, but the enforcement of RPO by states is weak and there is no strict penalty clause on the defaulters. To provide visibility and commitment, the states should be encouraged to enforce Renewable Purchase Obligations. Strong enforcement mechanisms with stringent penalty clauses should be used to scale-up the demand for renewable energy in the country, thereby creating an alternate instrument for market based financing for this sector.

b) A Uniform RPO across States: All states should stipulate a uniform RPO level. If states are free to set their RPO, the tendency would be to set it too low, and all states would have surplus renewable capacity and no buyer. Appropriate amendments to the Electricity Act and the National Electricity Policy may be carried out to enable the CERC to impose RPO guidelines in accordance to the capacity to generate renewable power. Every state utility must have some obligation, except North Eastern States, since the latter already have high hydroelectric power generation capacity and limited power transmission capacity.

c) Fixing of long term RPO targets by SERCs: The adjustment of previously declared RPO targets by SERCs has created uncertainty in the RPO/REC based market developments. To create visibility about solar power requirement, 5-10 years of the states' RPO target should be declared at one go.

d) Visibility of Floor & Forbearance Price: The Floor price of REC provides to the developer minimum revenue stream of a REC based project. The Forbearance price provides the distribution company an upper bound at which it can obtain renewable electricity. At present, RECs have a price visibility only till March 2017. The uncertainty of revenue stream for the debt repayment period beyond 2017 weakens the bankability of REC based projects. A floor price should be prescribed as a minimum FiT. This would at least ensure a minimum cash flow and reduce uncertainty. A national mechanism would have to be worked out to pay for all unsold renewable power. This price should be for at least 10 years to facilitate financial closure for RE plants. It should be set at a level that provides adequate return to RE producer. MNRE may explore the possibility of creating a fund to purchase unsold RECs at the floor price in case the total supply of RECs is greater than the demand for RECs. A forbearance price, an upper bound, should also be set. In case of short supply of RE, forced buy out at this price should be provided for. The price may be set at the highest level of other subsidized power.

e) Routing Penalty to the RE Generator: For the development of RE capacities to meet RPO requirement, strict penalty for non-compliance should be imposed by SERCs on the distribution companies. The penalty amount for non compliance which goes to the Government should be passed on to RE power generator. This should be a multiple of, say one and half times, the forbearance price.

f) Grid Linkage Obligation: Be it the Discom, or on the plant operator, for obligation to build the required transmission line should be clearly spelled out.

g) Multi-time Trading & Banking of REC: At present, the trading of REC is one-time and can only be undertaken by renewable energy (RE) project generators within one year of issuance of REC. This restricts the price discovery and long term multi-time trading of RECs. The trading of RECs should be allowed for more than one year and it should be multi-time tradable. Banking of RECs for a period of three years at least, should be permitted.

h) Requirement to Meet RPO Periodically: The RPO requirements by designated consumers are at present met at the end of a financial year. This affects the revenue cycle and the viability of the projects. In place of the annual requirement, the RPO requirement should be met on a half yearly or quarterly basis to reduce the payment risk and the year-end rush for the RECs.

D) Creating Domestic Manufacturing Capacity & Securing Long Term Supply Chain Policy measures like FiT, GBI and RPO/REC will create a market for renewable power. However, policies are required to facilitate the development of manufacturing industries. Domestic manufacturing industry needs to be encouraged if energy security based on solar and wind power is to be realized. The country cannot go from import dependence for oil and coal to import dependence for solar and wind equipment and its components.

While the solar sector in India is poised to grow in the near future, the Indian photovoltaic and solar thermal equipment industry is facing challenges from global players, who have overcapacity, have far lower interest costs and higher incentives or subsidies as compared to the Indian photovoltaic and thermal equipment manufacturers. Several solar equipment manufacturing industries in India are either operating at sub-optimal capacity and/or have shut down production. In order to achieve JNNSM objectives, the industry needs a level playing field where the government ensures a balance between indigenous manufacturing capacity and imports. A higher value add in the indigenous supply chain would lead to increased investment, job creation, reduce foreign exchange outflow and sustain long term growth of this sector.

The following list of recommendations can help domestic solar and wind plant manufacturers by providing a level playing field, and creating a sustainable, reliable and long term demand for the domestic renewable industry.

i) Capex Support for Solar Manufacturing: The midterm (up to 2017) and long term (up to 2022) requirement of funds for solar thermal is INR 1,186 crore and INR 5,886 crore, respectively, and INR 12,000 crore and INR 16,000 crore for solar photovoltaic. National Manufacturing Policy has identified solar as a sector of strategic importance. Sectors of strategic importance should be given special thrust in terms of capex support in the form of long term, low interest non-recourse loans.

ii) Technology Upgradation Schemes for Solar Manufacturers & Suppliers: A technology upgradation scheme for solar energy sector should be introduced to promote induction of the state-of-the-art or near-state-of-the art technology. Such a scheme can be supported through the National Clean Energy Fund (NCEF) to support technological upgradation and productivity enhancement in the solar energy industry.

iii) Tax & Duty Rationalisation: The inverted duty structure for the solar photovoltaic sector has been a matter of grave concern for this sector. There is an urgent need to rationalise taxes and duties along the solar thermal and solar photovoltaic value chain to restore the level playing field for the Indian solar manufacturing industry. While certain capacities should be developed through promotion of local manufacturing, there will be specific components which will have to be imported in the near future. Tax and duty rationalization of these components should be given top priority.

E) Providing Impetus to Off-grid and Decentralised Applications

Off-grid and decentralised solar energy generation can play a vital role in addressing India's increasing electricity demand. Promotion of off-grid and on-site generation of solar energy in different sectors will reduce their dependence on diesel power during unavailability of grid supply during day time:

a) Rooftop Solar: Inclusion of rooftop solar electricity generation in the RPO obligations on captive and open access consumers can make it an attractive opportunity for the large commercial and industrial establishments with vast unutilized rooftops. There is a need to provide a policy push for innovative techno-commercial models to kick start roof top solar in India. Further, distribution companies should provide net metering facilities for buildings with roof top solar installations.

b) Substitution of Diesel Power by Solar Energy during Daylight Hours: The cost of diesel generated power is significantly high. At the subsidized diesel price of Rs. 46.32/litre, it is estimated that the cost of electricity for a 20 KwH diesel generator at full load is Rs. 14.27/Unit and it increases to Rs. 21.40/unit at 25 percent capacity utilization. The solar photovoltaic systems are more economical than diesel power generation, if it is being used for more than 1 hour and 24 minutes a day. The solar energy can easily substitute diesel power generation during day time, especially during the peak hours. The best incentive for renewable energy will be elimination of subsidies from fossil fuels and competitive energy pricing.

10.2.8 Nuclear Power

Generation of nuclear power does not involve emission of GHGs, and since it provides a stable source of base load power, nuclear energy as a low carbon source of power is attracting attention. Development of nuclear power in India has been plagued with time delays and cost overruns. Yet, given the limited, and small reserves of fossil fuels in India; from a longer term perspective, development of nuclear power is very important. The government should take necessary measures to accelerate nuclear power development. These include enactment of an appropriate civil liability framework, and informing the public of the relative safety of our nuclear plants in operation. This will require increased transparency and better communication on part of the Department of Atomic Energy and the Atomic Energy Regulatory Board.

10.2.9 Advanced Coal Technologies

Equally important as a source of renewable energy is to improve the efficiency of coal based power plants. For example with Super Critical (SC) boilers, the efficiency of coal use can be increased from 34 percent in sub-critical boilers to 40 percent, and further to 46 percent with Ultra-Super Critical (USC) boilers. We have already made a push for supercritical boilers. We need to make an aggressive effort to develop and introduce USC boilers as soon as possible. The Expert Group recommends a national technology mission to develop ultra-supercritical power plant suitable for Indian conditions, with adequate finance and technology import, wherever required.

10.2.10 Smart Grid

A robust grid is required to absorb intermittent power from renewable power plants. Smart grid is the dovetailing of the electric grid with advanced communications, automation and IT systems that can monitor and control power flows, and match production and consumption in real time. A key driver of smart grids in developed nations is the transition towards a low carbon economy by integrating renewable generation, and energy efficiency through active monitoring and control of consumption.

Ministry of Power (MoP) has recently finalized a Smart Grid Vision and Roadmap for India with a timeframe of 15 years (2012-27) for transformation of the Indian power system to a secure, adaptive, sustainable and digitally enabled ecosystem by 2027, that provides reliable and quality energy for all, with active participation of all stakeholders. We recommend that smart grid road map be vigorously pursued. In particular, various business models may be piloted in different parts of the country, and with different applications to create a corpus of experience, understanding, and knowledge that can enable large scale replications.

10.2.11 Policy for Sequestration

Apart from the implementation of the Green India Mission, the green cover can be enhanced by a number of measures that can augment sequestration. Compensated afforestation (CAMPA) funds should be expeditiously made available for enhancing green cover in urban areas (city forests) and villages (village forests).

Sequestration can also be increased by curtailing use of fuel wood by promoting improved wood burning cooking stoves in rural areas, and by replacement of wood burning cooking stoves with less emission intensive fuels like LPG. Provision of clean cooking fuels is an important element of our inclusive growth. While the provision of LPG for all rural households may take time, other low emission and clean cooking technologies may be promoted through attractive schemes.

Since growing forests sequester more carbon than a mature forest, the sequestration rate can be increased by harvesting the wood, and locking up the carbon by using timber in building construction or furniture. This will also help in promoting sustainability by replacing cement, steel and plastic. Use of wood for construction and furniture should encouraged, when the wood comes from sustainable social forestry, which requires a practical and less intrusive framework of social forestry in the country.

10.2.12 Research & Development (R&D)

India should recognize the importance of technological innovations in implementing low carbon growth strategies and harness research and development in that direction. With due consideration to the targets, it is crucial to innovate for reducing cost and increasing the manufacturing capacity of domestic technology in the area of renewables. Feasible power storage options for solar and wind power, improved battery technology to promote electric mobility, energy efficient appliances and buildings, development of advanced coal technologies suitable for Indian conditions are important areas for research and development.

In order to enable innovation, including its rapid dissemination, it is necessary that research programmes are designed with clear price and performance targets. Research hubs should be supported in existing academic and research institutions to support advanced technology development, capacity building of manpower and facilities for testing. Appropriate agencies should be mandated to aggregate demand and enable bulk procurement when technologies with specified price and performance targets become available. Cost sharing facilities should be available for installation of early models of new technologies, in user premises, to assess their operative performance under actual working conditions.

In addition to R & D for technology development, research to value externalities is critical for rational policy making. We also recommend a dedicated research programme to value costs and benefits of externalities of low carbon policies.

10.3 Implementation Framework

Low carbon targets and policy instruments need to be mapped with each other, and to all stakeholders, including both private sector and Government at different levels. An implementation framework which outlines this relationship is summarised in Table 10.2.

Table 10.2 Implementation Framework

Sr. No.	Low Carbon Strategy	Target by 2030	Stakeholders	Policy Instruments
1	Advanced Coal Technologies	Super Critical and Ultra Super Critical Coal Plants should account for at least half of the coal based generation capacity.	Ministry of Power, Ministry of Coal, CSIR, NTPC and other PSUs, CEA, State Utilities, Private Power Developers, PGCIL.	Energy Pricing, Coal Cess, PAT.
2	Hydroelectric Power Generation	Installed capacity of 75 GW.	Ministry of Power, Ministry of Water Resources, , MoEF, CSIR, NHPC, PGCIL, CEA, Private Developers, State Utilities.	Energy Pricing, Grid Balancing, Environment Regulation.
3	National Wind Mission	Installed capacity of 120 GW.	Ministry of New and Renewable Energy, Ministry of Power, CSIR, , CEA, Private Developers, CWET, PGCIL, State Utilities.	Capital Subsidy, Interest Subvention, FiT, GBI, RPO, Energy Pricing.
4	National Solar Mission	Installed capacity of 100 GW.	Ministry of Power, CSIR, Ministry of New and Renewable Energy, CEA, State Utilities, NISE, Private Developers.	Capital Subsidy, Interest Subvention, FiT, GBI, RPO, Energy Pricing.
5	Nuclear Power	Installed capacity of 40 GW.	Department of Atomic Energy, CSIR, PGCIL, CEA.	Government Budgetary Support, Energy Pricing, Liability Law.
6	Dedicated Freight Corridors (DFCs), Larger Rail Share in Freight Transport	DFCs along the quadrilateral linking the four metropolitan cities and their diagonals.	Ministry of Railways, International Funding Agencies, State Governments, Private Developers.	Independent tariff regulatory authority.
7	Urban Public Transport	All cities should be covered with efficient means of public transport.	Ministry of Transport, State Transport Authorities, Urban Local Bodies, Local Transport Corporations.	Independent Tariff Setting Mechanism, Government Budgetary Support.
8	Fuel Efficiency of Vehicles	Both private and commercial vehicles should be compliant to Euro 6 standards.	BEE, Ministry of Transport, Department of Science and Technology.	Fuel Efficiency Standards.
9	Energy Efficiency in Industry	PAT Scheme for designated consumers only, and Energy Conservation Fund for all non-PAT industrial units.	Industry Associations, Ministry of Commerce and Industry Corporations, BEE, Private Industries, PSUs.	PAT, Energy Conservation Fund.
10	Energy Conservation and Building Codes	All States and Urban Local Bodies to mandate ECBC for commercial buildings and residential. apartments.	BEE, State Governments and Urban Local Bodies	ECBC, Property tax, Floor Area Regulations.
11	Appliance Labelling Programme	The Star Labelling Programme to cover all electrical appliances. Near Universal Coverage of Super-Efficient Lighting (CFLs+LEDs).	BEE, Private Industries, DIPP.	Mandatory Standards, Information Labelling.
12	GHG Inventory and Data Management System	Inventories of GHG gases such as CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 should to be prepared and reported annually.	Ministry of Environment and Forestry, Planning Commission, Ministry of Statistics and Programme Implementation.	Mandatory Reporting Requirements, Independent Inventory Agency.

10.4 Conclusion

Designing an appropriate mix of policy instruments, and implementation of low carbon strategies, is a task that is highly multi-sectoral and inter-disciplinary in nature. A body like the Planning Commission, whose mandate is to formulate growth policy and coordinate it across the Central Ministries and the State Governments, is best placed to monitor the achievement of these targets and place it before the Union Cabinet for information and direction. The Expert Group strongly recommends that this should be done on a yearly basis. It is no longer possible to pursue growth, inclusion and sustainability as independent imperatives. Faster, sustainable and more inclusive growth can only be realised, when all these goals are pursued together, in a unified framework, as systematic components of a well thought out growth strategy.

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